THE IMPACTS OF GLOBAL INFORMATION SYSTEMS (GIS) LEARNING ACTIVITIES ON HIGH SCHOOL STUDENTS' ATTITUDES AND BEHAVIORS

by

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ABSTRACT

Do students view using computer based mapping software or Global Information Systems (GIS) as hands-on, real-world learning activities? This study investigated student attitudes and behaviors around using GIS in a high school earth science curriculum. A single treatment compared three types of assignments during one unit of study. Students engaged in a traditional hands-on lab, a computer based assignment, and an assignment that used GIS. Students engagement for each assignment was measured using an observation rubric, completion rates were monitored, and student attitudes were tested using a student survey and student interviews. Students demonstrated a preference for hands-on labs, and GIS assignments were viewed as more hands-on when compared to other computer-based assignments. Students perceived GIS assignments as more relevant than other assignments. GIS assignments can be used to increase relevance in an earth science curriculum and to make computer-based curriculum feel more hands-on.

INTRODUCTION AND BACKGROUND

I have worked to incorporate Global Information Systems (GIS) computerized mapping software into my high school earth science curriculum in an effort to engage students in a real-world application, and to provide the opportunity for the hands-on learning of a new skill set. Though I am not a GIS expert, I have used various GIS applications in my courses for several years. GIS has a number of attributes that should engage students and encourage learning beyond the curriculum. It is visual and computer-based, it is connected to the internet and can be updated in real time. This connectivity allows students to search for the most current information, which they may be specifically interested in. This Action Research aimed to determine how GIS was perceived by my students. I was curious to see if extending the use of GIS into the earth science curriculum would improve student engagement, curiosity, and connections to novel academic and career goals.

Context of the Study

Hands-on and real-world learning are widely regarded as pedagogical approaches to increased student engagement. GIS provides a window into the most current physical landscape around the world. GIS maps are updated in real time allowing researchers and journalists the ability to use GIS to convey information of current events. GIS is a growing field and by teaching GIS in my curricula, students will develop useful skills they can use beyond the classroom. I do not find it questionable that GIS is indeed a real world application with great potential for authentic career and educational pathways for

the future. The question remains: Do students view GIS as hands-on and a real-world learning experience? The general focus of this Action Research project is to ascertain if students perceive that using GIS software has the benefits of hands-on and real-world learning.

Research Questions

In an attempt to make learning feel more hands-on and applicable to the real-world I will explore the use of GIS in high school earth science curriculum. My Action Research asks, Does GIS make learning feel more hands-on and applicable to the real-world?

My research will focus on the three sub-questions:

1. To what extent do students view GIS as hands-on, real-world learning?
2. How do GIS assignments impact patterns of work completion?
3. How does implementing GIS into the curriculum impact me as a teacher?

Sharing the Results

The data and conclusions from my Action Research project will most immediately impact me as a teacher and influence how much I attempt to integrate GIS into my earth science curriculum. I will additionally share conclusions with my colleagues at South Burlington High School. Other science teachers who are using GIS will surely be curious of my findings and I can imagine my colleagues both technology and humanities being curious if GIS is a reasonable tool to add dimension to their curricula. Information will also be shared within the Montana State University Masters

of Science and Science Education program. Though I do not have explicit intentions to share my findings beyond the South Burlington and Montana State communities, I could imagine the information being welcome at the Educators Day at the Northeast Arc Users Group (NEARC). NEARC is an organization dedicated to helping people succeed in the use and implementation of ESRI ArcGIS software. I attended this regional conference in the fall of 2019 and I would be interested to compare my findings to the experiences of other educators. ESRI also holds an education summit prior to their annual conference with a request for proposal of presentations if I choose to pursue sharing my findings at a national scale.

CONCEPTUAL FRAMEWORK

Hands-on and real-world applications engage students in learning across a variety of subjects (Winthrop, 2016). Since the early 20th century, educational theorists have advocated for the inclusion of pragmatic and authentic experiences in the classroom (Dewey, 1938). I strive to keep my curriculum relevant to the interests of my students. Relevant curriculum can be an intrinsic motivator for students (Jensen, 2005). Global Information Systems (GIS) provides a window into the present landscape of the world. Maps are updated in real time and are not static to the time of a published book or article. Practitioners and journalists use GIS to convey information of current events. When used in the classroom, GIS can extend technology skills and introduce students to a real-world, technical application (Starr, 2009). The general focus of this Action Research project is to ascertain if using GIS software has the benefits of hands-on and real-world learning.

Student Perception of GIS

Though I do not find it questionable that GIS is indeed a real world application with great potential for authentic career and educational pathway for the future. GIS is used in a wide range of applications from business planning franchise expansion to municipal government water and sewer upgrades. Scientists across disciplines rely on georeferenced data to answer questions such as how land use changes may impact biodiversity or how the historic range of prehistoric populations changed with climatic patterns. The question remains; whether or not students view GIS as hands-on and real-world learning experience? This research question focuses on student engagement,

motivation and perception. I focused on what research has been done to test student attitudes about GIS, and I steered away from research that sought to see how GIS improved test scores or achievement (Singh, 2016). I sought out research that tracked student behavior and perspective. Egiebor and Foster's (2019) *Students' Perceptions of Their Engagement Using GIS-Story Maps* is highly applicable to my Action Research project. While a middle school social studies teacher taught a GIS based lesson, the researcher observed student behavior and took note of student effort, interaction with a device, problem solving, off-topic discussion, complaints, frustration, and disruptive behavior. Following the lesson, students were asked to reflect on their perceptions of the connectivity and applicability of the lesson. Students found using GIS based lessons more engaging than worksheets (Egiebor & Foster, 2019). It was encouraging to see a clear connection between GIS and student engagement.

Though GIS has the potential to meet modern expectations in education, broad implementation has been limited by a variety of obstacles (Kerski, 2003). Research likely includes the caveat that GIS is not readily accessible to students. It requires substantial teacher knowledge and investment in creating a curriculum that connects to GIS. Teachers who have not been trained to use GIS will likely not see a benefit when used in the classroom (Mitchell, 2018). It becomes clear from the research that there is a risk in using GIS in the classroom without adequate skills preparation or lesson planning. Even Dewey warned of the potential for experiences to stymy learning if they were not organized by the teacher in a way to create growth (Dewey, 1938). Regardless of what happens within the educational community at large, it is clear that Action Research

questioning students' perspective of how GIS is used in my own curriculum would be a worthwhile endeavor.

