An Examination of GIS in Secondary Science Education

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Abstract

This capstone project explores the efficacy of Geography Information Systems (GIS) to promote scientific literacy in secondary science classrooms and students' preference of GIS when learning scientific literacy skills. For the scope of this project, secondary science classrooms are defined as grades 6-12 and scientific literacy is defined as 1) the ability to ask questions and define problems of a spatial-ecological nature, 2) the ability to identify cause and effect relationships to predict phenomena in natural systems, 3) the ability to explain natural phenomena using evidence obtained from observations and scientific investigations, and 4) the ability to obtain, evaluate, and communicate information through technology. This study examines three ways of utilizing GIS in the classroom in an effort to determine which approach students prefer: creating thematic maps using ArcGIS online, studying pre-made interactive maps, and studying pre-made ArcGIS Story Maps. The results of this study suggest that there is no clear student preference for one type of GIS, but rather that each type has its strengths and weaknesses in the classroom. Student responses point to the conclusion that various forms of GIS can be used for providing choice, challenge, and differentiation in the classroom. Implications of this capstone project and suggestions for future research conclude this capstone report.

Keywords: GIS, scientific literacy, science education, secondary school, capstone project

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Increasing scientific literacy in secondary students is essential for developing critical thinkers ready for a global workplace and a rapidly changing ecological and social world. This capstone project examines the use of GIS to promote scientific literacy in secondary science classrooms. GIS is an important addition to the science classroom and an essential tool to teach with the U.S. Department of Labor predicting that jobs using geospatial technology will grow by 19% between 2016 - 2026 (Bureau of Labor Statistics, 2017). Because of this great demand for qualified, educated STEM professionals, and specifically GIS professionals, there is a need to teach GIS in the classroom to prepare students for the modern workforce and raise awareness around these promising career opportunities (Schlemper et al., 2019). Examining research on the use of GIS-integrated science curricula as a way to teach scientific literacy allows teachers to be informed on the subject and target their instruction in order to address this need.

The primary goal of science education is to advance students' scientific literacy (Pan, 2017). The Next Generation Science Standards (2013) prepare students to work in contemporary science fields by teaching them how to master specific skills inherent in science. These practical skills build the foundation of scientific literacy, which can be observed through the ability to perform either intellectual or practical tasks, including the ability to formulate questions, identify problems, collect and analyze data, recognize trends, develop hypotheses, communicate information, and evaluate others' scientific arguments (Next Gen. Science, 2013). The American Association for the Advancement of Science defines scientific literacy as "the capacity to use scientific knowledge to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (AAAS, 2011). Scientific literacy can also promote multiliteracy by contributing to “...the development of skills such as critical thinking, reasoning, communication skills, and understanding of the world around us” (Pan, 2017, p. 2).

The literature review constitutes the first portion of this capstone project and will explore the impacts of incorporating GIS in secondary science classrooms to promote students’ scientific literacy. Specifically, the literature review will explain the benefits of incorporating GIS in the classroom, identify certain limitations of its use, and explore solutions to mitigate these challenges. The methodology section includes a description of the qualitative study composing the second portion of this capstone study. This qualitative study examines students’ preference of GIS when learning scientific literacy skills based on their ease of use and educational capabilities. The research question asks, what type of GIS do students prefer when learning scientific literacy skills? The third section of this capstone study includes the development of a GIS-integrated, standards-aligned science curriculum and the implementation of this curriculum. The final results of the qualitative study and the curriculum will be shared with colleagues at STEM schools and outreach programs. Critical elements of the study and future recommendations for research conclude the capstone report.

Research Objectives

1. To examine students’ perceptions of certain GIS capabilities to teach the following scientific literacy skills:
    i. Ask questions and define problems of a spatial-ecological nature
    ii. Identify cause and effect relationships to predict phenomena in natural systems
    iii. Explain natural phenomena using evidence obtained from observations and/or scientific investigations

iv. Obtain, evaluate, and communicate information through technology

2. To understand students' GIS preference of one of the following forms of GIS when learning scientific literacy skills:
    a. Creating thematic maps using ArcGIS online
    b. Studying pre-made interactive maps
    c. Studying pre-made ArcGIS Story Maps

In this project, secondary science classrooms are defined as grades 6 - 12 including middle and high school science classrooms. For the scope of this research, the potential of GIS to support scientific literacy skills will be examined by its ability to teach the four skills outlined in the Next Generation Science Standards' Middle School Life Sciences document (NGSS Lead States, 2013) and listed below.

1) "The ability to ask questions and define problems of a spatial-ecological nature
2) The ability to identify cause and effect relationships to predict phenomena in natural systems
3) The ability to explain natural phenomena using evidence obtained from observations and/or scientific investigations
4) The ability to obtain, evaluate, and communicate information through technology" (NGSS Lead States, 2013, p. 15)

Literature Review

Previous studies supply a multitude of evidence on the effectiveness of GIS in secondary classrooms for teaching social studies and science concepts (Brindisi, Saber, & Moore, 2006; Hong, 2016; Scarlett et al., 2019; Schlemper et al., 2019,). Repeated benefits of GIS explained by researchers include the ability to promote students' spatial reasoning (Scarlett et al., 2019), their ability to ask scientific questions (Baker & White, 2003), and their ability to draw meaning and conclusions from data (Brindisi et al., 2006). Additionally, working with GIS curriculum leads to community-engaged, placed-based, inquiry-based teaching (Scarlett et al., 2019) and increases students' motivation to learn (Brindisi et al., 2006). Limitations of GIS in secondary classrooms include the initial time investment and challenges teachers face when learning GIS software (Hong, 2016) and inquiry-based teaching practices (Scarlett et al., 2019). Additional limitations include the limited experience students have with thinking spatially or using geospatial technology and the need for differentiation techniques (Scarlett et al., 2019). Areas for future research could include studies identifying the most effective form of GIS to promote students' scientific literacy skills and studies focused on effective differentiation techniques so that all students could reap the benefits of GIS in the classroom. Each of these topics will be explored in depth in the following sections.

Benefits of GIS in Education

The benefits of using GIS in secondary science classrooms include an increase in students' scientific literacy skills, students' interest and motivation to learn, and students' involvement with the community while partaking in place-based, inquiry-based education. Repeated research supplies evidence of the ability of GIS to foster scientific literacy skills in students, first of which is "the ability to ask questions and define problems of a spatial-ecological nature" (NGSS Lead States, 2013, p. 15). Creating maps using GIS requires students to ask questions about the data and identify which problem should be highlighted before making design choices (Baker & White, 2003).

Research conducted by Schlemper et al. (2019) states that students' awareness of spatial thinking increased as a result of participating in citizen mapping activities. In this case study, students in grades 7-12 practiced their spatial thinking skills by brainstorming community issues, asking questions surrounding the issues, and identifying a specific community problem through using geospatial technology. For example, one student group formulated the following questions regarding community issues: 1) “How much does it cost to renovate a park? 2) “What is considered a park?” 3) “What can we plant that will help our community?” (Schlemper et al., 2019). Based on these questions, the students identified their overarching problem as “the need for a fairer distribution of services provided to all districts of the city” (Schlemper et al., 2019). The group then participated in two days of field work and data collection using a GPS device to pinpoint the locations of parks and community gardens. Following this, they created a reference map using ArcGIS online showing the parks and gardens surrounding their school. Finally, they used the buffer tool to show the proximity of these areas to the school and the unequal distribution of these resources to the other districts of the city. This case study is a strong example of how GIS can be used in the classroom to support students’ ability to ask questions and identify problems of a spatial nature. The results showed that GIS use did increase students’ spatial thinking by use of qualitative methods including daily exit slips and interviews evaluating the students’ progress and development of spatial thinking skills over the course of the workshops. During the interviews, when students were asked what they would always remember from participating in the workshop, 44% of students stated that they always remember an aspect of the workshop related to geospatial skills, including GIS, GPS, maps, or data collection during the fieldwork. When asked what skills they learned during the workshop, 65% of students stated that they learned geospatial skills with 20% of students stating they learned general skills (Schlemper et al., 2019).

The next two scientific literacy skills that GIS promotes are closely related. They include "the ability to identify cause and effect relationships to predict phenomena in natural systems and the ability to explain natural phenomena using evidence obtained from observations or scientific investigations" (NGSS Lead States, 2013, p. 15). In a qualitative study by Radinsky et al. (2014), middle school students studied historical census data web maps and the study's results showed that using the GIS web maps supported students' acquisition of "(1) making observations with data; [and] (2) drawing inferences from data…" (p. 143). Baker and White (2003) also state that the cartographic design choices presented to students in GIS curriculum challenges students to understand data distribution spatially as it is related to the real-world distribution influenced by environmental factors. Even when students are not creating original map products themselves, simply working with existing geospatial data and interactive maps can also benefit students' ability to explain natural phenomena (Doering & Veletsianos, 2008).

In a study by Brindisi et al. (2006), researchers studied the use of an educational internet resource titled Discover Our Earth with a group of middle school students and a group of undergraduate students. In this study, students learned about plate tectonics, and more specifically, about "earthquakes, volcanoes, topography, and sea level change" (Brindisi et al., 2006, p. 1). Researchers used summative and formative evaluations and quantitative and qualitative methods to evaluate the efficacy of using Discover Our Earth in the classroom. Quantitative methods included pretests and posttests and qualitative methods included questionnaires and observations. Researchers found that students learned about plate tectonics and the causes and effects by interacting with the data and drawing their own conclusions. In fact, students stated these elements of the curriculum were what they like the most about the lessons. 34% of the students stated they liked interacting with the data, 11% of the students liked visual learning the most, 8% of the students liked learning about plate tectonics, and another 8% of the students liked drawing their own conclusions from the data. This practice of using data to identify cause and effect in natural phenomena, such as plate tectonics, is an important scientific literacy skill that GIS can support development of in the classroom. GIS use in the classroom facilitates student inquiry, allows students to explore data sets visually, and in turn, enables them to construct their own meaning of scientific topics (Brindisi et al., 2006).

