The Use of ArcGIS Online in a Contemporary AP Human Geography Classroom and its Impact on Student Spatial Awareness and Perception of Geography

by

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FAIR USE AND AUTHOR'S PERMISSION STATEMENT

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LIST OF ABBREVIATIONS

Abbreviation	Description
AP	Advanced Placement
APHG	Advanced Placement Human Geography
AGOL	ArcGIS Online
CED	Course and Exam Description
FRQ	Free Response Question
IRB	Institutional Review board
MCQ	Multiple Choice Question
SST	Spatial Skills Test
STAT	Spatial Thinking Ability Test

ABSTRACT

Geospatial technologies such as ArcGIS Online have become increasingly accessible to the public. Studies have shown that the benefits of using geospatial technology in the classroom increase a student's geographic knowledge, including spatial awareness (Kerski, 2003; Lee & Bednarz, 2012; Jo et al., 2016). They also demonstrate the importance of spatial awareness in the classroom. The development and use of spatial awareness skills such as analyzing spatial patterns are critical components to the AP Human Geography Curriculum and Exam Design (2020). The present study uses the Spatial Ability Thinking Test (STAT) to measure the effectiveness of ArcGIS Online use in the freshmen AP Human Geography (APHG) classroom. The APHG classes consist of 132 predominately freshmen within the 14-15 age range. Two classes are assigned as the experimental group and the remaining two sections the control group. The experimental group received APHG instruction using ArcGIS Online while the control group received the traditional, paper and pen, instructional approach. Most students experience an increase in their spatial awareness through the normal course of the school year. But this study found that while both the experimental and the control group's spatial awareness increased, the experimental group did not experience a greater increase.

I. INTRODUCTION

A student's spatial awareness and ability to identify spatial patterns is a key skill in AP Human Geography. Most AP Human Geography students are 14 years old and have limited experience with identifying spatial patterns and interactions at the collegiate level. Their evaluation skills for identifying patterns are not as developed as a college level student (Golledge et al., 2008). This problem requires that teachers think outside the box to maximize the lesson time and reinforce the skills to recognize or explain spatial patterns throughout the year.

Geospatial technologies such as ArcGIS Online have become increasingly accessible to the public. While there are many benefits to its use in the classroom, there are also many challenges. Studies have shown the benefits of geospatial technology use in the classroom increases a student's geographical knowledge including spatial awareness (Kerski, 2003; Lee & Bednarz, 2012; Jo, et al., 2016) Another benefit is increased student engagement working on real-world issues (Kerski, et al., 2013; Goldstein & Alibrandi, 2013).

One of the biggest challenges discussed is teacher training and teacher's knowledge on the applications (Kerski, et al.., 2013). Teachers having time to learn and create ArcGIS Online lessons is a major concern from Hohnle, et al., (2013). Another challenge is related to the student's experience in different types of technologies. While students are proficient with mobile technology and enjoy lessons that have any form of technological practice, many of them lack the soft skills of working on computers with more advanced technologies (Shuster, 2011). Computer soft skills include how to open necessary documents and using a mouse on a desktop or laptop computer.

This study examines the potential of using geospatial technologies, specifically ArcGIS Online, in the high school AP Human Geography classroom. ArcGIS Online is not widely used in secondary education for various reasons including teachers' lack of a general understanding of its many uses (Gonzalez & Torres, 2020). There are studies available that state the use of geospatial technologies is beneficial for students (Lee & Bednarz, 2012; Jo et al., 2016). Some studies are specific to the use of ArcGIS, and I aimed to demonstrate further evidence of the benefits of its use specific to an AP Human Geography classroom. Studies (Jo, et al., 2016; Goldstein & Alibrandi, 2013; Gonzalez & Torres, 2020) have stated that further research is warranted regarding the effectiveness of ArcGIS in the classroom.

An important issue in geography is the critical need for a student's spatial thinking skills. There are many studies defining and evaluating spatial awareness. Gersmehl (2007) describe spatial thinking as skills or modes that are used to analyze spatial relationships in the world. He identified thirteen different modes such as defining locations, spatial comparisons, patterns, etc. These identified skills are so important that they are listed in the AP Human Geography CED (2020, p.14) specifically, to APHG skills

- "Category 2: Spatial Relationships- Analyze geographic patterns, relationships, and outcomes in applied contexts."
- "Skill Category 3: Data Analysis - 3.C. Explain patterns and trends in maps and in quantitative and geospatial data to draw conclusions."
- "Skills category 5: Scale Analysis- Analyze geographic theories, approaches, concepts, processes, and model across geographic scales to explain spatial

relationships. 5.B Explain spatial relationships across various geographic scales using geographic concepts, processes, models, or theories."

I examined if implementing a series of ArcGIS Online activities in APHG increases a student's spatial awareness and if it affects the student's overall perception of geography. The research questions are: (1) Does exposure to ArcGIS Online in the APHG classroom increase a student's spatial awareness? (2) Does exposure to ArcGIS Online in the APHG classroom affect a student's overall perception of geography? Four sections of APHG students were divided into two groups during instruction for Unit 1 and Unit 2 (approximately 7 weeks). Two sections were exposed to ArcGIS online through a series of Esri's GeoInquiry lessons and Story Maps (experimental group) while the remaining two sections learned the same content using paper maps and other paper-pencil-based materials (control group). A spatial thinking ability test and a student perception survey were administered before and after implementing the lessons. I hypothesized that after the 7-weeks of intervention those who were exposed to ArcGIS online would show greater increases in their spatial awareness and more positive changes in their perception on geography.