Student Attitudes and Motivation

Many of the articles I searched through regarding student attitudes and motivation referred the attainment-value theory of Jaqueline Eccles. According to this theory, students can value learning for its usefulness to them in the future and can also find an intrinsic value from enjoying an activity in and of itself, and not as a means to an end (Eccles, 1983). A troubling finding comes from later work, "In summary, children's ability-related beliefs and values become more negative in many ways as they get older, at least through early adolescence. Children believe they are less competent in many activities and often value those activities less" (Wigfield & Eccles, 2000, p. 77). Similar to how poorly planned GIS learning might not be accessible to students, there is a risk that previous success or failure in learning new technologies might prevent students from perceiving GIS as an attainable skill set.

In my search to find a quantitative means to measure student attitudes, I read the following study that did not focus on GIS at all, but did look at a variety of ways to assess student perceptions. In *When Am I Ever Going to Use This in the Real World? Cognitive Flexibility and Urban Adolescents' Negotiation of the Value of Mathematics,* Mathews (2018) studied how urban Black and Latino adolescents understood the relevance of mathematics in their lives. Research was comprised of a concurrent mixed method approach where attainment-value was measured quantitatively through a Likert Scale survey. Findings were corroborated through student interviews. The study found that an

increase in students' interest in math if the teacher utilized a real-world approach to teaching the concepts.

Implications for my Research

It is clear that educators and theorists value real-world, hands-on learning as a means of increasing student engagement. Furthermore, computerized mapping software such as GIS is perceived by researchers as a real-world, hands-on application. It is also clear that there is some risk in using GIS in the classroom. More important for my students than what educators and theorists think, it is important for my students to perceive GIS as accessible new technology that relates to their lives. Within this ambiguity lies a perfect space for Action Research to explore and uncover how my students respond to my teaching practice.

METHODOLOGY

I have developed a methodology that systematically traces student perspectives across three types of assignments. I will focus on a qualitative approach to data collection including observations, surveys, and student interviews.

Sampling Strategies

Data collection occurred in two courses I taught at South Burlington High School (SBHS) in South Burlington Vermont during the 2019-2020 and 2020-2021 academic years. Physical Geography is a semester long elective course that I taught in both Fall 2019 and Spring 2021. This course is taught to 10^{th}-12^{th} graders and had 13 students in 2019 and 15 students in 2021. I attempted to interview all students in 2019. In 2021 I administered a survey to and monitored the submission timeline of all 15 students. I also conducted classroom observations of a subset of students in the 2021 Physical Geography class.

The second course I sampled was my 9^{th} grade Earth and Space Systems (ESS). Data collection occurred during and after an earth structure and plate tectonics unit that used the Geographic Information Systems (GIS) application Google Earth Pro. The use of this course as a treatment allowed me to increase the sample size. I taught 4 sections of ESS with a total of 45 9^{th} grade students. I conducted classroom observations of all four sections and asked all students to complete a student survey.

Demographics

Students at SBHS are required to take three years of science, ESS in 9th grade (physics, astronomy, geology) followed by Living Systems in 10th grade (biology, ecology) and after those two course requirements students were free to choose from a catalog ranging from Advanced Placement sciences to semester long electives. The semester long classes were designed to be less academically rigorous and to accommodate students who struggled to find academic success in traditional courses.

My Physical Geography rosters were comprised of a mix of students spanning a spectrum of academic success. There were students who struggle in school and would not be successful in an upper level science course and there were students taking Physical Geography in addition to another science course. Students ranged from 10th to 12th grade. Of the 15 students in 2021, three students had Individualized Education Plans (IEP) with our Special Education department, four students had health conditions that necessitate special accommodations (504) and one had been identified as a student who struggled with school but had not qualified for federal programs. SBHS serves this kind of student with an Educational Support Teams (EST) though accommodations and support may be limited.

To increase the sample size of students I also administered a treatment unit to 9th grade ESS. ESS is a core science class that all students take at SBHS. The students are heterogeneously mixed across academic ability. I taught 2 sections of ESS in the Fall of 2020 with rosters of 24 and 21 students. Of the 45 students, 5 had IEPs, 1 with a 504, and 4 with EST plans.

South Burlington High School had a graduation rate of 93.36% in 2016 with 79% of students proceeding to post-secondary education. 18% free and reduced lunch. 82% White and 9% Asian. The non-white percentage at South Burlington High School is slightly larger than the Vermont state average of 10%. Of the 235 students tested for the Vermont State Science Assessment in 2019, 25 (11.9%) qualified for the federal Free and Reduced Lunch program. The same statewide science assessment showed South Burlington scoring above the statewide average with 59.1% above proficient while the statewide average was 41.4% above proficient (State of Vermont Agency of Education, 2021).

Treatments

I teach with a variety of learning activities including hands-on labs, video and articles, computer simulations, and pen and paper assignments. My Action Research aimed to compare GIS applications to these types of assignments. Both Earth and Space Systems and Physical Geography contain content that is closely tied to geographic features of specific parts of planet earth. It was not hard to include GIS based learning activities that connected to the scientific content I taught. For instance, I had students use Google Earth Pro to create a map of recent earthquake activity as they learned about tectonic plate boundaries (Goodell, 2013). During a unit on wildland forest fires, I used a learning activity from ESRI's teaching with ArcGIS website to create a fire dashboard of active forest fires in the United States (Szukalski, 2020). These types of assignments were considered GIS treatments.

I compared these GIS assignments to more traditional hands-on labs and computer simulations. While studying plate tectonics, students measured and compared the densities of different rock types representing earth's layers. They also used a computer simulation that visualized how seismic waves reveal earth's internal structures. The students studying wildfires conducted a hands-on lab manipulating the three legs of the fire triangle and played a video game created by the United Nations to educate about wildfire management. The final unit I used as a treatment was a glacier unit where students modeled glacial movement by making a viscous borax and glue mixture, learned about land ice using an online interactive text from TERC and then used Google Earth Pro to map sea level rise in several coastal cities.