Throughout the entire educational process, students acquire and assess data and then communicate scientific information using geospatial technology, which is, in itself, a scientific literacy skill. "The ability to obtain, evaluate, and communicate information through technology" (NGSS Lead States, 2014, p. 15) is the fourth and final scientific literacy skill supported by GIS use in the classroom. Learning to utilize technology and advancing one's computer skills are crucial elements when preparing secondary students for the workforce. In recent years, technology has made its way into people's everyday lives and technological advances continue to change the way people work in educational and professional sectors. This shift towards a more technology-centered workplace has changed content delivery and daily functions in secondary science classrooms. Students appear to be embracing the change with Schlemper et al. (2019) stating that students in the case study were "enthusiastic about learning new tools and related technology." However, it is imperative to know how to utilize technology as an effective tool in the classroom and mitigate the challenges that accompany technology integration (Brindisi et al., 2006). One position posited by Doering & Veletsianos (2008) is to maintain an emphasis on "learning *with* technology" in the classroom. In other words, the technology can support students as they obtain and evaluate information to construct new concepts and meaning about the world surrounding them.

In the study by Brindisi et al. (2006), students responded in interviews commenting on the aspects they liked most and least about the Discover Our Earth GIS-integrated science curriculum. Below, Figure 1 displays the five highest percentages of common responses for each of the categories, including what students liked most and what students liked least. After a brief examination, it is evident that what the students liked most about the GIS-integrated science curriculum corresponds directly with the scientific literacy skills educators strive to develop in their students. The association between student preference and scientific literacy skills can be synthesized as follows:

1) Interactivity with data and drawing one's own conclusions correspond to "The ability to identify cause and effect relationships to predict phenomena in natural systems" (NGSS Lead States, 2014, p. 15).

2. Visual learning corresponds to "The ability to ask questions and define problems of a spatial-ecological nature" (NGSS Lead States, 2014, p. 15).

3. Learning about plate tectonics corresponds to "The ability to explain natural phenomena using evidence obtained from observations and/or scientific investigations" (NGSS Lead States, 2014, p. 15).

4. Using computers corresponds to "The ability to obtain, evaluate, and communicate information through technology" (NGSS Lead States, 2013).

Figure 1

Qualitative results from Brindisi et al. (2006, p. 6).

TABLE 1. UNDERGRADUATE STUDENT COMMENTS ON THE USE OF QUEST FOR THE PLATE TECTONICS LESSON, LISTED BY PERCENTAGE OF RESPONSES

A

What students liked most	Percent of student responses
Interactivity with data	34
Visual learning	11
Learning about plate tectonics	8
Drawing own conclusions	8
Using computers	8

B

What students liked least	Percent of student responses
Speed of map server	31
"Nothing"	17
Button design and/or functionality	17
Using computers	11
Instructions	9

A: Top five "liked best" comments.
B: Top five "liked least" comments. Note that 34% of the "liked best" comments praised the interactivity with the data, and 31% of the students' "liked least" comments complained about the speed of the map server.
QUEST—Quick Use Earth Study Tool.

This is one of many studies displaying a correlation between what students enjoyed the most (Brindisi et al., 2006) or what students tend to remember from a GIS-integrated science curriculum (Schlemper et al., 2019) and the scientific literacy skills educators strive to promote.

In addition to promoting scientific literacy skills, GIS in the classroom also has benefits connected to other aspects of students' learning, including an increase in student involvement with place-based, collaborative, inquiry-based learning and an increase in students' interest and motivation to learn the subject matter. When students engage with GIS curriculum, they tend to simultaneously engage in place-based, collaborative, inquiry-based inquiry learning with rich community interaction. This type of inquiry-based or problem-based learning is defined by Brett et al. (2013) as a meaningful way to promote positive social impact, feelings of empowerment, and interest in the learning environment. In the case of Schlemper et al. (2019), students used

GIS to identify problems in their community and then connected with local community leaders such as local government officials, university faculty members, school administrators, neighborhood organizations, and fair housing officials to bring these problems to light and brainstorm solutions. In a study by Scarlett et al. (2019), students used local data and partnered with community organizations to not only learn the science or social studies curriculum, but also give back to the broader community. They fulfilled this service-oriented element of their curriculum by updating important historical data and creating presentations for the public based on the integration of content lessons and the GIS platform. The goal of this form of education was to “incorporate community engagement and service-learning into [students’] curricula to connect content with real-world applications and to help create civic-minded graduates” (Scarlett et al., 2019, p. 12). In a study by Doering & Veletsianos (2008), middle school students participated in an Adventure Learning (AL) curriculum integrated with two GIS programs. The AL curriculum is similar to the place-based, inquiry-learning curriculum due to the authentic data and collaborative learning environment. After each lesson, students participated in a focus group interview. Themes that emerged in students’ interviews and topics discussed included “1) learners developing a sense of place [and] 2) the use of real-time authentic data in analysis” (Doering & Veletsianos, 2008, p. 8). Results from the focus groups provided evidence of GIS supporting place-based, collaborative, inquiry-based learning. Major findings are as follows:

> “The analysis of the focus group data indicates that the use of geospatial data within the geospatial technologies, especially GE, revealed five major findings. It (1) assisted learners in developing a sense of place through the use of authentic, pre-existing data, (2) assisted learners in developing a sense of place through the use of authentic newly

acquired data, (3) provided opportunities for the co-construction of knowledge through learner-created data…"(Doering & Veletsianos, 2008, p. 12).

The study by Brindisi et al. Moore (2006) echoes the findings in the studies described above. In their research of the Discover Our Earth curriculum with inquiry-based learning and GIS integrated into the Earth science curriculum, researchers found that students were empowered "to learn about Earth processes through inquiry and discovery" (Brindisi et al., 2006, p. 2).

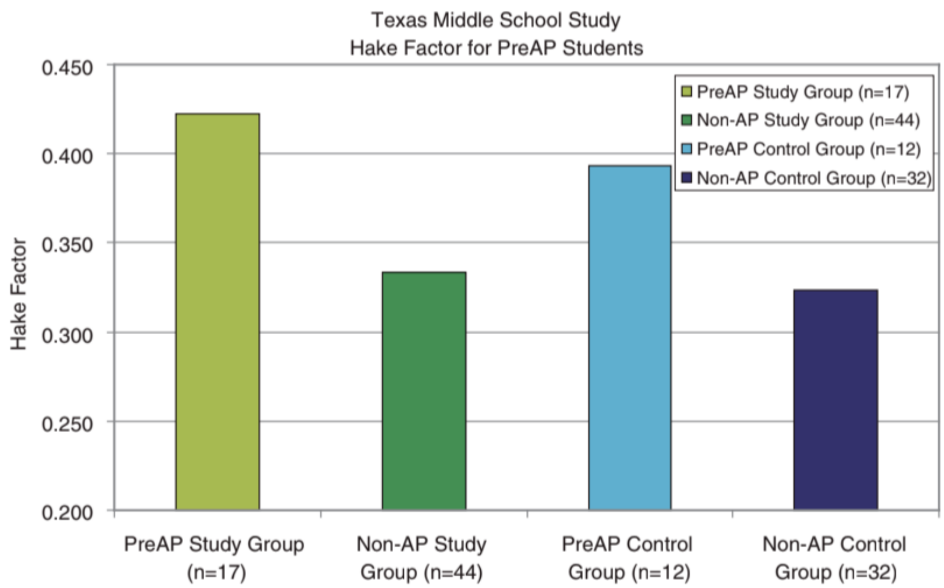
GIS' role in fostering meaningful, engaging educational opportunities cannot be understated. GIS can be used as a tool to deliver a content-rich curriculum in a format that is relevant for students. By solving problems collaboratively, working with community partners, and utilizing local data to solve actual problems, students reap the benefits of a well-rounded education through learning countless skills, from how to use geospatial technologies to how to communicate with diverse community members in order to achieve a common goal.

Finally, GIS leads to increased student interest and motivation to learn the subject matter. Scarlett et al. (2019) found that when students worked with local, real-time data, this increased student motivation and excitement to learn about the content in an applicable and authentic manner. Doering & Veletsianos (2008) reported that students were motivated "to explore geographic locations through ease of use" (p. 10). In the Schlemper et al. (2019) case study, researchers reported that students provided daily feedback describing how they were able to understand their community on a deeper level and brainstorm meaningful solutions to problems while engaging in the GIS, inquiry-based learning curriculum. Finally, Brindisi et al. (2006) reported on an important element that GIS brings to the secondary science classroom: interactivity. The interactive components of GIS incorporated into science lessons led to increased student interest and motivation to learn. Brinidisi et al. (2006) state "Traditional learning materials are often static and allow for little or no interactivity" (p. 2). In contrast to this are interactive GIS learning materials. Students can follow methods that actual scientists use in their careers and work with authentic data sets that researchers use. They are able to "...manipulate, query, and display the data. They may do this in any manner that they choose, not only by following a specific set of instructions supplied by their teachers" (Brindisi et al., 2006, pg. 2). These interactive components and authentic aspects of GIS lead to a shift in students' motivation as compared to a traditional classroom. Students are intrinsically motivated to learn the scientific literacy skills and concepts due to their own curiosity and as a result, they become "empowered to learn" (Brindisi et al., 2006, p. 2).

The factors of GIS-curriculum explained above all work together to create an optimal learning environment for students in the secondary science classroom. By teaching science curriculum with GIS, teachers are able to support students' practice of scientific literacy skills, integrate place-based, inquiry-based learning, and spark students' curiosity and motivation. As a result, students make larger gains in their scientific literacy skills and retain more scientific concepts. Below, Figure 2 shows the Brindisi et al. (2006) results from Texas middle school students who participated in the Discover Our Earth, GIS-integrated, science curriculum. The graph displays the average Hake factor of PreAP students, Non-AP students, and their corresponding control groups. This Hake factor compares actual score improvement to possible score improvement. In this study, AP students made the greatest gains in improvement when compared to their control group, with Non-AP students making smaller, but still positive, gains in improvement when compared to their control group (Brindisi et al., 2006, p. 7).

Figure 2

Quantitative Results from Brindisi et al. (2006, p. 7).



This study and others explained above continue to supply an abundance of evidence supporting the efficacy of GIS as a science education tool to support students' acquisition of scientific literacy skills and increase their interest and motivation to learn scientific concepts.