Literature Review

Spatial Thinking and Geography

There is a great deal of literature regarding the importance of spatial thinking in education (National Research Council, 2006; Gersmehl & Gersmehl, 2007; Jo et al., 2010; Lee & Bednarz, 2012). For example, the National Research Council's Learning to Think Spatially (2006) describes spatial thinking as involving three key components the concept of space, representation tools, and reasoning processes:

1. Examples of the concept of space would be location, direction, distance, and movement. These are concepts we use to understand and organize our world (Sinton, 2013).
2. Representation tools are maps or geospatial technologies such as ArcGIS Online (AGOL).
3. Reasoning processes, making decisions about choices, and communicating them.

Spatial thinking and geospatial thinking are very similar and it's easy to assume that they are the same concept. Spatial thinking is used across multiple disciplines, such as math and science. Baker et al. (2015) state that it is a "set of abilities to visualize and interpret location, position, distance, direction, relationships, movement, and change through space," while geospatial thinking is a specialized subset of spatial thinking. Geospatial thinking is tied to the earth, landscape, and geography (Baker et al., 2015; Bodzin et al., 2014). Geospatial thinking uses tools such as interactive maps to understand or organize information related to the landscape (Bodzin, 2014). Often, the two terms appear to be used interchangeably, but the difference can be noticed in their use in geography content. For example, geospatial thinking is how students could solve issues in geography over multiple scales. Something as simple as determining the patterns noted in the distance at a regional scale versus a local scale. Students can locate issues in distance, such as traffic patterns which at a regional scale is difficult to identify but easier to notice at the local scale.

Geospatial technology instruction and spatial thinking

There is a difference between technology use in the classroom and geospatial technology use. Everyday technology use in the classroom has become standard due to the recent Covid pandemic, and most schools turned to online learning for 1.5 years. From experience, various forms of technology were used via district-issued Chromebooks or iPads. Teachers would use apps on iPads or the internet. Common tools used were Nearpod, Kahoot, and Gimkit. In contrast, Baker et al. (2015) describes geospatial technologies,

> "GST facilitates data collection, visualization of spatial relationships, analysis, and filtering or querying of geospatial data, all activities that can be of use in making sense of spatial data and patterns."

According to Baker et al. (2015), there are four main types of geospatial technologies (GST). They include remote sensing (RS), global positioning systems (GPS), digital globes, and geographic information systems (GIS). The geospatial technology that I chose to use is GIS. Geographic information systems (GIS) is an application that uses different types of layers with a specific theme to organize the earth's surface. This allows the users to manipulate the data and layers to evaluate patterns and relationships. It also allows viewing at multiple scales, such as local, regional, and global. For example, the user can apply national data sets such as population density to identify and evaluate settlement patterns and issues. Initially, GIS was a complicated desktop program, but now, due to the internet has evolved into web-based GIS. I chose to use ESRI's ArcGIS Online (n.d.) program for my classes. This program does not require special software, and free accounts are available.

There are many studies regarding the use of geospatial technologies and their impact on students' spatial thinking. De Miguel Gonzalez and De Lazaro Torres (2020) studied the effectiveness of GIS for secondary students and teachers in training. They used a Digital Atlas on ArcGIS Online. Their approach was to see how much using the Digital Atlas would improve a student's spatial thinking skills and critical thinking, as well as whether using the geospatial technology promotes better geography learning. The study subjects were comprised of 14–15-year-old high school students (n=43) and master students average age of 22 (n=40). The results indicated that all students experienced success with their spatial thinking skills, content knowledge, and enjoyment of learning. However, the researchers suggested future research was warranted for identifying connections between GST and spatial awareness.

Perugini and Bodzin (2020) study the use of ArcGIS Online in an AP Environmental Science class with 11th and 12th-grade students. This study was based on one lesson spread out over four days. Throughout the lesson, students worked in groups and created additional layers in GIS. The complexity of the activity increased the difficulty level for the students and caused some student frustration. They found that students experienced increased knowledge of the content on hurricanes but did not experience any changes in spatial thinking. The researchers used Kim and Bednarz's (2013) Spatial Habits of Mind Inventory (SHOM) to measure students' spatial thinking. The authors recognize that spatial thinking develops over time, and the lesson was short, which probably contributed to the lack of improvement in spatial thinking.

The Liu and Laxman (2009) study used project-based learning (PBL) instructional approach with GIS at a Singapore high school with students aged 14. The study aimed to use GIS to train learners to become proficient spatial thinkers. The study period was not stated in the article, except they only described that three PBLs were created for the study. They found that using GIS improved students' attitudes about learning and the subject material. However, they also discovered by their Likert scale student survey that 85% of the students were frustrated with GIS. They stated it could have been more user-friendly, and additional how-to lessons would have been beneficial. While GIS was used, spatial thinking was not specially measured in this study. Overall, they considered the use of GIS as helpful to assist students with inquiry learning and critical thinking.

Measuring Spatial Thinking

While there was a great deal of literature available about measurements of one's spatial cognition, there needed to be a consistent way to measure the growth of spatial thinking. This is something that Lee and Bednarz (2009) attempted to resolve. They recognized that previously available tests did not measure the specific spatial components (e.g., spatial relations) necessary for their study. The researchers used guidelines suggested by Golledge and Stimson (1997) to develop questions for the Spatial Skills Test (SST). The resulting test consisted of 25 questions. The study was conducted over a semester with university students. Their goal was to measure how geospatial technologies such as GIS help students think spatially. They recognized that while the study was a success, it was the beginning of identifying the connection between GIS and spatial thinking skills.

Lee and Bednarz (2012) sought to revise their original SST to create a test that would measure content and skills promoted by the Association of American Geographers' Teachers' Guide to Modern Geography. The researchers took this information and revised their SST to create the Spatial Thinking Ability Test (STAT). It was given to 532 middle school, high school, and college students. The test provided predictable results, such as the older the student's academic level, the better they performed. College students performed the best, while high school students performed better than middle school students.