Table 1. Treatment table shows three units of study each with three different types of assignment.

Unit	Hands-on Lab	Computer Simulation	GIS Assignment
Earth's Structure	Measure Density with rock samples	Layers of the Earth from Classzone	Plate Tectonics with Google Earth Pro
Wildfires	The Fire Triangle with Candles	Stop Disasters! from UN	Wildfire Dashboard with ArcGIS
Glaciers	Glacial Movement with Oobleck	Land Ice EarthLab from TERC	Sea Level Rise with Google Earth Pro

Data Collection Instruments

During and after a unit that contained a round of these three assignment types, I implemented a multifaceted data collection protocol outlined in the table below. During the assignment I observed students and reflected in a teaching journal. I asked about student opinions in a survey immediately after each unit was completed. After a series of units were completed, I conducted a long form student interview to ascertain more detail. Student completion of tasks was monitored retrospectively through the timestamps of our learning management system to compare the completion rates of GIS and non-GIS assignments.

Table 2. Research instrument timeline will be scheduled during a unit where three categories of learning activities will be assigned.

Before Unit	During Unit	After Unit
• Write entry in teacher journal.	• Observe students' habits of work and levels of interest. • Write entry in teacher journal.	• Administer student feedback survey. • Conduct student interview. • Collect data on rate of completion. • Write entry in teacher journal.

As I am interested in student opinions and perspectives, qualitative data were used in the research design. I added a few quantitative treatments into my research methodology such as the use of a Likert Scales in appropriate survey questions to ascribe quantitative value to otherwise qualitative data. I also monitored the completion of student work and was able to compare numbers of assignments completed. Other than these few quantitative data, my data will be largely qualitative.

To answer the sub-question, “To what extent do students view GIS as hands-on, real-world learning?” I sought information in the form of student feedback surveys and student interviews. Questions can be simply stated, and students will have the opportunity to answer in both written and spoken form. I conducted individual student interviews during Physical Geography last year and the data provided by students was squarely focused on this sub-question.

To answer the sub-question, “How do GIS assignments impact patterns of work completion?” I monitored my gradebook and be able to compare the rates of work completion between assignments with and without GIS components. This straightforward piece of quantitative data can be augmented by what I observe from student behavior and keep track of in my teaching journal. At least anecdotally from the course I used GIS in last year, students seemed less eager to complete GIS assignments and I heard more confusion and dissatisfaction from them about those assignments.

The main source of data to answer the sub-question, “How does implementing GIS into the curriculum impact me as a teacher?” was the teacher journal. Daily entries combined with more intermittent reflections provided a window into the teaching process as I implement GIS into the curriculum. I was also curious to augment this section about my own teaching with feedback from other teachers within the science department at South Burlington High School to see if they share similar or contrasting perspectives.

Table 3. Research matrix shows which data collection instruments will be used to answer my Action Research questions.

Research Matrix		Data Collection Instruments				
		1	2	3	4	5
		Student Observations	Student Work Completion	Student Surveys	Student Interviews	Teacher Journal
Research Questions	To what extent do students view GIS as hands-on, real-world learning?	x		x	x	
	How do GIS assignments impact patterns of work completion?	x	x			x
	How does implementing GIS into the curriculum impact me as a teacher?	x				x

Student Observation Rubric

I conducted student observations were conducted over the course of three assignments within a unit of study. On the day of the first assignment, I randomly choose four students to observe. Throughout the class I would take note on the student observation rubric (Appendix A). The same students were observed for the next two assignments. Each piece of evidence is an either/or statement where students would

receive a 1 or 0. The first three categories show more student engagement and therefore increased the total score while the fourth category showed behaviors of disengagement and the third category decreased the score. An individual engagement score was tabulated for each student and a total score was tabulated for each assignment. I then compared the engagement scores of the GIS assignments to hands-on labs and computer simulation.

This process was repeated eight times. I observed four different 9th grade sections of Earth and Space Systems during a single unit. I observed two different sections of Physical Geography over the course of two different units. Different students were observed each time to total a sample size of 32 students.

Assignment Completion Data

The learning management system used by South Burlington High School, NEO, indicates the date and time that an assignment is submitted for grading. I tabulated the submission dates for six homework assignments in Physical Geography. All assignments were formative assessments using a similar format with the difference between assignments being how students consumed information. Three assignments required students use some sort computer based learning program that was not GIS enabled. One was a Rock Cycle Interactive from Annenberg Learner, the second a review of an NPR podcast, and the third used an assessment website Quizizz.com. Three other assignments required students use some GIS application. Two assignments followed Google Earth voyager modules to view volcanoes and glaciers while the third assignment required students use ArcGIS software to locate earth impact craters.

I tabulated the data at the end of the course, which was 15 days after the due date of the sixth assignment. I placed each student submission into 1 of 5 categories: early, on time, late, very late, and incomplete. Most of these categories are self-explanatory, the only subjective categorization I made was to consider 7 days the difference between an assignment being considered late and very late. I then compared the rates of completion and timeliness between the two different types of assignments. I found it helpful to collapse the data into just three categories: on time, late, and incomplete. Since I was trying to compare two types of assignment, computer based and GIS, I also calculated the average rate of completion for each type of assignment.

Student Survey

I created a survey for students to complete using Google Forms. The survey was administered at the end of a unit in which students had engaged in the three types of assignments I was comparing, a hands-on lab, a computer simulation, and a GIS assignment. I administered the survey three times. The first time with two different sections of 9th grade science after they completed an earth structure and plate tectonics unit. I also administered the same survey two more times to the one section of my Physical Geography class after they completed a wildfire unit and after they completed a glaciers unit. The three surveys were identical except for the specific assignment referenced for each assignment category (Table 1).

The survey asked a mix of open-ended questions, binary response, ranking, and Likert Scale. Students were asked to describe their experience using GIS. They were asked if using GIS felt more hands on. They were asked to rank the three assignments in

order of how much they learned. They were on a scale of 1-5 how much they agree that they can focus more on GIS assignments. (Appendix B).

In the two 9th grade classes 35 of 44 students responded (80%). In Physical Geography 11 of 15 students responded to the first survey after the Wildfire Unit and 9 of 15 students responded to the second survey after the Glacier Unit (73% and 60% respectively). I combined data from all three surveys into 1 composite data set to analyze. A total of 55 survey responses were analyzed.