Limitations of GIS in Education

Previously identified challenges of using GIS in the classroom include the initial time investment teachers face when learning GIS software and curriculum (Meyer et al. 2004), students' limited experience with geospatial technology (Schlemper, 2019), and a need for teacher training (Doering & Veletsianos, 2008). Teachers face challenges when they initially approach GIS-integrated science curriculum because they have to take time to learn the GIS software (Meyer et al. 2004). It is also difficult for teachers to know how to utilize the software with ease (Hong, 2016). In addition to learning the geospatial technology, teachers also struggle to implement the place-based and inquiry-based aspects often accompanying GIS-integrated, science curriculum in a manner that fits the fast-paced timeline of a standards-based education. Regarding the time investment required to lead this type of curriculum, Schlemper et al. (2019) state, “We appreciate the hesitation that teachers may have in using PBL and inquiry learning, which can be time consuming, but we found there are many benefits to this approach.”

Additionally, Schlemper et al. (2019) state that students’ inexperience with spatial thinking and geospatial technology is a hurdle for educators when attempting to lead students in a GIS-integrated, science curriculum. Schlemper et al. (2019) report the following:

> “One of the challenges in teaching and learning geospatial technologies is that students often have limited background in using tools such as Google Earth or Google Maps. Even the task of finding their own neighborhoods on a map or interpreting 3D visualizations of the neighborhoods can be difficult.”

The need for scaffolding and differentiation options within the curriculum is evident in order to improve the quality and ease of using GIS in the classroom.

To remove the barriers to implementing GIS curriculum in the classroom, teachers need training on how to use GIS software, how to incorporate it into their curriculum, how to lead inquiry-based curriculum modules, and how to differentiate instruction for individual learner’s needs. Meeting the need for professional development can simultaneously decrease the challenges explained above since training would give teachers the tools to overcome these obstacles. Teachers cannot be successful in integrating GIS in the classroom without in-service teacher education programs demonstrating how GIS can support and enrich existing curriculum (Doering & Veletsianos, 2008). Doering & Veletsianos (2008) state that teachers need access to “...relevant, authentic, and accessible lessons to motivate them to use the GIS technology within their classroom” (p. 13). Without proper training and accessible resources, GIS can feel complex and too laden with data for many educators to experience it as a user-friendly and effective curriculum tool. Radinsky et al. (2014) states that “Learning to use new technologies often involves significant challenges for teachers and learners” (p. 143) Finally, Schlemper et al. (2019) state that their next steps after conducting the initial research on inquiry-based, GIS curriculum are to provide “professional development opportunities to social studies and science teachers that guide them in integrating problem-based citizen mapping in their classes.” Creating professional development programs focused on GIS and inquiry-based curriculum is the next important move for curriculum developers and school administrators to take based on the multitude of research supporting the efficacy of GIS in the secondary science classrooms.

This capstone project includes the development and implementation of a 20-week, GIS-focused, 6th grade science curriculum with inquiry-based and project-based components. It addresses the limitations described above by giving teachers the resources necessary to familiarize themselves with GIS and understand how it can reinforce instruction of scientific literacy skills and science standards. This capstone project also includes results from a mixed-methods survey suggesting how different types of GIS can be used to differentiate instruction for a variety of learners in the science classroom.

Methodology

The methodology for the research portion of this capstone project included the development and implementation of a 20-week, GIS-focused, 6th grade science curriculum and the use of a mixed-methods survey to determine students’ preference of GIS when learning scientific literacy skills in middle school classrooms. The project-based, GIS curriculum was designed for middle school science classes, grades 6-8, and aligned with NGSS and AZ State Standards.

Following completion of the curriculum unit described above, the qualitative survey asked students to rate the types of GIS on their ease of use, educational capabilities, and students' personal preferences. First, the survey asked students to reflect on which GIS best supported them to ask, understand, explain, and define problems of a spatial and ecological nature, as outlined in the four scientific literacy skills previously examined in this research. Next, students reflected on which form of GIS they preferred the most when using GIS to learn scientific literacy skills by using a 1-7 Likert scale. The survey also included eight open-ended questions about GIS preference, including favorite parts of the course, recommendations for the future, and skills they gained that were unique to the course. See Appendix B to view the complete survey instrument. All students participated in each type of GIS instruction through the duration of the GIS-integrated, science curriculum.

Following student participation in the survey, raw data from the multiple choice questions was used in addition to qualitative analysis of written responses to determine emerging trends. Responses were grouped based on emerging trends as determined by repeating keywords in each phrase such as "satellite imagery," "make maps," or "affect." If exact keywords were not present, associated words such as "make maps," "create maps," and "creativity" were placed in the same group. Percentages were then derived from the number of responses within a group divided by the total number of responses. An excerpt of the methodology process is located in Appendix C. While the quantitative results were initially designed to form the majority of the analysis, upon further examination, the qualitative responses yielded more meaningful results.

Types of Data and Potential Variability

The research portion of this capstone project contains quantitative and qualitative data representing students' personal GIS preference, including: which GIS form the students found most effective and engaging as well as any challenges they encountered in other types of GIS. Factors that might influence variability in this study include the demographic configuration of the students. Variability in the qualitative data could be analyzed to determine if certain types of GIS platforms are preferred for developing scientific literacy in certain ethnicities, genders, or ages.

Results

The analysis of the GIS Preference Survey identified student reports of five major trends listed below, echoing previous research on GIS and scientific literacy. A complete list of tables and figures representing all quantitative data can be found in Appendix A. A methodology excerpt in Appendix C displays how percentages were derived from qualitative data. For ease of reading the sections below, the percentages have been rounded to the nearest whole number followed by exact percentages in parentheses.

1. GIS helped students explain natural phenomena using evidence obtained from observations, specifically satellite imagery. In response to, “What was your favorite part of the GIS course?” Fourteen percent (13.6%) responded that examining satellite imagery was their favorite part (Table 1). One student responded, “My favorite part was looking at satellite pictures because it was a new way of looking at different parts of earth.” After studying satellite imagery of glaciers receding, two students remarked, “You could see the earth's ice, and that's interesting” and that it was fun and interactive “seeing the ice move.”
2. GIS helped students ask questions and define problems of a spatial-ecological nature. The largest percentage of students, at 47.6% of the total, stated that learning ecological concepts was their favorite part of the GIS course. Thirty three percent (33.3%) of

students stated that creating maps was their favorite part of the GIS course (Table 1). These results suggest the interconnectedness of the spatial and ecological questions inherent in the scientific process of the GIS course. When asked to identify what was fun and interactive about the GIS course, 31.8% of students reported new ecological facts they learned through asking questions, looking for trends, and finding solutions using GIS (Table 1).

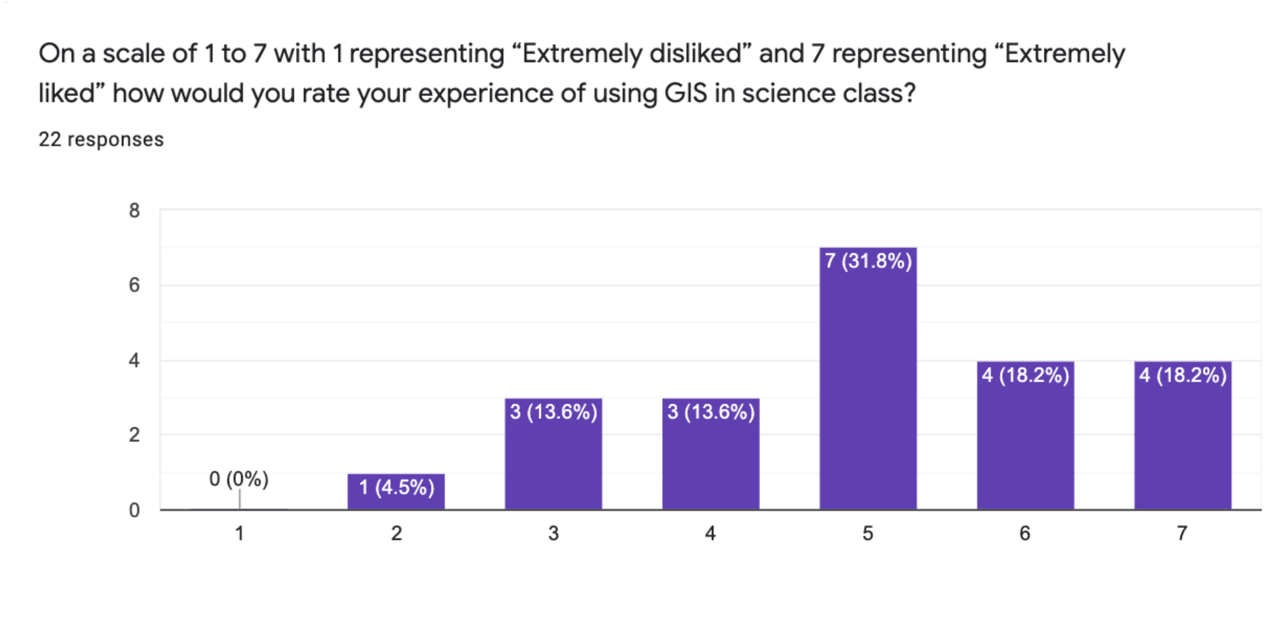
3. GIS taught students to identify cause and effect relationships to predict phenomena in natural systems. One student stated, “I would recommend this because it's important to learn how carnivores and biodiversity affect each other and the ecosystem.” When asked about concepts they learned in the GIS course that they would not have learned in a traditional science course another student stated, “I learned a lot about consistency and cause & effect.”
4. GIS was a fun and interactive way to learn the scientific content and scientific literacy skills. When asked to describe which components were fun and interactive, a significant portion of students at 36.4% wrote about a sense of ownership and choice when creating their maps (Table 1). One student stated, “I liked the way that I/we were able to choose the things that we wanted on the map” and another stated, “It was fun that we got to create and make what we see and interact with it and change it up.”
5. Alongside a sense of ownership and choice, GIS fostered personal interest and motivation in students to care for their environment and take action to improve human-environment interactions. When asked why they would recommend a GIS and ecology course, students stated, “I would recommend this because I think it's important to understand

glaciers for climate change" and "Because I thought is was really fun and cool and people should learn more about our earth and all the issues so maybe they could help stop it."