The use of STAT was explored with college-level students in the study by Jo, Hong, and Verma (2016). This study used 306 undergraduate students from two public universities. They were taught by different instructors who used various methods of teaching. The two sections (classes) that were conducted using ArcGIS Online did experience improvement overall between the pre-and post-test. However, the other sections experienced less progress.

There is a gap in the available research using ArcGIS to increase a student's spatial awareness with APHG. There are many studies with middle school students (e.g., Goldstein & Alibrandi, 2013; Aladag, 2014) and studies at the university level (e.g., Jo et al., 2016). There are some studies with older high school students (e.g., Ivan & Glonti, 2019; Perugini & Bodzin, 2020). The students in the same age range as my study are of the most interest to me (Milson & Earle, 2007; Gonzalez & Torres, 2020; Metoyer & Bednarz, 2017). The gap identified in the freshmen age range was the subject taught. These were students in World Geography and Pre-AP World Geography courses but not APHG. I discovered one study by Patterson et al. (2003), but it is an early study using desktop GIS with AP Human Geography students. Today, most APHG students are freshmen in high school. It is one of the largest AP-tested courses with 222,938 students taking the exam in May 2022 (College Board, 2022). One gap is with empirical research using ArcGIS Online to study its effect on students' spatial thinking skills with AP Human Geography students.

Student perceptions of learning with GIS

Young students often find engagement with increased technology use in the classroom. For example, Kerski et al. (2013) discussed the increased student engagement with using WebGIS in the classroom. WebGIS is an internet-based GIS platform that gives users access to GIS applications such as terrain and land use data that can be accessed with large groups instead of specific desktop software (ESRI, n.d.). Once they had practiced using WebGIS, students found the different learning methods more effective and enjoyable. Students initially expressed nervousness while learning WebGIS but preferred the experience over the traditional pen-and-paper learning style (Perugini & Bodzin, 2020).

Aladag (2014) studied 4th – 7th-grade teachers using GIS in their lessons. There were 14 Social Studies teachers from Turkey involved in the study. They received six hours of training overall before the lesson was provided. Teachers reported that while there was a lack of computer skills, there would be high student engagement. Goldstein and Alibrandi's (2013) study on 1425 (control group n=1,169) middle school students stated their results suggested that the 256 students who used GIS experienced increased engagement in their lessons. The study was used in two different courses. The first was a social studies course where students received twice-a-week lessons using GIS for two semesters. The second course was an elective introduction to GIS class where students receive GIS instruction five days a week over two semesters. The lessons were relevant to the students' lives and interests, especially for the English Language Learners (ELL) who could research their home country. While the students worked on individual computers, this learning encouraged and received increased collaboration between students. All teachers know that the more engaged students are in the lesson, the more they will learn.

Students' enjoyment of using technology in the classroom is further represented in the study by Gunes et al. (2020). The study was conducted with 60 students from Turkey in the fifth-grade class. Over six weeks, half of the students learned with GIS and the other half with the textbook. The feedback from the students learning with GIS was very positive. Students stated they could explore locations they had never seen before. They also expressed that learning with GIS will help them remember the content in the long term. Another interesting comment from the students as they were not bored and were not just memorizing facts.

Summary

A large amount of literature available for GIS and a student's spatial thinking skills suggests the strength of the topic, the use of ArcGIS in the classroom will increase a student's spatial thinking skills. While there is research already available on the use in K-12 (e.g., Metoyer and Bednarz 2017, Gonzelez and Torres 2020, Aladag 2014, Baker and White 2003, Sabo 2015, Ivan and Glonti 2019, Patterson, Reeve, and Page 2003, Milson and Earle 2007, Kerski, Demirci, and Milson 2013, Kerski 2022) research specific to high school freshmen AP Human Geography is limited. Since so many advanced students are taking AP Human Geography, a study specific to this population is needed for at least two reasons. One is to expand on the existing research on measuring a student's spatial awareness skill using STAT. Two, to add to existing empirical research by a practicing high school teacher to measure the effect of ArcGIS in the classroom on student learning and perception of geography.

Methods

Participants

The participants in this study are AP Human Geography students at Harlan High School in San Antonio, TX. Many students in Texas take World Geography during their freshmen year (College Board, 2020). AP Human Geography is offered as an Advanced Placement alternative for World Geography in Harlan High School and most Northside ISD schools. Most students participating in the study were freshmen, ages 14-16, but there was a small number of upper classmen, ages 15-17, who are taking the class since moving to Texas from other states. A detailed syllabus and IRB approved informed consent letter explaining the study were sent to students, parents, and guardians at the beginning of the semester. They were instructed to inform me by September 1, 2022, if they chose to opt out of the study. No students, parents and/or guardians chose to opt out of the study. A total of 132 students in my four AP Human Geography classes participated in the study. Seventy-two were female and 60 were male. The participants ethnic/race backgrounds were diverse; 71 (53.78%) students identified Hispanic; 34 (25.75%) identified white; 11 (8.3%) students identified multiple- not Hispanic; 8 (6%) students identified as black; 7 (5.3%) students identified as Asian/Pacific Islander; and 1 (.7%) student identified as Native American. The study began during the second week of school; therefore, most students were new to the high school environment as incoming freshmen. There were three participants who were not freshmen: one sophomore and two juniors. Most of the participants arrived from four feeder middle schools within the Northside ISD, and they have experienced some geography instruction in the 6th grade.