Student Interview

Towards the end of the Physical Geography course, I isolated a specific class day where students had independent work to complete and I had the flexibility to circulate throughout the class and conduct interviews. I printed copies of six questions with space to take notes and I printed enough copies to conduct a one-on-one interview with every student. I intended to ask the six following interview questions:

1. Do you know what I mean when I say GIS? Describe how it is used.
2. Have you ever used GIS before? (This includes Google Earth and Google Maps)
3. Have you ever used GIS in another classroom? If so which ones? If not which classes should it be used in?
4. What are your first impressions of using ArcGIS in this science class?
5. What kinds of things could a teacher do to make learning GIS easier?
6. Can you imagine using this kind of technology in the future? Do you think the work you are interested in could have some GIS component?

Of these six questions the two that I had to modify during the interviews were questions 1 and 6. A lot of students were stumped by being asked to define GIS and struggled to describe how it was used. However, they knew that we had been using GIS so I would say, "How would you describe GIS to a 5th grader?" This tended to help students stop editing themselves and stop seeking for the right answer and allowed them

to just say what it was they knew. Another road block came with the final question when I asked if students could see GIS being used in their future. I changed the interview process to just ask simply what their plans were for the future. When asked this more concrete, albeit still challenging question for high school students, they found a much easier job seeing where GIS could connect.

Of the 15 students in this physical geography class, 11 were present on the day of the interviews and I ended up only having time to conduct 8 interviews. Each interview lasted less than 10 minutes although this is an approximation as I did not time them. I had assumed since I had a relatively small class I could get to everybody however this was not the case. As I was intending to interview every student, I did not devise some method for random sampling. As it were, I selected students haphazardly. I believe the cross section provided a good reflection of the class. I interviewed some of the highest and lowest performing students, most and least talkative, male and female.

Students were amenable and willing to engage in the interview process. Of the eight students I interviewed only one student provided consistently short responses such as a simple “No” or “Not sure” or “Not really” and could not be prompted to expand in more detail. This student is particularly soft spoken and shy, and I see her engagement in the process at all as a successful demonstration of the trust I have established with her over the course of the year.

After the class, I spent some time reviewing the responses and forming my first impressions of what the students had said. Several patterns readily emerged regarding student experience with the software and their attitudes towards it. A few exciting

outliers provided encouraging anecdotes of the software providing engaging learning opportunities and relevance to students' lives.

Teacher Journal

My teacher journal consisted of notes and reflections that I would write over the course of the Action Research. I made entries while preparing for a learning activity I had to create several new learning activities to round out the three by three treatment schedule I created and the teacher journal reflects the planning phase of creating new curriculum. I also took notes while students were actively working on specific assignments. This happened concurrently with student observations but the objective was not how the students were feeling, but rather how I was feeling as a teacher. At the end of a unit, I reflected not only on which assignments students seemed to enjoy the most, but also which assignments they seemed to learn the most from and which assignments I enjoyed the most as a teacher.

Validity of Results

Several steps were taken to ensure the validity, authenticity, and ethical collection of data. Instruments were vetted by peers and instructors during my MSSE coursework. Several instruments were used to assess similar information. For instance, student engagement could be gleaned from observations, surveys, interviews, and assignment completion data. Multiple sources allowed me to triangulate claims with several pieces of evidence. To ensure a standard of ethics, the research methodology received an exemption from Montana State University's Institutional Review Board (Appendix C).

DATA AND ANALYSIS

Learning Activities using Global Information Systems (GIS) were compared to hands-on labs and other computer based assignments that did not use GIS.

Student Observation Rubric

Student observations were conducted on a single cohort of students but with different types of assignments. Observations revealed a clear pattern of engagement. Of the eight cohorts, six showed the highest scores of student engagement with hands-on assignments. The two cohorts that did not show a clear preference for hands-on assignments had a much smaller range between assignment types. The G3 Wildfire cohort scored the computer simulation just 3 points higher than the hands-on assignment and the G2 Plate Tectonics cohort scored the GIS assignment only 2 points higher than the hands-on assignment.

When comparing the engagement scores of just the computer simulations to GIS assignments. Five out of eight cohorts scored higher engagement scores for the GIS assignments. One cohort (G3 Plate Tectonics) had equal scores and two cohorts scored the computer simulations higher than the GIS assignments, though B2 Plate Tectonics on had a range of 1 point between these assignment types.

Engagement scores for each type of assignment were averaged for all 8 cohorts. The hands-on assignment was the most engaging assignment with an average score of 25 points. GIS assignments were more engaging than other computer based simulations

scoring an average of 15.625 and 11.75 points respectively. The difference between these two averages was 3.875.