Table 1: GIS Preference Survey Results

6th grade science student responses to the GIS Preference Survey Top three categorical responses from each survey question	
A. Students favorite part of the GIS course ● Creating Maps ● Learning ecological concepts ● Studying satellite imagery	Percent of student responses ● 47.6% ● 33.3% ● 13.6 %
B. Components of the GIS course that were fun and interactive ● A sense of ownership and choice with creating the map ● Learning ecological concepts ● A sense of exploration and discovery	Percent of student responses ● 36.4% ● 31.8% ● 9.1%
C. Components of the GIS course that were challenging ● Challenges with technology ● Challenging to understand the course content ● Overwhelmed with the amount of data	Percent of student responses ● 31.8% ● 27.3% ● 13.6%
D. Components of the GIS course students would change ● Nothing ● Make the course easier ● Miscellaneous, No identifiable trend	Percent of student responses ● 45.5% ● 18.2% ● N/A
E. Skills and concepts learned in the GIS course that they would not have learned in a traditional science course ● How to use GIS Technology ● Analyzing satellite imagery ● Identifying a trend	Percent of student responses ● 27.3% ● 13.6% ● 13.6%

Figure 3: Likert Scale Results



Sixty eight percent (68.2 %) of students Liked/Extremely Liked their experience using GIS in science class as seen in Figure 3 above. While the data does not point to a clear student preference of GIS use in science class, students did report the strengths of using each type of GIS. Teachers and curriculum can utilize the survey results to point to the best choice of GIS integration for the topic of study and the goal of the unit at the time. Depending on these factors, the optimal type of GIS could change dependent on the learning target and the students' learning preferences.

Strengths and Limitations of GIS Types

The following section describes the strengths and limitations of each type of GIS as documented by the students' survey responses. The percentage of students' recommendations for the type of GIS that future teachers use when teaching science is also stated alongside the rationale when providing the recommendation.

1. ***Studying pre-made interactive maps***

    a. *Strengths:* Studying pre-made interactive maps was the most preferred form of GIS to use when practicing scientific literacy skills as seen below in figures 4 - 5. Fifty nine percent (59.1%) of students also reported that studying pre-made interactive maps was the easiest and most user-friendly type of GIS as seen below in Figure 6. In addition to being an easier form of GIS, students liked the wealth of interesting information to explore. One student stated, “The fun thing about pre-made interactive maps is that there's so many things to explore and it goes on and on and on!” Another student stated, “It was fun because it was easy to check off what I wanted to see and it was easy to observe colors and locations.”

    b. *Limitations:* Students reported becoming overwhelmed when using this type of GIS, stating there were “too many options” and “so many colors”

    c. *Recommendations:* This type of GIS received the smallest number of recommendations for future science teachers to use with 27.3% of students recommending pre-made interactive maps (Figure 11); However, reasons students chose this type included the ease of use, the science topics we studied when using it, and the ability to work in teams.

Figure 4: Studying pre-made maps reported as the preferred method for answering ecological questions

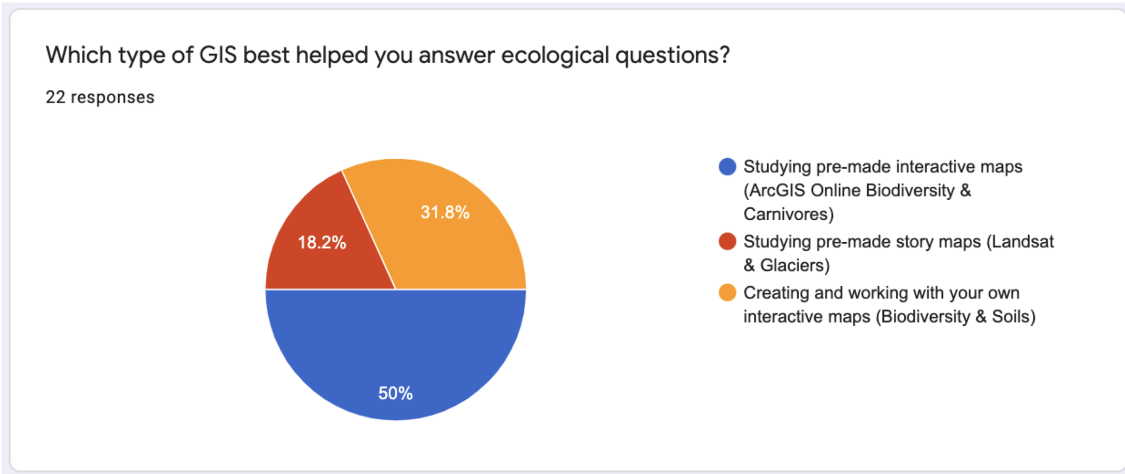
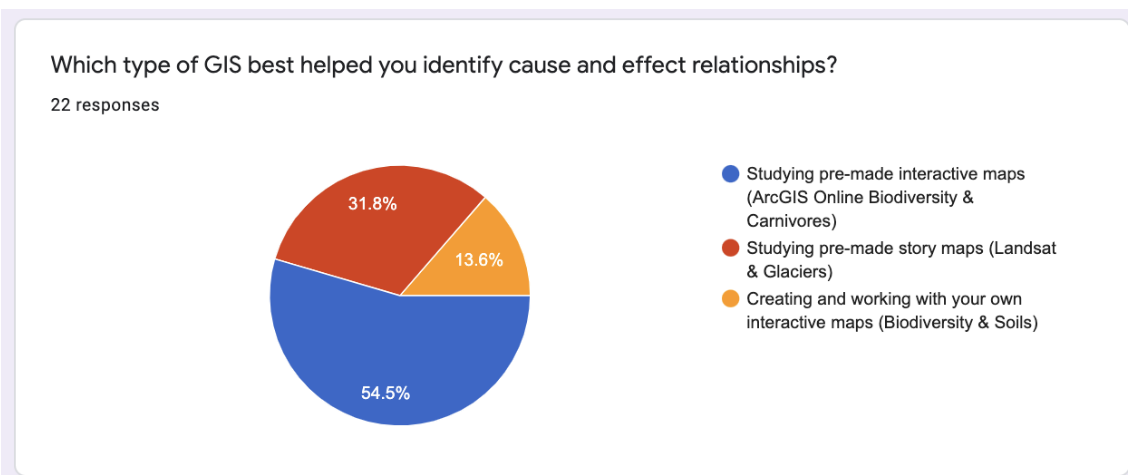


Figure 5: Studying pre-made maps reported as the preferred method for identifying cause and effect relationships



2. Studying pre-made story maps

a. *Strengths:* Forty six percent (45.5%) of students identified studying pre-made story maps as the best way to explain natural phenomenon as seen in Figure 7. They reported that they enjoyed the scientific content they explored with this format and also identified it as an easier form of GIS. In one story map module, students studied glaciers. They stated, " I got to learn about glaciers and how we can help them survive" and "You could see the earth's ice, and that's interesting." Another student stated, "It is reading. I like reading." Studying pre-made story maps also was ranked as one of the preferred methods for communicating scientific information as seen in Figure 8.

b. *Limitations:* Students reported technical difficulties with this type of GIS stating that the "website was challenging" and it was "time consuming."

c. *Recommendations:* Thirty six percent (36.4%) of students recommended studying pre-made story maps tying with creating interactive maps as the most popular GIS recommendation (Figure 11). Reasons students chose this type included the ease of use and the science topics we studied when using it. One student described their recommendation as follows: "Because I thought it was really fun and cool and people should learn more about our earth and all the issues so maybe they could help stop it."

Figure 7: Studying story maps to understand natural phenomena

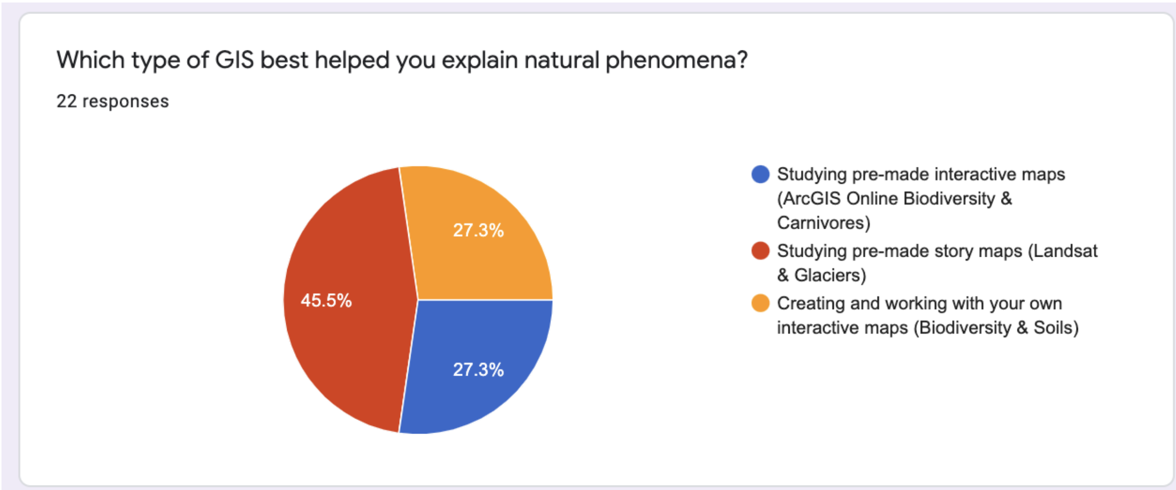
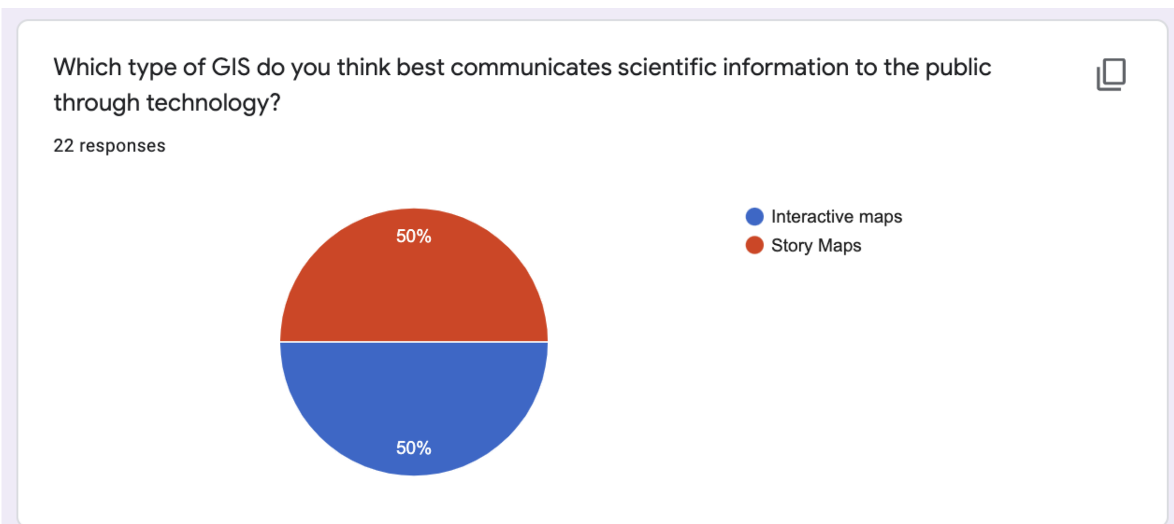