This study was approved by the Texas State Institutional Review Board (IRB) on July 5, 2022. (IRB #8396)

Instruments

Two instruments were used for the study. First, the Student Thinking Ability Test (STAT) developed by Lee and Bednarz (2012). Two versions of the test are available, Form A and Form B. Each test consists of 16 multiple-choice questions. The growth in a student's spatial thinking skills as a result of an educational intervention could be assessed by using the two forms of test as the pre- and post-test. Lee and Bednarz (2012) STAT was a revision of their original Spatial Thinking Test (SST) from 2009. The SST was established to measure the student's spatial thinking growth after completing GIS coursework. They discovered a positive correlation between growth in spatial thinking and the completion of at least one GIS course. STAT was created to continue to measure spatial thinking growth and to include mastery of content described by the Association of American Geographers' *Teachers' Guide to Modern Geography* (TGMG). The TGMG provided materials to assist geography teachers' ability to improve student spatial thinking. Multiple skills are assessed by STAT such as understanding orientation and direction, mentally visualizing 3-D images based on 2-D information, and overlaying maps. In developing the pre-(Form A) and post-tests (Form B), Lee and Bednarz (2012) worked to ensure the level of difficulty and skills measured remained consistent. The same skills are being measured between the pre-test and the post-test but there are variances in the questions to allow for authentic student learning and not memory. Figure 1 and 2 show questions number 1 and 5 on the STAT Form A and Form B as examples.

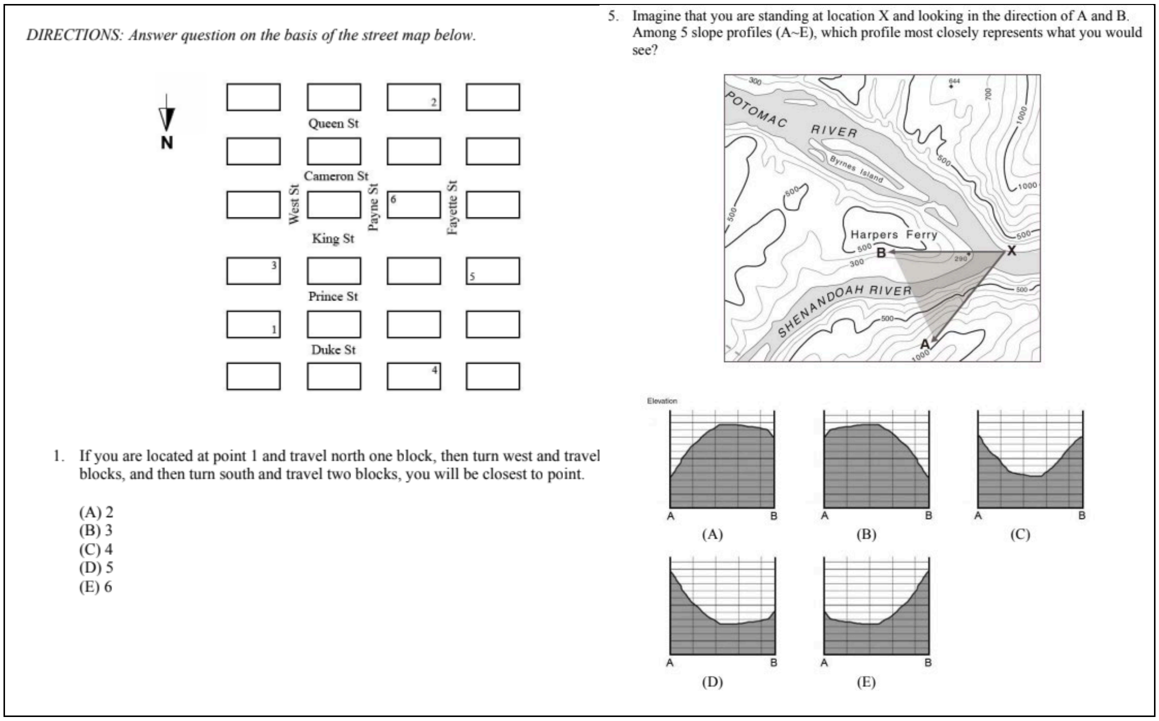

Figure 1: STAT Pre-Test Questions 1 and 5 (Lee and Bednarz, 2012)