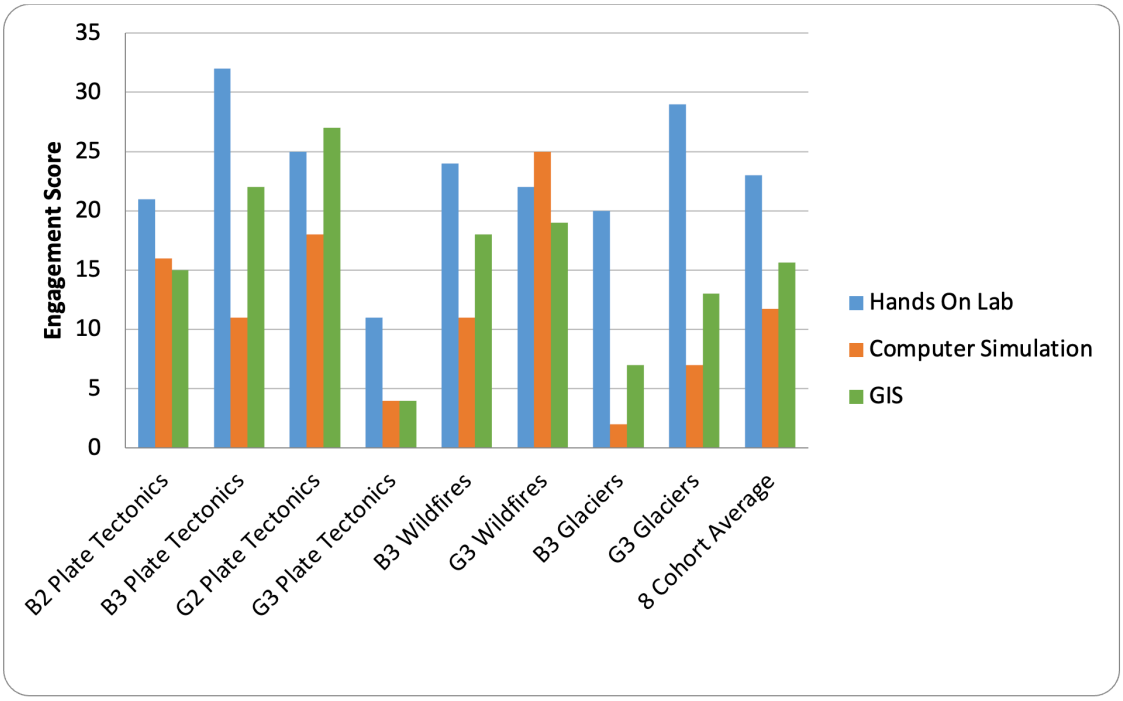

Figure 1. Student engagement observation rubric compared 3 types of assignments with 8 cohorts. Engagement scores were averaged for all 8 cohorts, (n=32). Hands-On Labs consistently score the highest engagement score followed by GIS Assignments and finally Computer Simulations score the lowest engagement score.

Assignment Completion Data

Data from six Physical Geography homework assignments show the GIS assignments were completed at a slightly lower rate than the other computer based assignments. Out of a total of 15 students, on average 9 submitted the computer based assignments early or on time compared to an average of 8.3 early or on time GIS submissions. However, the use of a chi-square calculator did not show a significant difference between categories.

Table 4. Assignment completion rate comparing three computer based assignments to three GIS assignments (n=15).

		3 Computer Based Assignments			
		Annenberg	NPR Podcast	Quizizz	average
Time of sub-mission	early	10	9	8	9
	late	2	3	4	3
	incomplete	3	3	3	3
		3 GIS Assignment			
		GoogleEarth	ArcGIS	GoogleEarth	average
Time of sub-mission	early	10	6	9	8.3
	late	3	2	2	2.3
	incomplete	2	7	4	4.3

Completion rates as a whole are consistent between assignment types. Again, the use of a chi-square calculator did not show a significant difference between completion rates. I suspect the slight decrease in average GIS assignment completion rate across all 3 assignments was due to singularly to the low completion rates of the ArcGIS assignment. This particular assignment required the most self-direction out of any of the six assignment and used the ArcGIS software which students found more challenging.

Student Survey

Fifty-five students responded from 3 classes responded to the student survey. When asked to provide a binary response to the question, "Did using GIS make learning science feel more or less hands-on?" 60% (33 students) choose the "More hands-on" option. When asked to choose a binary response to the question, "Did using GIS make learning science feel more or less applicable to the real world?" 85% (47 students) choose the "More applicable to the real world" option.

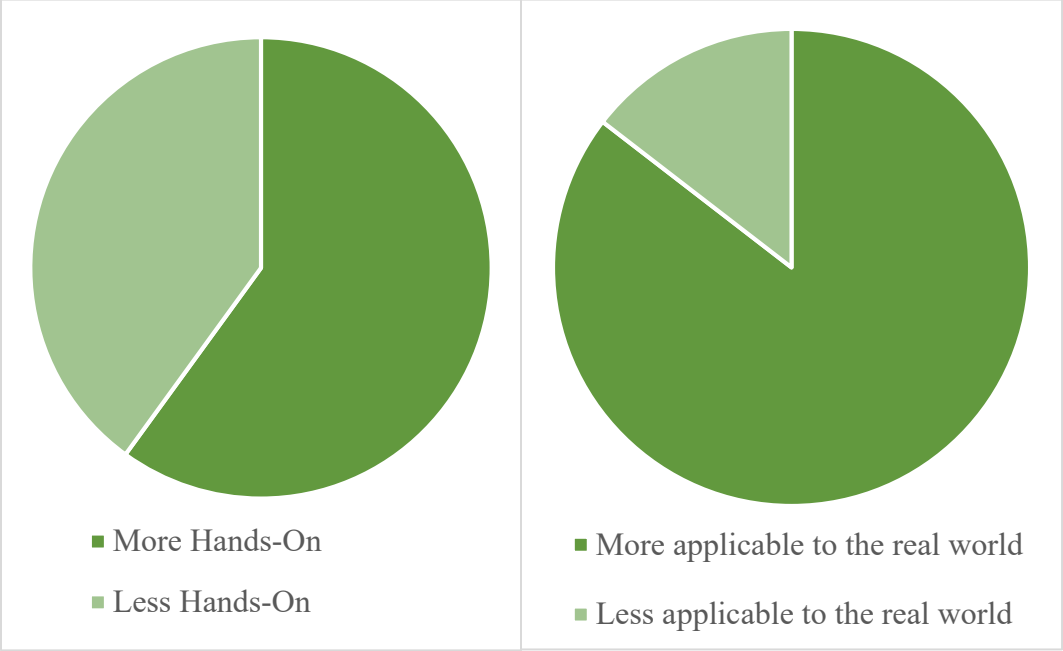

Figure 2. Binary responses from student survey for two research questions Did using GIS make learning science feel more hands-on and more applicable to the real world (N= 55). 60 % of students respond that GIS Assignments make learning science feel more hands-on and 85% of students responded that GIS Assignments make learning science feel more applicable to the real world.

When asked to rank three different assignments the majority of students ranked them as the hands-on lab feeling most hands-on (84%), the computer based assignment as the least hands-on (56%), and the GIS assignment as fairly hands-on (60%). Ten students ranked the GIS assignment as the most hands-on while only 6 students ranked the computer based assignment as feeling the most hands-on.