Figure 8: Studying pre-made maps reported as one of the preferred methods for communicating scientific information



3. ***Creating interactive maps***

   a. *Strengths:* The main strength identified in creating interactive maps was that it was fun and interactive as reported by 45.5% of students seen below in Figure 9. Students enjoyed creating the maps and having choice and autonomy over how they created the map and the map's focus. One student stated, "You could make a map about whatever you wanted" and another student stated,"It was fun that we got to create and make what we see and interact with it and change it up."

b. *Limitations:* Students reported that creating interactive maps was one of the most challenging forms of GIS because of technological difficulties such as "being hard to move" or "trouble with the map website" (Figure 10). Students also stated that the content was more challenging to derive from the lesson when also working on creating a map. One student stated, "Creating the maps was the most hardest thing because you have to really focus and figure out A LOT of stuff."

c. *Recommendations:* Thirty six percent (36.4%) of students recommended studying pre-made story maps tying with studying pre-made story maps as the most popular GIS recommendation as seen below in Figure 11. Students described this form of GIS as the most "fun" and "interactive." They also recommended this form because it allowed for "personalization," "creativity", and autonomy when learning. One student stated, "Because this map encourages creativity and it is fun for kids." Another stated, "I would recommend this type because it gives the students a better understanding when doing it themselves.

Figure 9: Creating interactive maps reported as the most fun and interactive

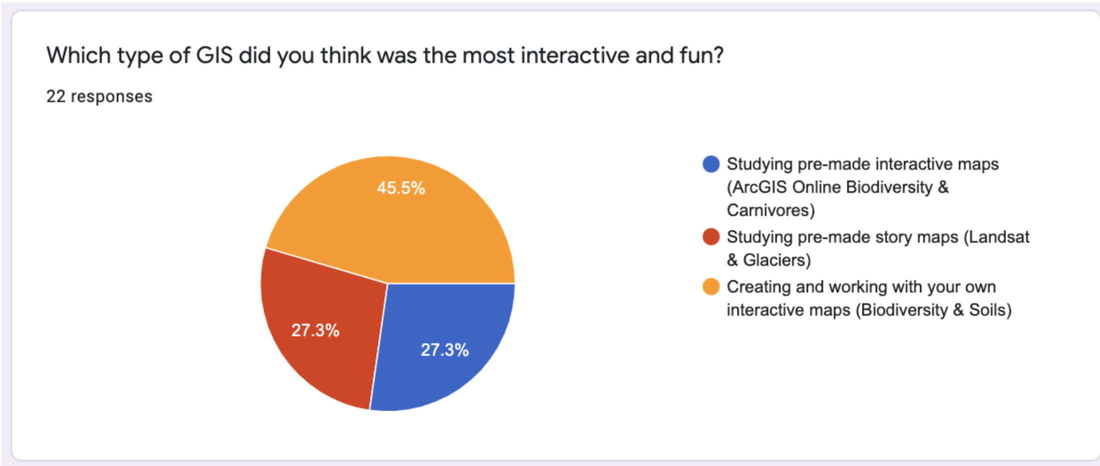


Figure 10: Types of GIS reported as the most challenging

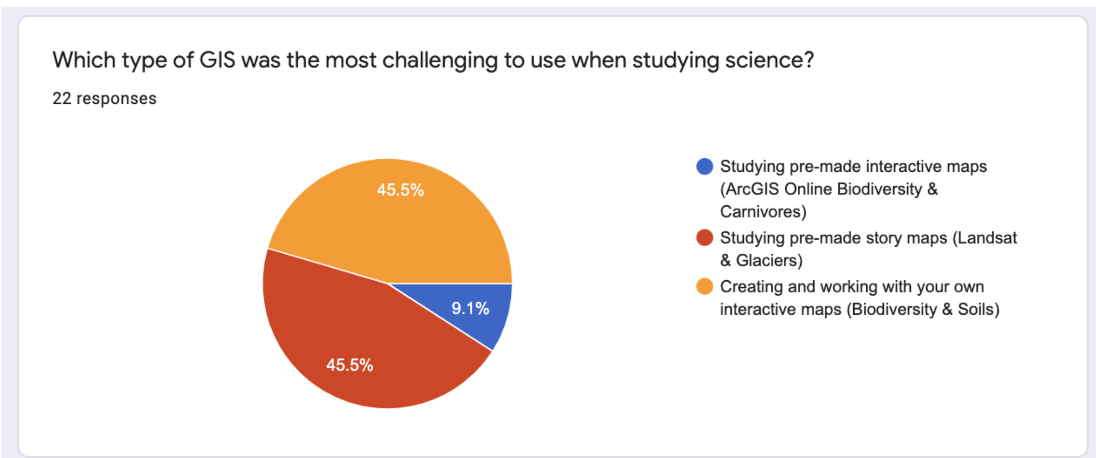
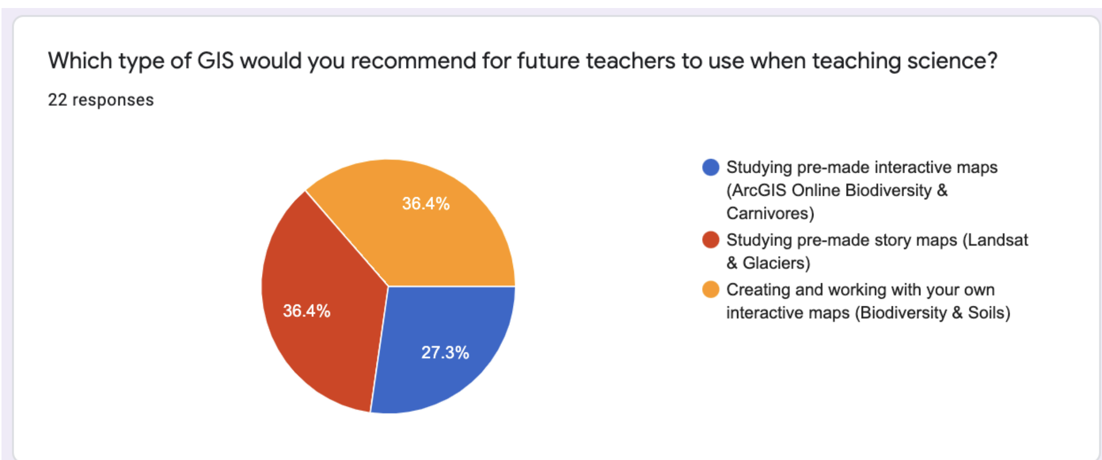


Figure 11: Types of GIS recommended by students



Discussion

These survey results clearly display that each type of GIS had a strength which stood out to specific types of learners. Studying pre-made interactive maps was identified as an easy and user-friendly activity. Studying pre-made story maps helped students learn and explain natural phenomena while creating interactive maps was fun and interactive. Knowing the strength of each form of GIS can help teachers decide when and how to incorporate the various forms of GIS in the classroom.

GIS for Differentiation

Students who enjoy an easier and more comfortable learning environment were drawn to the pre-made interactive maps and story maps. Students who enjoyed creating their own maps and having more autonomy in their learning were drawn to creating their own interactive maps. With a variety of learners in the class, differentiation within the GIS types offered to students could be another way to personalize learning in the science class. Students in this survey who stated that they like reading may prefer to learn through reading and could have greater success in studying pre-made story maps. Those who like to draw, create, and experiment could have more success learning science through creating interactive maps.

Challenge and Learning

Another trend that emerged from this study was that the two forms of GIS that students identified as the most challenging were also the two forms of GIS that students would recommend for future teachers as seen in Figures 10 and 11. While this data does not display a 1-to-1 comparison with all students identifying the most challenging GIS as the same one they would recommend to future science teachers, 18.2% of students did choose the same GIS type for both categories. This is indicative of prior research in education stating that a certain degree of challenge is necessary for student engagement and a rewarding learning experience (Strati, Schmidt, & Maier, 2017). In comparison, 59.1% of students stated that studying pre-made interactive maps was the easiest (Figure 6), but only 27.3% of students would recommend this form of GIS to future science teachers (Figures 11). Finally, one way to interpret the evenly spread data in students' responses to most of the survey questions, but specifically as seen in Figure 11, is to acknowledge that challenges and fun will look different across the classroom to various learners. This resulted in a class sample recommending a variety of GIS types. With a wide spectrum of learning styles in the classroom, there is a need for learning options delivered in a variety of modalities to promote access to scientific knowledge for all types of learners.

Student Gender: Finally, an examination of students' genders revealed some preferences when using GIS in the science classroom. The most identifiable difference between genders for GIS preference was a ratio of 3:1 with girls preferring creating their own interactive maps three times as much as boys.

Implications of the Capstone Project

The results of this capstone project can be utilized to guide the development of future GIS curriculum and STEM outreach programs promoting scientific literacy in secondary students. Three main trends were identified, which can be applied to all curriculum planning and program implementation, whether in a traditional classroom or an outreach environment.