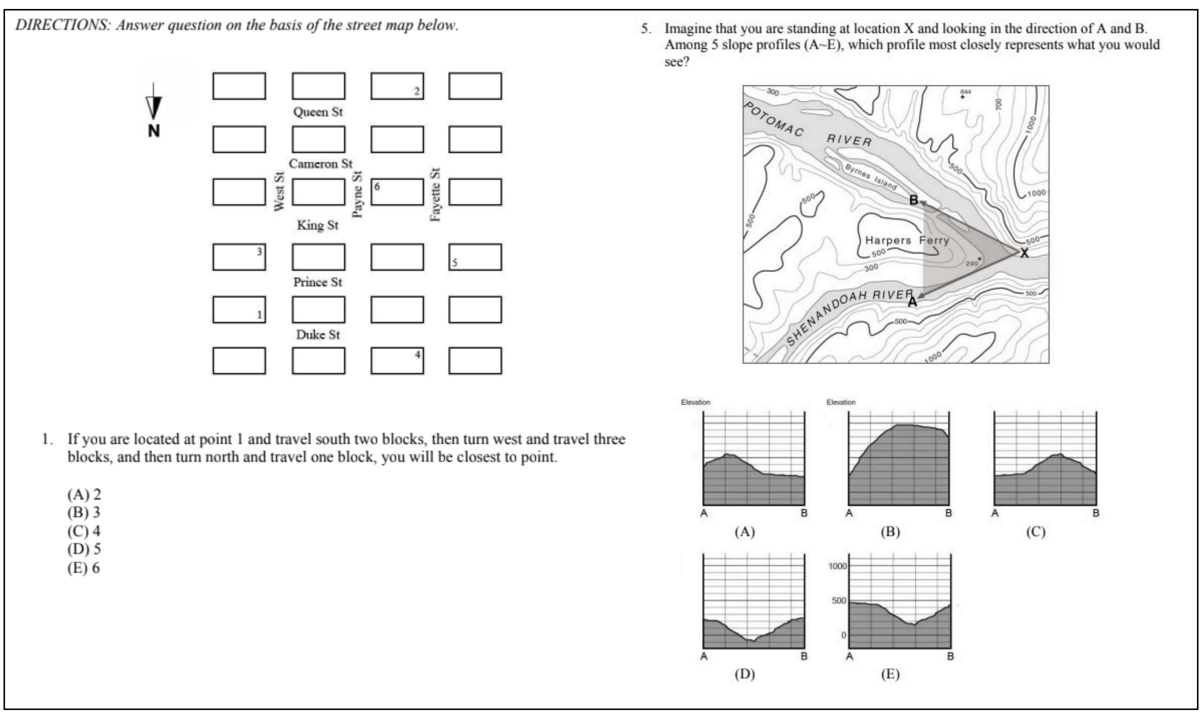

Figure 2: STAT Post-Test Questions 1 and 5 (Lee and Bednarz, 2012)

The second instrument I chose to use was a student perception survey created by Martin (2022). The survey aims to measure changes in students' perception of geography. The survey (Table 3) consisted of five Likert Scale questions. Each question was followed with an optional, open-response field where students could elaborate on their answers if they chose to. I included the option of open-ended responses, hoping that providing optional responses could provide insight into students' thought processes that can supplement the numeric data collected.

Table 1: Student Perception Survey (Martin, 2022)

Question	How much do you agree or disagree with the following statements?
1	Geography is an enjoyable subject
2	Geography is useful for solving problems in my community.
3	Geography has great value in modern society.
4	I am interested in taking a Geography course at the postsecondary (college or university) level.
5	Geography class is useful for my potential career(s).

Question 1 intends to assess the level of students' enjoyment of the geography content. Question 2 aims to measure the students' perception of geography's usefulness in their own lives. Martin (2022) adopted Question 3 from the Powerful Geography student surveys (Larson et al., 2022). Questions 4 and 5 measure students' interest in pursuing geography content after graduation and their perceptions of the impact of taking a geography class on their career choices.

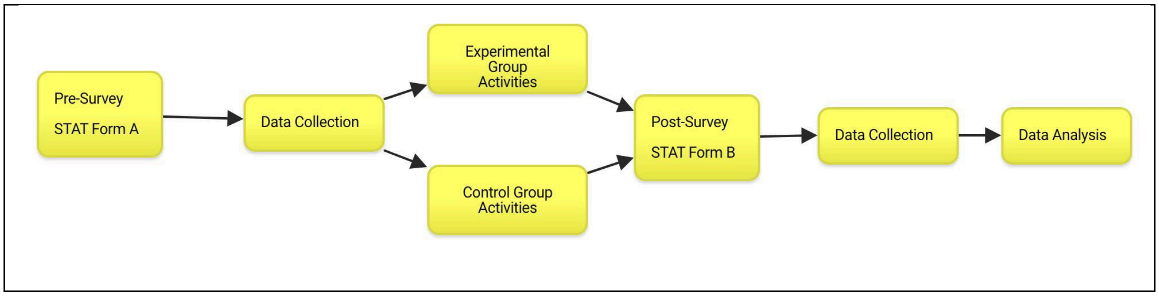

Figure 3: Study phases flow chart.

Design and Procedures

This study used differentiated instruction to teach students topics according to the AP Human Geography Course & Exam Description (CED). Topics from Unit 1, Thinking Geographically, and Unit 2, Population & Migration, were the focus of the study. In addition, the development concept from Unit 7: Industrial and Economic Development Patterns and Processes, was moved from the end of the course to the end of Unit 1. Through my experience, students learn the AP Human Geography concepts better if development concepts are taught at the end of Unit 1 and before Unit 2. Among the four sections of APHG students who participated in the study, two sections were taught using ArcGIS Online activities (Experimental group: a total of 60 students), and the other two were taught without using ArcGIS Online but using equivalent paper-pencil-based materials sections (Control group: a total of 59 students).

Table 2: Instructional Activities, Skills Practiced, and Spatial Concepts Discussed for Experimental and Control Groups.

Activity	Experimental Group	Control Group	Skills Practiced	Spatial Concepts Discussed
1	ArcGIS Online Latitude & Longitude	Classroom Atlas Large World Map on the Wall	Identify, analyze, compare	Measurement, Distance, estimation, absolute location, comparison
2	ESRI GeoInquires Distance and Scale	Paper map of ArcGIS Map Image	Visualize and analyze variations in time-space compression	Distance, scale, location, place, interconnections
3	ArcGIS Online London Cholera Mapping	Paper map of London and John Snows Map	Evaluation, patterns, historical map vs modern map, source, location	Patterns, distance, location
4	ESRI GeoInquires Comparing Country Development	Choropleth maps with Legend, multiple scales	Identify, compare, evaluate, define	Spatial variation, patterns, regions, interconnections,
5	ESRI GeoInquires Human Development Index	Choropleth maps with Legend, multiple scales	Analyze, identify, explain, compare	Patterns, measurements, density, layer, scale, connection & linkage, region, location
6	ESRI GeoInquires World Population	Choropleth maps with Legend, multiple scales	Analyze, identify, explain, compare	Patterns, distribution, dispersion & clustering, density, layers, scale, movement, connections, distance
7	ESRI GeoInquires Standards of Living	Choropleth maps with Legend, multiple scales	Analyze, hypothesize, compare, identify	Patterns, region, connection, direction, scale

Multiple ArcGIS Online activities were implemented to the experimental group during the first two months of school. The activities were spread out based on student need. The first few weeks of school with freshmen is spent climatizing them to high school expectations. AP students experience an additional layer learning how to be AP students. For example, the additional reading and writing in an AP class is more than what freshmen are used to. Geography classes also lose instruction time to campus initiatives such as Chromebook distribution. It was important to spread out the activities to accommodate the various functions.