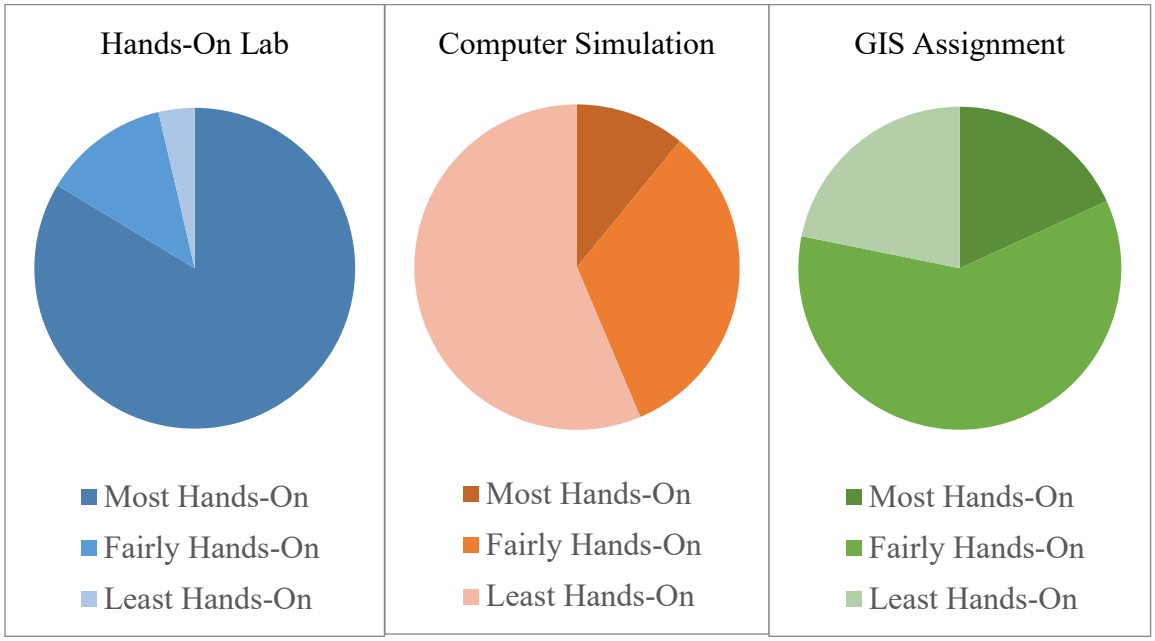

Figure 3. Students were asked to rank three assignments in order from which one felt the most hands-on to least hands-on (*N*=55). Hands-on Labs were rated most hands-on by a majority of students, Computer Simulations were rated least hands-on by a majority of students, and GIS assignments were rated Fairly hands-on by a majority of students.

When asked to rank the relevance of three different assignments the majority of students (52.7%) ranked the GIS assignment as the most relevant. The hands on lab had the next highest number of students (32.7%) rank it as most relevant. Only a small minority of students (14.6%) ranked the computer simulation as the most relevant.

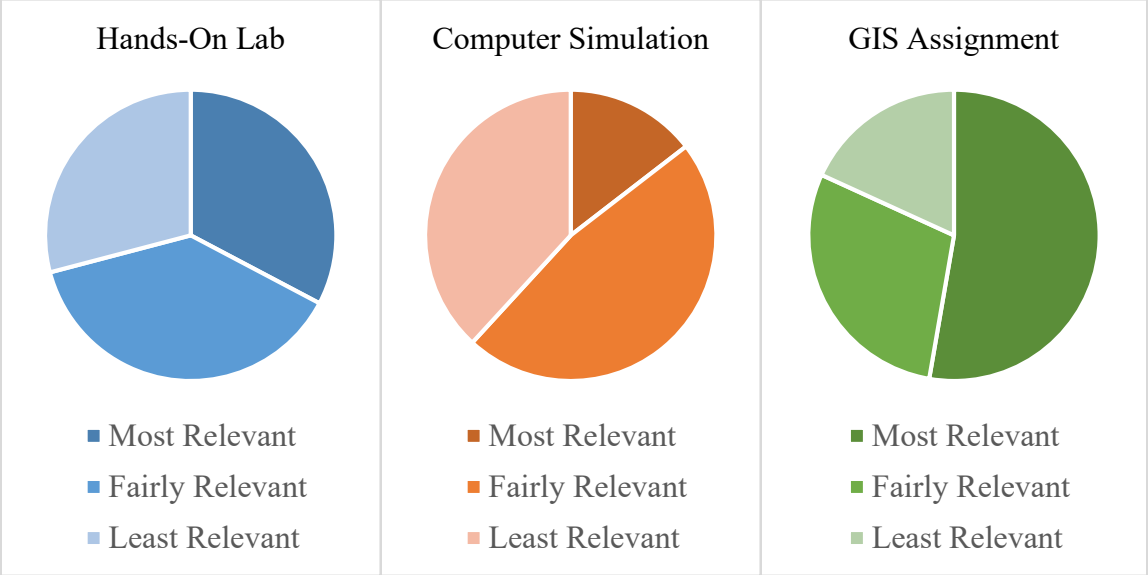

Figure 4. Students were asked to rank three assignments in order from which one felt the most relevant to least relevant (*N*=55). Hands-on labs were evenly rated by students as most, fairly and least relevant. 85% of students rated Computer simulations either fairly or least relevant. 53% of students rated GIS Assignments as most relevant.

When asked if the GIS assignments are more interesting than other assignments, student responses using a Likert Scale show a normal distribution. Seventeen students disagreed or strongly disagreed and 19 students agreed or strongly agreed. When asked if students could focus better when working on the GIS assignments, the Likert Scale shows more students either disagreed or strongly disagreed. Twenty-two students disagreed or strongly disagreed and 14 students agreed or strongly agreed. Responses skewed even more when asked if the GIS assignments are easier to complete, even more students either disagreed or strongly disagreed. Twenty-six students disagreed or strongly disagreed and just 10 students agreed or strongly agreed. Also note that 13 students strongly disagreed which skew even further away from a normal distribution.

Table 5. Survey questions using a Likert Scale asked students to agree or disagree with the following statements (*N*=55).

Likert Scale 1: strongly disagree – 5: strongly agree	The GIS assignments are more interesting than other assignments.	I can focus better when working on the GIS assignments.	The GIS assignments are easier to complete than other assignments.
1	6	7	13
2	11	15	13
3	19	19	20
4	14	8	8
5	5	6	2

The student survey also asked for written responses and a quick way to analyze this data was to look for words that students used again and again. The word "confusing" was used 48 times. Of these 48 instances only 2 were in reference to the computer simulations and 0 were in reference to the hands-on lab. Forty-six of the 48 times the word "confusing" was used was in reference to the GIS assignments. The repeated use of the word "confusing" clearly shows that students find GIS assignments complicated to or even beyond the point of their comfort level.