1) Allowing students choice in the learning process increases students' interactivity and enjoyment learning the content.
2) A variety of GIS types allows for differentiation of course material and personalization of the learning experience.

3) Incorporating challenging components in the GIS curriculum will lead to increased student engagement.

Specifically, this capstone project will culminate with a presentation sharing the results and curriculum with students and faculty at Oregon State University during a final capstone presentation. The capstone project will also include the distribution of the GIS curriculum throughout the middle schools at the district and charter level in Prescott, Arizona. The link to the complete 20-week, GIS-focused, 6th grade science curriculum used in this study is listed in Appendix D alongside GIS teaching resources from a variety of sources such as National Geographic, Esri, and NASA. These supplemental resources could be used to differentiate GIS and science curriculum up to the high school level or down to the elementary level. Additionally, the STEM Outreach Office at Embry-Riddle Aeronautical University, which provides experiential STEM opportunities for Central Arizona students, will integrate the GIS curriculum into the summer and afterschool STEM outreach programs for secondary students. Finally, the grant provided by GEM Environmental will be used to contribute to the purchase of drones for Granite Mountain School's STEAM class. The remaining amount will be used to pilot the first year of SciTech's Chief Science Officers Program in Yavapai County. This program promotes students in grades 6-12 to be STEM ambassadors for their peers and community through receiving STEM training and then hosting STEM events. This global community of SciTech's Chief Science Officers spans 10 states and 4 countries and promotes leadership training, STEM learning opportunities, scientific literacy, and diversity in the STEM fields (SciTech Institute, 2019).

Communicating Results

Based on the critical social, institutional, and political elements described above, the intended audiences for this capstone project report are practitioners and policy makers. The main intended audience for the capstone project's report is practitioners, including fellow teachers and STEM program educators, since they will utilize the GIS-infused, inquiry-based science curriculum. The overarching goals of this project are to promote students' scientific literacy skills and their interest in the STEM fields by providing educators a unique, standards-aligned curriculum enabling them to teach science through GIS.

Additionally, the audience for this report could include policy makers such as principals and superintendents. Eventually, the results of this capstone project and others like it could lead to a policy change requiring a more robust science curriculum to be provided state-wide up to a certain grade in the state of Arizona based on the benefits these programs offer to students and society.

Recommendations for Future Research

Existing research focuses on the use and effects of incorporating web maps (Radinsky et. al. 2014), paper maps (Baker & White, 2003), story maps (Egiebor & Foster, 2019), GIS data and GIS technology (Schlemper et al., 2019) in the classroom, but does not point to a conclusive approach that is most effective for students to develop necessary scientific literacy skills. A potential area of future research would be a rigorous quantitative study on various types of GIS in secondary science classrooms in an effort to determine which approach is the most effective for developing students' scientific literacy. Conversely, attention could be given to increasing the depth of the qualitative survey to include structured student interviews following the curriculum unit. Research from this capstone project's mixed-methods survey found the qualitative results to provide more valuable information than the quantitative results. An in-depth, qualitative interview approach could build on the results from this study and deepen the content and value of student responses.

Additional areas for future research include an examination of the efficacy of new professional development programs and the areas trainers should focus on to best support teachers. Finally, researching best practices for scaffolding and differentiation techniques would provide beneficial knowledge for teachers implementing inquiry-based, GIS-integrated, science curriculum in their classrooms. Schlemper et al. (2019) make this point clear by concluding "Additional research is needed to provide scaffolding of these methods to disciplinary content standards in the social studies and sciences at the state and national levels across the grade levels." Continued mounting evidence on the effectiveness of using GIS in the classroom can incentivize teachers to invest the time and energy into more complex and lengthier curriculum units knowing they have the tools they need to help their students succeed.

Conclusion

GIS has many benefits in the secondary science classroom. It has the ability to promote students' scientific literacy skills including students' ability to 1) "ask questions and define problems of a spatial-ecological nature, 2) identify cause and effect relationships to predict phenomena in natural systems, 3) explain natural phenomena using evidence obtained from observations and scientific investigations, and 4) obtain, evaluate, and communicate information through technology" (NGSS Lead States, 2013, p. 15). An additional benefit includes the ability of GIS to support place- and inquiry-based science curriculum while fostering connections with community members in order to create meaningful change. Finally, GIS leads to increased student interest and motivation to learn science: students are engaged in their learning within a social environment, while tackling real-world challenges, with a sense of autonomy and choice over their learning progression. Since incorporating GIS in the classroom is a relatively new practice, educators still face challenges and limitations when teaching science through GIS. These challenges can be mitigated by providing support for teachers in the form of professional development, which could teach GIS fundamentals, inquiry-based teaching methods, and differentiation. This professional development would mitigate the majority of the challenges and limitations experienced by educators using GIS in the classroom. Potential areas of future research include quantitative research recommending the most effective types of GIS to use in the secondary science classroom and the best ways to differentiate the curriculum to diverse learners. Additionally, researchers could identify the most vital aspects of professional development programs to benefit teachers. All future research regarding GIS in education can continue to provide evidence for the value of inquiry-based, GIS-integrated, science curriculum and incentivize teachers to use this approach in their classrooms. Based on the literature review presented in this paper, it is evident that inquiry-based, GIS-integrated, science curriculum should be developed and utilized by teachers in order to give students the skills they need to confront 21st century issues, excel in their education, and lead meaningful careers.

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Appendix A

Tables and Figures

Table 1: GIS Preference Survey Results

6th grade science student responses to the GIS Preference Survey **Top three categorical responses from each survey question**	
A. Students favorite part of the GIS course ● Learning ecological concepts ● Creating maps ● Studying satellite imagery	Percent of student responses ● 47.6% ● 33.3% ● 14.3 %
B. Components of the GIS course that were fun and interactive ● A sense of ownership and choice with creating the map ● Learning ecological concepts ● A sense of exploration and discovery	Percent of student responses ● 36.4% ● 31.8% ● 9.1%
C. Components of the GIS course that were challenging ● Challenges with technology ● Challenging to understand the course content ● Overwhelmed with the amount of data	Percent of student responses ● 31.8% ● 27.3% ● 13.6%
D. Components of the GIS course students would change ● Nothing ● Make the course easier ● Miscellaneous, No identifiable trend	Percent of student responses ● 45.5% ● 18.2% ● N/A
E. Skills and concepts learned in the GIS course that they would not have learned in a traditional science course ● How to use GIS Technology ● Analyzing satellite imagery ● Identifying a trend	Percent of student responses ● 27.3% ● 13.6% ● 13.6%

Figure 1: Qualitative results from Brindisi et al. (2006, p. 6).

TABLE 1. UNDERGRADUATE STUDENT COMMENTS ON THE USE OF QUEST FOR THE PLATE TECTONICS LESSON, LISTED BY PERCENTAGE OF RESPONSES

A

What students liked most	Percent of student responses
Interactivity with data	34
Visual learning	11
Learning about plate tectonics	8
Drawing own conclusions	8
Using computers	8

B

What students liked least	Percent of student responses
Speed of map server	31
“Nothing”	17
Button design and/or functionality	17
Using computers	11
Instructions	9

A: Top five “liked best” comments.
B: Top five “liked least” comments. Note that 34% of the “liked best” comments praised the interactivity with the data, and 31% of the students’ “liked least” comments complained about the speed of the map server.
QUEST—Quick Use Earth Study Tool.

Figure 2: Quantitative Results from Brindisi et al. (2006, p. 7).

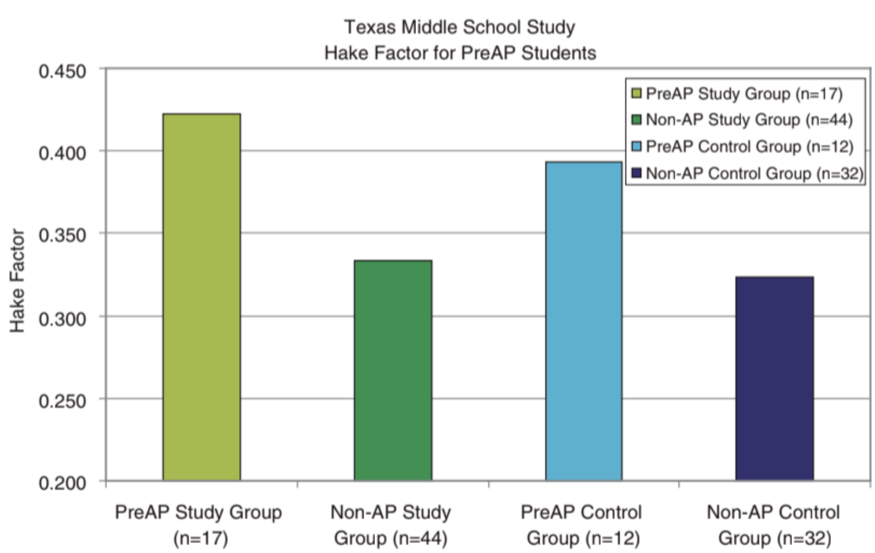


Figure 3: Likert Scale Results

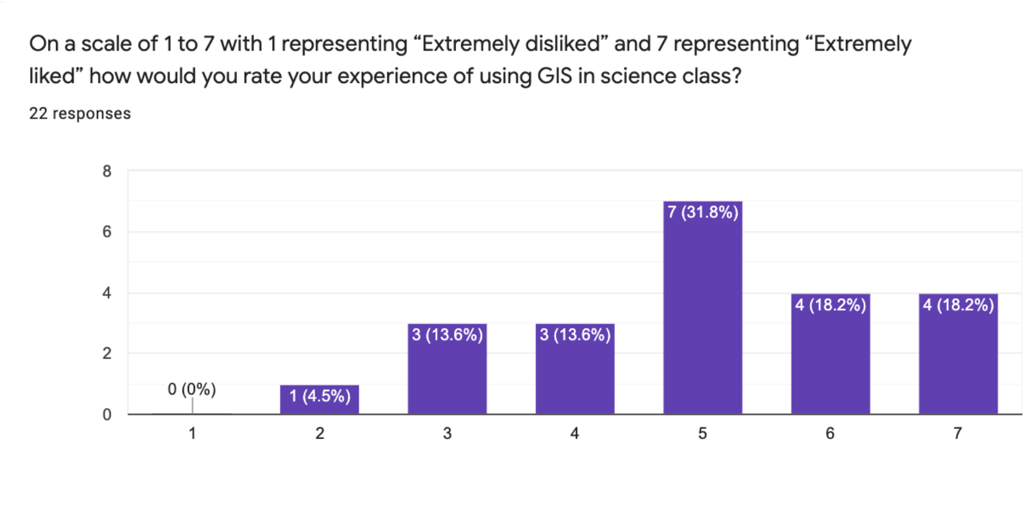


Figure 4: Studying pre-made maps reported as the preferred method for answering ecological questions