Activity 1: The first ArcGIS Online activity used was a simple latitude and longitude practice (Appendix A). I started the year off learning and refreshing their memory on map skills. Most students have learned some map skills in middle school but due to student movement the skill mastery can be inconsistent. Students worked with a partner and their campus issued Chromebooks to access ArcGIS Online. I chose to use this as the first activity to help the students get used to viewing and using ArcGIS Online. The students practiced viewing the information at multiple scales, identified absolute location, and compared locations to the equator.

The control group used the Atlas classroom set with a partner. I completed a short introduction on how to use the Atlas to look for specific regions and absolution locations. To assist the students, I also included page numbers for some of the questions. I preferred the students practice using latitude and longitude coordinates over extensive page turning in the large classroom Atlas. Many students chose to use the large wall map to identify absolute locations and comparisons. Students were also viewing the maps at multiple scales but were restricted to the scales presented in the Atlas or the large wall map.

My role as a teacher for both groups was modeling how to use and complete their activity questions. I then spent the rest of the activity time moving between partner groups to guide and ask additional questions. The students needed the whole class period (45 minutes) to complete the full lesson. They identified and answered questions. Upon my review of the students work, most of the student's experienced success with the activity.

Activity 2: I taught both groups about measuring distance and viewing at multiple scales. For the experimental group I choose to use the distance and scale lesson from ESRI GeoInquires (Appendix B). This lesson allowed for evaluation at multiple scales, practice measuring distance, and making decisions on the data presented. The students used their Chromebooks to access ArcGIS Online and worked through the presented questions with a partner. I moved throughout the room providing guidance and identifying possible issues for the students. One issue that needed additional whole group clarification was the question with the saying, "as the crow flies". Freshmen were confused about the meaning of the statement. Most students were not able to apply that statement to answer the question. I called the whole class back together and guided them to the answer. We evaluated multiple angles that could be taken to get to the correct answer. This question challenged the students view of scale, distance, and evaluation.

The control group used four maps at various scales for the same region to answer the same questions. They also used the map scale to help answer distance questions. This group also required additional instruction and guidance on the "as the crow flies" question. I brought the class together after working independently for about 10 minutes to discuss that question. Then, I proceeded to move about the room offering guidance for struggling partners. Both the experimental and control groups were able to finish the activity within the 45-minute class period.

Activity 3: I taught both groups about the history of John Snow's Cholera discovery. We discussed about the challenges of the time-period for the people of London. The experimental group used their Chromebooks and a partner to work through guided evaluation style questions. There were simple questions such as exploring the number of layers on the ArcGIS Online map (Appendix C), and more complicated questions, such as predicting how John Snow's mapping style could be used in modern times to find the source. Many students made immediate connections to modern day mapping of Covid-19 and scientists locating the source.

The control group worked with the same evaluation and prediction style questions (Appendix D). All questions were free response style questions. The difference with the control group was they work with an image of John Snow's map overlayed on a modern map of London. They discussed different possible layers, but it was more difficult to identify the number of layers in the map. The control group had two scales of the same map view to use for evaluation.

Activity 4: Each year, I move the development content from Unit 7, Industrial and Economic Development Patterns and Process, to the end of Unit 1, Thinking Geographically. Through experience, my students understand the content better and faster if they have levels of development knowledge. Many AP Human Geography teachers that I have collaborated with do the same. Activity four encompasses segments of ESRI GeoInquires (2014) Comparing Country Development. All classes received instruction the previous day regarding development and data used to determine a country's development. Instructional time was limited in class, so I reduced the questions from the original GeoInquiry. I chose three countries at different levels of development. They were Germany, China, and Mali.

The experimental group used ArcGIS Online to gather development data for the three countries. After collecting and comparing the data, the students completed an FRQ-style response question using the information (Appendix E). The experimental group took longer than I expected to gather the data since they began exploring other available country information. The students worked in pairs to gather and evaluate the data before independently writing their responses.

The control group's approach was different since they did not have access to ArcGIS Online. The students were provided a choropleth map demonstrating the development levels of countries in the world. It was vital that they could also view the world map to help identify development patterns. The students were provided with the same three countries. The difference was the data was provided for the students in a table (Appendix F) for Germany, China, and Mali. The students worked in partners to complete their evaluation of the country day and then completed six free-response style questions. Two of the six questions required an FRQ format response.

Activity 5: For this activity, I completed a short lesson on the Human Development Index (HDI) the day before completing this activity. I modified the existing GeoInquiry (ESRI, 2014) for the Human Development Index to fit the needs of my students. The focus of this inquiry was on HDI and the fertility rate.

The experimental group explored HDI scores for three countries: U.S., Brazil, and Pakistan (Appendix G). They used AGOL to identify the regions of the world that were the most and least developed. The last activity for this group was gathering fertility rates for seven countries for 2018 and 1990. The goal was to notice patterns and possible trends. The last question was an open-response style question to document their evaluation.

The control group experienced similar questions but had paper-based maps to evaluate the different development levels of countries. Their exploration of the seven country fertility rates differed from the experimental group. The control group was provided with the country data and worked with a partner to evaluate it. Their last action was completing two open-response questions requiring comparison and evaluations.

Activity 6: This activity was a modified version of ESRI's GeoInquiry (2014) over World Population. The full version of the GeoInquiry was not used due to instructional time constraints in the class. The goal was to use it to reinforce the students' knowledge of world fertility rates and more exposure to the Natural Increase Rate data.

The experimental group used ArcGIS Online to evaluate and answer the open-response questions (Appendix I). They worked with a partner and were instructed there was a time limit. This lesson was conducted as a warmup at the beginning of class. I try to be careful with my warmups because if not managed correctly, there will not be time for the entire class lesson. After the students completed their evaluations, we conducted a class discussion about their observations.