Table 6. Three examples of student responses in the survey using the word "confusing" when asked to describe their experience using GIS.

It was very confusing at times and I definitely struggled a bit, but overall I really liked using it. It was very engaging and fun to use.
At first it was confusing to use but once I got the hang of it I breezed through the tasks. Overall I quite enjoyed it and found it to be a very useful tool.
I learned a lot but found it very confusing

Students used the word "life" 13 times in their responses. Twelve of these referred to GIS assignments while only one instance referred to a hands-on lab and zero to computer simulations. Students could often make connections between the GIS

assignments and their own lives. These connections included personal interests such as travel and weather reports.

Table 7. Four examples of student responses in the survey using the word "life" when asked to rank the relevance of assignments.

The sea level rise [GIS assignment] was the most relevant to my life because it had to do with global warming and the impact that rising sea levels would actually have on us.
Because the GIS showed me different places around the world and stuff about the places and maybe later in life I will want to travel to some of those places. But the other ones won't ever really be part of my life most likely.
GIS I know I will use in life. The other [assignments] were somewhat useful but more of a fun way to understand a concept.
I don't think that I will use GIS academically too much in my future academics or career because that is not the career I'm going for. But I think in my normal life I will use it often in the form of GPS, radars, etc.

Student Interview

Students found using GIS "complicated" and "difficult" and this description arose even in the first question when asked to define and describe GIS. Concerns about the challenging nature of the software came up when asked to share their first impressions of using ArcGIS in this science class. One student went so far as to express that ArcGIS is "Too complicated and I'd much rather use a piece of paper." And again, when I asked what kinds of things a teacher to do to make learning GIS easier. Common responses asked if I could "spend more time explaining each component" or "work with students to show how different features work." The ArcGIS software was clearly pushing the limit of what students could use without generic skill development.

Since this was a pilot data collection instrument, I did not have a specific question regarding my curiosity if students viewed GIS as a hands-on learning experience.

However, one student provided a clear rebuke of this idea when he said, “I am more of a hands on learner and this feels more like reading.”

Though there were many negative comments about GIS there were also some positive accounts. Students could imagine using GIS in social studies classes. Comments such as, “It would be good to map historical events” were common. One student explained how they had been using paper maps in their Race and American Society class. The paper maps identified one particular anomaly of a highly diverse location surrounded by less diverse areas. Of her own volition, not as part of the assignment, the student “used Google maps to see that the one spot was actually a prison!” It was clear that this level of detail was highly engaging for the student and I was impressed that they had used a GIS application to deepen their own understanding of the academic content.

Another student expressed how GIS would be useful in the plate tectonics project he remembered from 9th grade science. Since he took the course we actually developed the plate tectonics project into a GIS exploration using Google Earth. It was encouraging to hear this student describe GIS as a valuable learning tool.

Most students could not see the use of GIS in their future. However, two students interested in careers in the military could easily see connections to military strategy. One of the students even knew that GIS technology was developed by the military before it became more commonplace in civilian life. Another student hopes to take over the family business repairing water lines and was curious if water pipe and well depth data was available through ArcGIS. The relevancy of GIS to students’ lives was not strongly

appreciated by students in the interview, however these outliers provided a small but compelling counterpoint.

Teacher Journal

It is clear to see from my teaching journal that the hands-on labs are also more enjoyable for me like they are for the students. I had more conversations with students and felt like I got to know them better as people while they were working on these assignments. The computer-based assignments were quite boring for me. In fact, I wrote that I would have transitioned all of the computer-based assignments to independent homework if I did not need to designate class time for them solely for student observations.

I did notice several instances during the GIS assignments where students would say something like “this is cool” and I did not hear comments like that during the computer simulations. Immediate feedback from students is important for me to know that I am reaching them in a way that they are enjoying school.

CLAIMS, EVIDENCE, AND REASONING

Students show changes in their attitudes and behaviors when participating in learning activities that are hands-on, computer based, or that include Global Information Systems (GIS) applications. Patterns of work completion are also different depending on the type of assignment. Furthermore, my experience as an educator changes depending on the type of learning assignment students are engaged in.

Claims From the Study

Student Attitudes

Students show a clear preference for true hands-on learning experiences that allow them to use manipulatives and collect data in the classroom. Student interviews, observations, and surveys all show more excitement, enjoyment, and engagement when students were provided the opportunity to work on a hands-on activity. This type of activity reaches a variety of student learning styles and I believe is a welcome change in the typical pace and structure of a school day. Other core academic classes do not have as much readily available hands-on content so I doubt students get much opportunity to learn in this style outside of physical education and visual and performing arts.

Students showed a slight preference for GIS based assignments over other computer simulations that I used. When ranking all three types of assignments, the majority of students labeled GIS assignments as feeling fairly hands-on while the majority of students ranked other computer simulations as feeling the least hands-on. Even though true hands-on learning experiences hold a clear advantage in garnering

student interest, it does appear that GIS assignments have some advantages in the minds of students.

GIS fared even better in students' view in regard to relating to the real world. The majority of students ranked GIS as the most relevant to their lives. A few students could see clear connections to their future careers, made connections to other content areas, or personal interests.

Work Completion

GIS assignments actually had a negative impact on patterns of work completion in my classroom. My gradebook showed a slightly lower rate of GIS assignments completed on time and a slightly higher rate of incomplete GIS assignments. I believe the added complexity of GIS assignments as evidenced by how often students describe them as "confusing", could play a large role in this lower completion rate. The Likert scale questions in the student survey skewed slightly in favor of GIS in regard to how interesting the assignments were but skewed away from the GIS assignments regarding the difficulty of the assignments and students' ability to focus.

Students consistently found GIS assignments confusing. This feedback came consistently through student interviews and surveys. In response to my Action Research question on how to make learning GIS easier, students asked for more instruction using GIS software. Students seemed to feel overwhelmed by the technical nature of the program when thrown into trying to navigate the software without specific instruction.