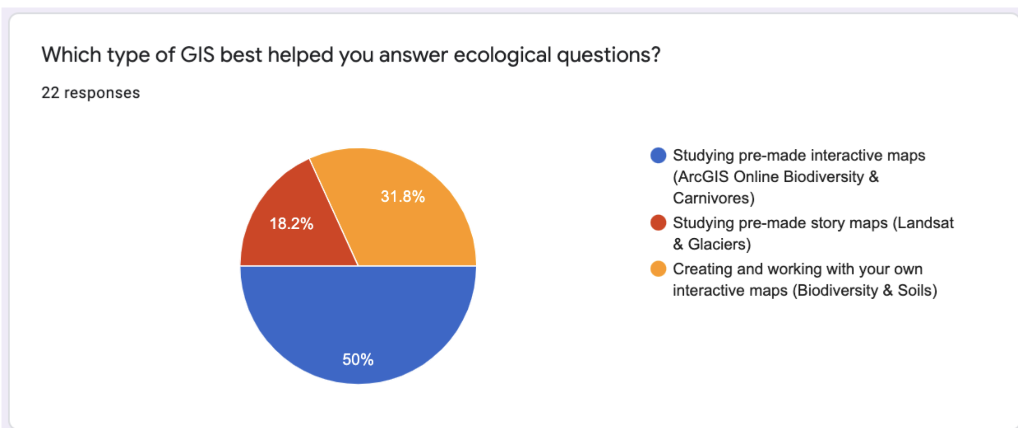


Figure 5: Studying pre-made maps reported as the preferred method for identifying cause and effect relationships

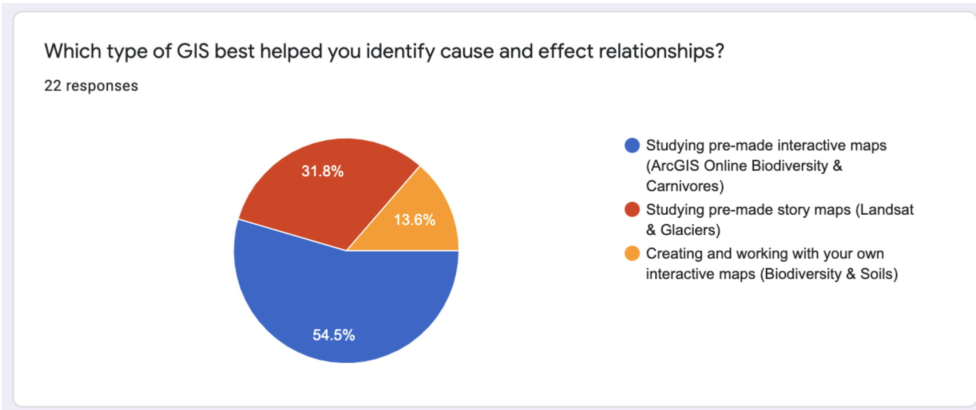


Figure 6: Studying pre-made interactive maps reported as the easiest form of GIS

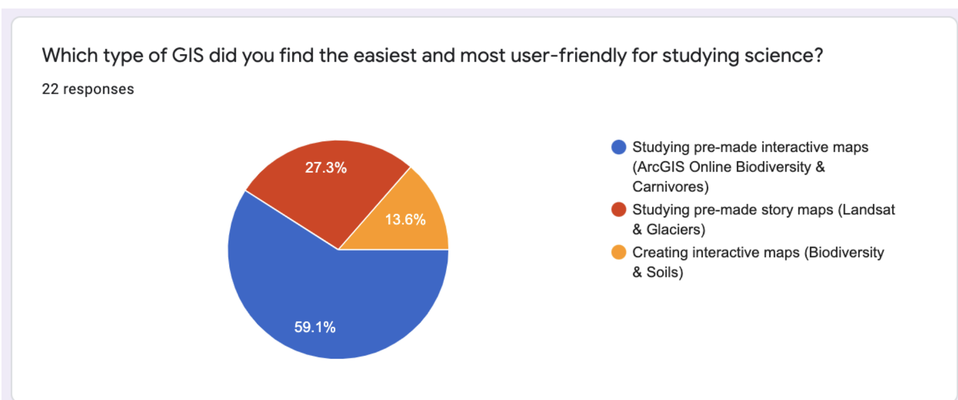


Figure 7: Studying story maps to understand natural phenomena

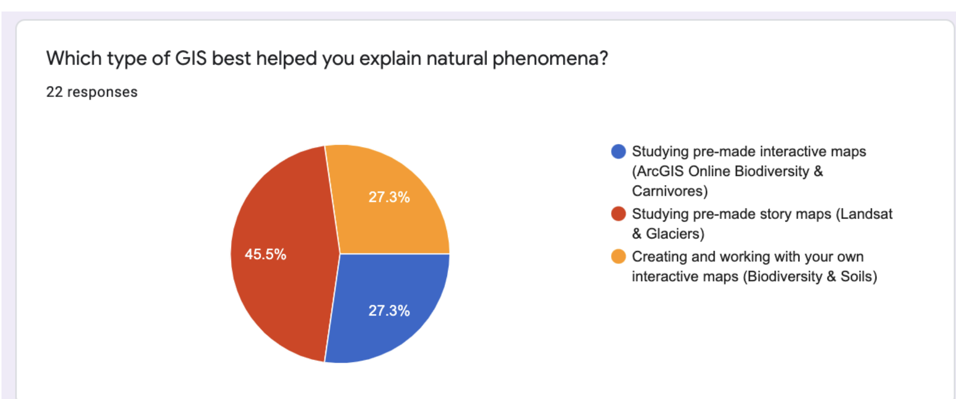


Figure 8: Studying pre-made maps reported as one of the preferred methods for communicating scientific information

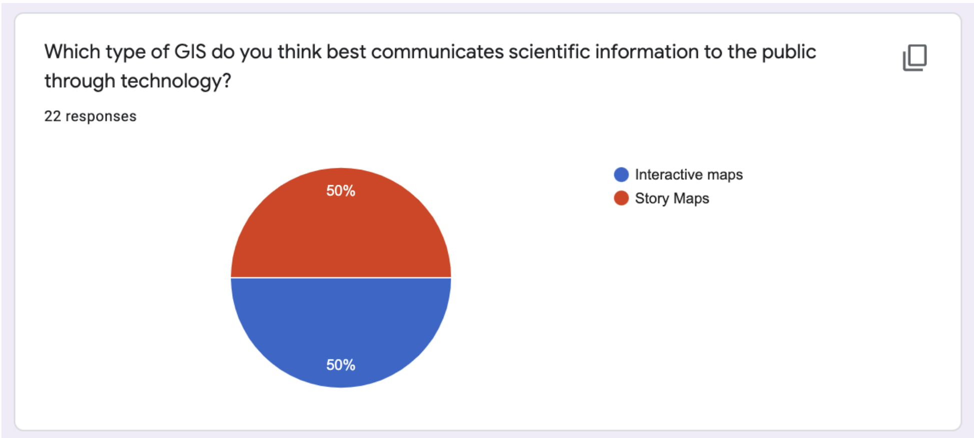


Figure 9: Creating interactive maps reported as the most fun and interactive

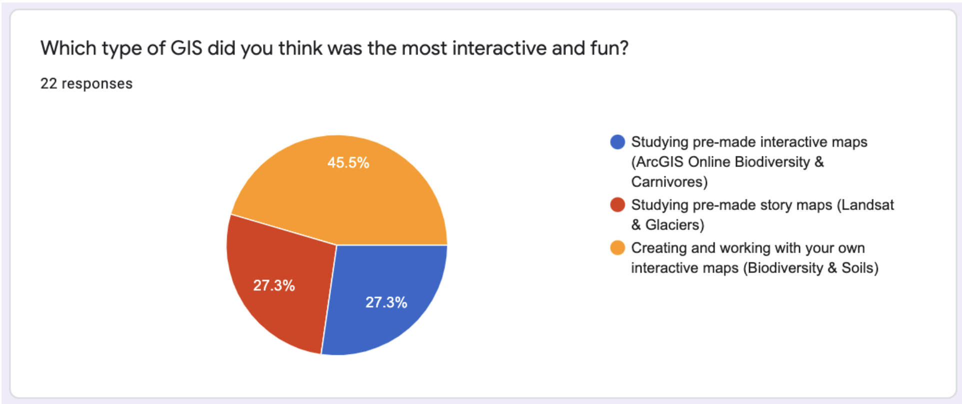


Figure 10: Types of GIS reported as the most challenging

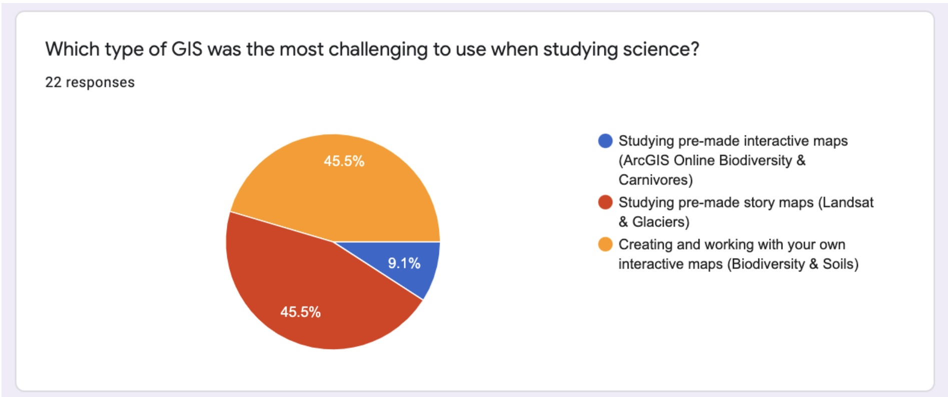
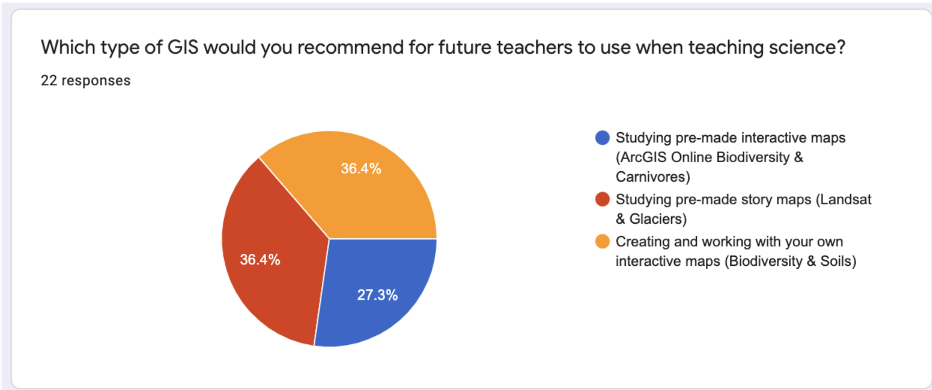