The control group had a similar evaluation but used paper maps to answer the open-response questions (Appendix I). Again, the students worked with a partner to evaluate the provided maps and answer the questions. After the time allotted for the warmup, we conducted a whole class discussion over the observations.

Activity 7: The last activity I conducted during the research period was ESRI's GeoInquiry on Standard of Living (Appendix J). I chose this short lesson to reinforce the content learned during the previous day's lecture. I limit the amount of time I lecture to one day each week. In my experience, freshmen learn better during inquiry-based lessons requiring application. We spent the lecture day with an interactive and whole group discussion that evaluated several maps of the world indicating the Gross Domestic Product (GDP), the workforce in services, and literacy rates. Unfortunately, I could not use the full GeoInquiry because our class had yet to learn about net migration. I also needed to limit the time for the lesson because of campus bandwidth issues.

The experimental group worked with a partner to use ArcGIS Online to answer the questions. Next, they explored the world to locate countries and regions with older populations. There were many conversations around the room about the U.S. not appearing in the highest category. Their following action was to compare GDP per capita and services workforce layers. The final step was to identify countries with the world's highest and lowest literacy rates.

The control group used provided paper maps to answer the same questions. They worked in pairs to evaluate the data provided on the maps. Questions about U.S. data were expressed with this group as well. The final action with the experimental and control groups was a class discussion over the results. Both groups discussed spatial patterns noticed in the data without me guiding them to the outcome.

Data Collection and Analysis

The study began in the second week of school when the students were administered the STAT Pre-Test Form A. Students used pen and paper to complete the

STAT Form A in one class period. Students were not able to access other materials or devices during the test. The pre-survey was administered to all students during class on the following day. They used their Chromebooks to complete the pre-survey.

At the end of the two-month period the students were given the STAT Form B, the post test. Students used pen and paper to complete the STAT Form B in class. Students were not able to access other materials or devices during the assessment. After completion of the assessment students were instructed to use their Chromebooks to complete the post-survey. Both the STAT Form B and student post-perception survey were completed during the same 45-minute class period.

In summary, the purpose of the study was to see if exposure to ArcGIS Online increases a student's spatial awareness and changes a student's perception of geography. The quantitative method was used to collect and analyze the gathered data. Statistical analysis was used on collected data such as: STAT test A and B results and the student perception survey responses.

Results

Paired *t*-tests were used to see if there is significant difference in the students' overall mean as well as category mean scores between pre- and post-STAT results. One-way ANOVA was used to further breakdown the data by ethnic group and assess possible differences in the test scores.

The study started with 132 AP Human Geography students. The final evaluation results were comprised of 119 student participants from the control group (n= 59) and the experimental group (n=60). The difference (n= -13) in participants between the beginning and end of the study is due to absences for the pre- or post-test and student movement. The table below shows the results from the pre- and post-STAT. The level of statistical significance set for all tests was α=.05.

Overall mean STAT scores of experimental and control groups

The experimental group's mean difference between the pre- and post-STAT was not statistically significant (*p*=.2517) while the control group's was statistically significant (*p*=.0243). The mean difference of pre minus post for experimental group equals to -0.35 with a 95% confidence interval of the difference from -0.96 to .026. The mean difference of pre minus post for control group equals to -0.61 with a 95% confidence interval of the difference from -1.14 to -0.08. The detailed paired *t*-test results are stated in Table 3.

Table 3: STAT pre- and post-test results.

Group	Pre/Post	N	Mean	Std. Dev.	Std. Error Mean	Sig. p<.05 (two tailed)
Experimental	Pre	60	9.22	2.6	0.34	.2517
	Post	60	9.57	2.73	0.35	
Control	Pre	59	9.08	2.53	0.33	.0243
	Post	59	9.69	2.62	0.34	

Overall mean STAT scores of at-risk-students

The at-risk students' pre- and post-test results are in the Table 4. At-risk students are those who, due to low family income, qualify for programs such as free/reduced lunches. This was measured to see if there was a difference in results between the two types of student population within the experimental and control groups. The experimental and control at-risk groups did not show statistically significantly different scores. The

95% confidence intervals of the differences were from -1.76 to 0.56 for the experimental group and from -1.35 to 1.80 for the control group.

Table 4: STAT pre- and post-test At-Risk Student population results.

Group	Pre/Post	N	Mean	Std. Dev.	Std. Error Mean	Sig. p<.05 (two tailed)
Experimental	Pre	15	9.00	3.05	0.79	0.2866
	Post	15	9.60	2.87	0.74	
Control	Pre	9	9.00	2.92	0.97	0.7531
	Post	9	8.78	2.86	0.95	

Category mean STAT scores of experimental and control groups

I took the STAT results a step further by examining students' scores on specific question categories from the pre- and post-STAT. As presented in Table 5, the mean difference in Category 1 (orientation, and direction) was not statistically significant. In Category 2 (discerning spatial patterns) the results were not statistically significant. Both groups experienced an increase in the mean for Category 3 (comprehending overlay and dissolve) but only the control group was statistically significant. For Category 4 (recognizing spatial forms) both groups experienced increases in the mean but were not statistically significant. The experimental group in Category 5 (comprehending spatial association and comparison) experienced a decrease in the mean but the control group experienced an increase. For Category 6 (transform perceptions, representation, and images from one dimension to another) both the experimental and control groups showed increased scores from the pre- to post-test, but the differences were not statistically significant. In Category 7 (overlaying and dissolving maps), both the experimental and groups experienced increased that were statistically significant. For Category 8 (understanding spatial shapes and patterns) the experimental group experienced a decrease while the control group experienced an increase. Neither result was statistically significant.