Teacher Impact

One of the major impacts of this Action Research on me as a teacher was to remind me how important I think hands-on learning is. Not only did I see such positive responses from my students, but my teaching journal clearly shows that I enjoy preparing for and teaching those types of learning activities. In fact, I found myself creating additional hands-on learning activities to incorporate into my curricula as an immediate result of this Action Research. I created a viscosity lab that used pancake batter to follow immediately after the earth structure unit in 9th grade Earth and Space Systems and then modified the lab to use in Physical Geography. I also exchanged a river landforms learning activity that I had planned to implement with GIS and instead used paper topographic maps.

Value of the Study and Consideration for Future

This Action Research shows promising implications for using GIS in an Earth Science Classroom. GIS assignments are more engaging than other computer based assignments and they were more applicable to the real world than other hands-on assignments. These are both evidence that GIS could enhance the classroom experience and learning outcomes for students.

It is clear that extra work should be done to teach how to use the GIS applications before assignments that use them are given to students. Students find the software confusing and rates of work completion are lower. Modifying assignments to explicitly teach GIS skills should be prioritized before using GIS to teach or expand on scientific content.

On the other hand, free software available from both Google and ESRI as well as readily made educational content make adding GIS to high school curriculum relatively easy. The response from students makes the addition of GIS to earth science curriculum worth the time it takes to include.

Impact of Action Research on the Author

Especially during the digital age of the 21st century and even more important during the hybrid model of the COVID pandemic, it was important for students and for me as their teacher to turn away from computers for more hands-on learning opportunities.

However, I intend to continue using GIS as a teaching tool. I believe that GIS adds dimension to my science curriculum, and I see that students preferred using GIS over other computer simulations. I also think that the ability to use GIS is a skill set that students will likely revisit in a variety of different academic and career pathways. In the last year, the COVID pandemic and the American election both presented GIS content to news consumers and concerned citizens on a daily basis through dashboard trackers and election maps.

I will certainly need to face concerns raised from students regarding the difficulty of the GIS software and the confusion they faced with these types of assignments. The slightly lower rate of completion in the GIS assignment makes it clear that using GIS needs to include a training period and jumping into content with students might be counter-productive. This concern was raised in my review of the research and also played out in my own classroom as well.

The students feeling that GIS is confusing does not motivate me to do less of it. If anything pushing them to the edge of their comfort with the software is likely an indication that they are learning from it. It does however, mean that I should not jump right into trying to use GIS to teach content. I should incorporate some general GIS education and some assignments that simply allow students to familiarize themselves with various features of the program.

As I build out a general GIS introduction, I would also like to feature some additional content that emphasizes how valuable the software is. I should not leave the real-world connections up to chance, but I would rather like to help students make these connections.

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APPENDICES

APPENDIX A

STUDENT ENGAGEMENT OBSERVATION RUBRIC

Four students will be randomly selected for observation during independent work time. Behaviors should be noted that indicate engagement and evidence of work completion.

Class: _____ Grade Level: _____

Assignment: _____

Category: _____

Date: _____ Time: _____

Student	1	2	3	4
Name				
Work Initiation				
Independently started work				
Worked through initial challenges				
Asked questions of peers				
Consistent Focus				
Stayed in classroom during work time				
Discussion on topic with peers				
Worked for entire time allotted				
Work Completion				
Persisted through challenges				
Talked about task with classmates				
Completed assignment				

Disengagement				
Off topic discussion with peers				
Off task, worked on something else				
Left classroom during work time				
Score				
+1 for first 3 sections -1 for final section				
				Assignment Total Score

Other Notes and Observations:

APPENDIX B

STUDENT SURVEY

Physical Geography Name _____

Student Survey

Please complete the following survey to help answer the Action Research question regarding using GIS in the classroom.

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. Does GIS make learning high school science feel more hands-on and/or applicable to the real-world?

More hands on?	Yes	No	More applicable to the real world?	Yes	No

Provide a short reason why you answered these questions the way you did?

2. Place the following assignments in order from least relevant to most relevant to your life:

- GIS Assignment: 1854 London Cholera Epidemic
- Film: TEDed How Pandemics Spread
- Computer Simulation: Solve the Outbreak CDC Game

	Assignment
Most Relevant	
↕	
Least Relevant	

Provide a short reason why you answered this question the way you did?

3. Place the following assignments in order from which one felt the most hands-on to least hands-on:

- GIS Assignment: Using Satellite Infrared to visualize Australia's Wildfires
- Lab: Fire Lab
- Computer Simulation: Firestorm Computer Game

	Assignment
Most Hands-on	
↕	
Least Hands-on	

Provide a short reason why you answered this question the way you did?

4. Place the following assignments in order from which one felt the most enjoyable to least enjoyable

- GIS Assignment: Guatemala Volcano Story Map
- Lab: Volcanic Rocks and Viscosity
- Computer Simulation: How are Volcanoes Related to Plate Tectonics?

	Assignment
Most Enjoyable	
↕	
Least Enjoyable	

Provide a short reason why you answered this question the way you did?

5. Work completion: Do you agree or disagree with the following statements about how it feels to works on GIS assignments.

	Strongly Disagree	Disagree	Agree	Strongly Agree
The GIS assignments are <u>more interesting</u> than other assignments.	○	○	○	○
The GIS assignments are <u>easier to complete</u> than other assignments.	○	○	○	○
I can <u>focus better</u> when working on the GIS assignments.	○	○	○	○

Provide a short reason why you answered these questions the way you did?

6. Relevance: How do you believe GIS will help prepare you for your future academic and career goals?

	Strongly Disagree	Disagree	Agree	Strongly Agree
I will use GIS in my future <u>academic pathway</u>.	○	○	○	○
I will use GIS in my future <u>career</u>.	○	○	○	○
Knowing how to use GIS will help me in my <u>future</u>.	○	○	○	○

Provide a short reason why you answered these questions the way you did?

APPENDIX C

INSTITUTIONAL REVIEW BOARD EXEMPTION

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Gabriel Calvi and John Graves

FROM: Mark Quinn
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: October 26, 2020

RE: *"The Impacts of Global Information Systems (GIS) Learning Activities on High School Students' Attitudes and Behaviors" [GC102620-EX]*

The above research, described in your submission of October 25, 2020, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (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.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).

____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.