Figure 11: Types of GIS recommended by students



Appendix B

GIS Preference Survey

Name: ___________________

GIS Preference Survey

1. **Which type of GIS did you find the easiest and most user-friendly for studying science?**

a. Studying pre-made interactive maps b. Creating interactive maps

c. Studying pre-made story maps d. Creating story maps

2. **What made it user-friendly?**

____

3. **Which type of GIS did you think was the most interactive and fun?**

a. Studying pre-made interactive maps b. Creating interactive maps

c. Studying pre-made story maps d. Creating story maps

4. **Which parts were interactive and fun?**

____

5. **Which type of GIS was the most challenging to use when studying science?**

a. Studying pre-made interactive maps b. Creating interactive maps

c. Studying pre-made story maps d. Creating story maps

6. **What made it challenging?**

____

7. **Which type of GIS would you recommend for future teachers to use when teaching science?**

a. Studying pre-made interactive maps b. Creating interactive maps

c. Studying pre-made story maps d. Creating story maps

8. **Why would you recommend this type?**

____

9. Which type of GIS best helped you answer ecological questions? For example, an ecological question is, “Why does more cactus grow on the South-facing slopes?”

a. Studying pre-made interactive maps b. Creating interactive maps

c. Studying pre-made story maps d. Creating story maps

10. Which type of GIS best helped you identify cause and effect relationships? For example, a cause and effect relationship is that less sun on North-facing slopes causes a difference in the type of plants on these slopes due to growing conditions.

a. Studying pre-made interactive maps b. Creating interactive maps

c. Studying pre-made story maps d. Creating story maps

11. Which type of GIS best helped you explain natural phenomena? For example, the way rock erodes on certain slopes due to weather, rock type, soil type, human impact, etc.

a. Studying pre-made interactive maps b. Creating interactive maps

c. Studying pre-made story maps d. Creating story maps

12. Which type of GIS best helped you communicate scientific information to the public through technology?

a. Studying pre-made interactive maps b. Creating interactive maps

c. Studying pre-made story maps d. Creating story maps

13. On a scale of 1 to 5 with 1 representing “Extremely disliked” and 7 repreesenting “Extremely liked” how would you rate your experience of using GIS in science class?

1 2 3 4 5 6 7

1 = Extremely disliked **7 = Extremely liked**

14. What was your favorite part of the GIS science course?

____

15. **What would you change about the GIS science course?**

____

16. **What did you learn or experience from the GIS course that you don’t think you would have learned from a typical science course?**

____

Please add any additional comments or suggestions to improve the future of this course.

____

Appendix C

Methodology Excerpt

Raw Qualitative Data in the form of students' responses

What was your favorite part of the GIS science course?

21 responses

To make the maps

I like studing gis becous it is a new thing and how they used satilit imiging to creat a map.

My favorite part was obviously all of it, I love life science and GIS.

when we learned about biomes

the story maps

Making the group project.

Doing the map that we got to draw on.

I My favorite part about GIS science was when we got to learn about the glaciers because I learned some stuff that I didn't know before. Now because of that I can correct my mom.

My favorite part was look at satilight pictures because it was a new way of looking at different parts of earth.

What was your favorite part of the GIS science course?

21 responses

My fravoit parts if biomes

My favorite part about the GIS science course was just all in all learning about the subject because I thought that it was interesting how they used those pieces of technology.

making maps

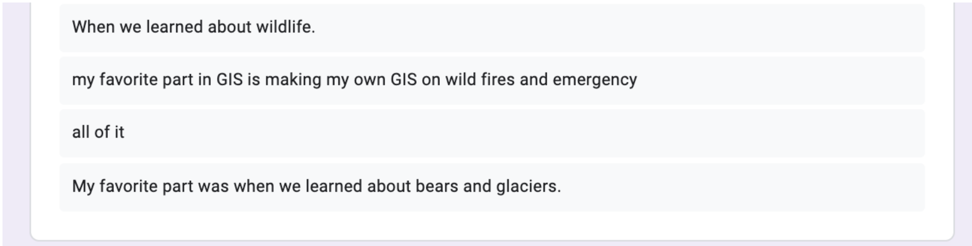
that it was very learning for me

My favorite part was when we had to explore the map.

My favorite part was looking at satalite pictures.

My favorite part was learning about our earth and all the plants and animals and mostly getting to do it with you as my teacher.

Making the maps.


When we learned about wildlife.

my favorite part in GIS is making my own GIS on wild fires and emergency

all of it

My favorite part was when we learned about bears and glaciers.

Total Responses: 21, Student response, “All of it,” was removed from the sample due to lack of clarity.

Learning ecological concepts: 10/21 or 47.6% of responses

- “My favorite part was obviously all of it, I love **life science** and GIS.”
- “when we learned about **biomes**”
- “the **story maps**”
- “My favorite part about GIS science was when we got to **learn about the glaciers** because I learned some stuff that I didn't know before. Now because of that I can correct my mom.”
- “My favorite parts if **biomes**”
- “My favorite part about the GIS science course was just all in all **learning about the subject** because I thought that it was interesting how they used those pieces of technology.”
- “that it was very **learning** for me”
- “My favorite part was **learning about our earth and all the plants and animals** and mostly getting to do it with you as my teacher.”
- “When we **learned about wildlife.**”
- “My favorite part was when we **learned about bears and glaciers.**”

Creating Maps: 7/21 or 33.3% of responses

- "To **make the maps**"
- "**Making** the group project."
- "**Doing the map** that we got to **draw on.**"
- "**making maps**"
- "My favorite part was when we had to **explore the map.**"
- "**Making the maps.**"
- "my favorite part in GIS is **making my own GIS** on wild fires and emergency"

Studying satellite images: 3/21 or 14.3% of responses

- "I like studing gis becous it is a new thing and how they used **satilit imiging** to creat a map."
- "My favorite part was look at **satilight pictures** because it was a new way of looking at different parts of earth."
- "My favorite part was looking at **satalite pictures.**"

Results

Students favorite part of the GIS course	Percent of student responses
• Learning ecological concepts • Creating Maps • Studying satellite imagery	• 47.6% • 33.3% • 14.3 %

Appendix D

Links to Lesson Plans

- Complete GIS Curriculum Map:
    - https://docs.google.com/document/d/1WEWADwAyEA7KwQ-d1f_hs2eIIzYJKU__c816ZFvKF2U/edit?usp=sharing
- Studying pre-made interactive maps at Esri Geoinquiries:
    - https://www.esri.com/en-us/industries/education/schools/geoinquiries-collections
- Studying pre-made interactive maps at Google Earth Timelapse:
    - https://earthengine.google.com/timelapse
- Studying pre-made story maps at NASA Arctic Sea Ice Lesson Plan:
    - https://nasa.maps.arcgis.com/apps/MapSeries/index.html?appid=2adb302f548945d08f9aed5e41352255
- Slide Resource at What is GIS Slides:
    - https://www.slideshare.net/aGISGuy/what-is-gis-1655272
- Esri's GIS Applications:
    - https://www.youtube.com/watch?v=pg7ByVZo_sg
- Video Resources at National Geographic's Exploring with GIS:
    - https://www.nationalgeographic.org/education/exploring-with-gis/
- Additional Lesson Plans at National Geographic:
    - https://www.nationalgeographic.org/topics/gis/?q=&page=1&per_page=25
- Nitty Gritty ecology curriculum:
    - https://nittygrittyscience.com/product/principles-of-ecology/

Appendix E

Links to Selected Student Excerpts

- Recorded GIS lessons:
  - https://drive.google.com/file/d/1RB_lcDunbLfuMxF7QSbigHmUIE-2iRBT/view?usp=sharing
  - https://drive.google.com/file/d/1pz-tsfU5tq2LGE4Ti-i1mlqcc0zWaL4Z/view?usp=sharing
- GIS scavenger hunt:
  - https://drive.google.com/file/d/177S-33R-4H0CqbJqFPP2w1J2IbdqmXKE/view?usp=sharing
- Digitizing assignment examples:
  - https://drive.google.com/file/d/1jOKTCWgy28fba0SZuJLe-2GQ9483eM3B/view?usp=sharing
  - https://drive.google.com/file/d/1-JxhDjuM0v1JnV7E5AE0-XuP5TIFHjy6/view?usp=sharing
- Written projects reinforcing ecological concepts taught with GIS:
  - https://drive.google.com/file/d/10bJvZ2UydikD01rgV2SRYytu5ofFOxcd/view?usp=sharing
  - https://drive.google.com/file/d/1t-dkPoi8ophRTPzES0K9L4Ew0rAbeOj4/view?usp=sharing
  - https://drive.google.com/file/d/1t-dkPoi8ophRTPzES0K9L4Ew0rAbeOj4/view?usp=sharing