Table 5: STAT Pre- and Post-Test Category Results.

Category	Question/s	Group	Pre/Post	Mean	Mean difference (*Sig. p<.05 (two tailed)
#1 orientation and direction	1, 2	Experimental (n=60)	Pre	1.57	-0.07
			Post	1.5	
		Control (n=59)	Pre	1.63	-0.04
			Post	1.59	
#2 discerning spatial patterns	3	Experimental (n=60)	Pre	0.97	-0.02
			Post	0.95	
		Control (n=59)	Pre	0.95	0.02
			Post	0.97	
#3 Comprehending overlay and dissolve	4	Experimental (n=60)	Pre	0.70	0.05
			Post	0.75	
		Control (n=59)	Pre	0.47	0.19*
			Post	0.66	
#4 Recognizing spatial forms	5	Experimental (n=60)	Pre	0.70	-0.25
			Post	0.45	
		Control (n=59)	Pre	0.64	-0.17
			Post	0.47	
#5 Comprehending spatial association and comparison	6, 7	Experimental (n=60)	Pre	1.05	0.00
			Post	1.05	
		Control (n=59)	Pre	1.02	-0.07
			Post	0.95	
#6 transform perceptions, representations, and images from one dimension to another	8	Experimental (n=60)	Pre	0.20	0.12
			Post	0.32	
		Control (n=59)	Pre	0.22	0.09
			Post	0.31	

Category	Question/s	Group	Pre/Post	Mean	Mean difference (*Sig. p<.05 (two tailed)
#7 overlaying and dissolving maps	9, 10, 11, 12	Experimental (n=60)	Pre	1.97	0.25*
			Post	2.22	
		Control (n=59)	Pre	1.97	0.40*
			Post	2.37	
#8 understanding spatial shapes and patterns	13, 14, 15, 16	Experimental (n=60)	Pre	2.37	-0.02
			Post	2.35	
		Control (n=59)	Pre	2.14	0.23
			Post	2.37	

Student Perception Survey Results

To assess if there was a significant change in the student perception of geography as a result of the differentiated instruction implemented in the study, a related-sample sign test was conducted using SPSS. This test was chosen since the data were categorical, and the same students were measured. The median scores of pre- and post-surveys were compared, and the statistical significance for all questions was .050.

The Likert Scale in the pre- and post-survey questions were: Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. The scale categories were converted to numbers (Table 6) to carry out the related-sample sign test. The number of students who participated in the surveys were different from the number of students who completed STAT tests: 48 for the control group and 40 for the experimental group. Students' responses were excluded from the data analysis if they completed only one of the surveys, either the pre- or post-survey.

Table 6: Pre- and Post-survey Likert scale

Likert Scale Category	Numerical representation
Strongly Agree	5
Agree	4
Neutral	3
Disagree	2
Strongly Disagree	1

Question 1 of the surveys asked how much they agreed with the statement, “Geography is an enjoyable subject.” The experimental group and the control group both experienced positive differences. However, the experimental group’s difference was not statistically significant while the control group’s was statistically significant (Table 7, Figure 4).

Table 7: Statistical Analysis for Question 1: Geography is an enjoyable subject.

Group	N	Test Statistic	Standard Error	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Exact Sig. (2- sided test)
Experimental	40	12.000	2.121	1.179	.239	.238
Control	48	15.000	2.179	2.294	.022	.019

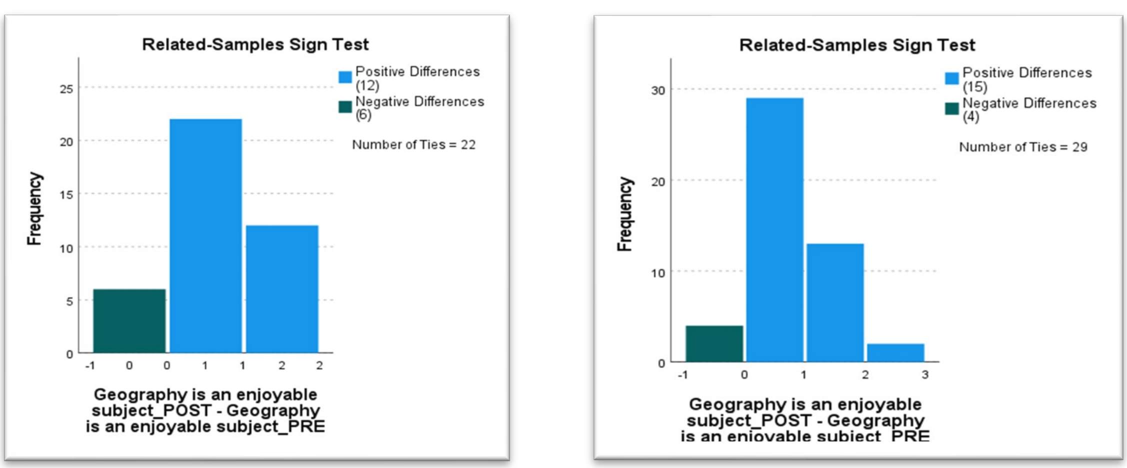

Figure 4: Frequency Distribution of Pre- and Post-responses to Question 1.

Geography is useful for solving problems in my community and/or the world.

Question 2 from the pre- and post-surveys asked students how much they agreed or disagreed with the statement, "Geography is useful for solving problems in my community and/or the world." Results for the related-samples sign test are displayed in the Table 8 and Figure 5 below. The results indicated that there was not a statistically significant positive or negative change for both groups.

Table 8: Statistical Analysis for Question 2: Geography is useful for solving problems in my community and/or the world.

Group	N	Test Statistic	Standard Error	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Exact Sig. (2- sided test)
Experimental	40	12.000	2.062	1.455	.146	.143
Control	48	17.000	2.646	.945	.345	.0

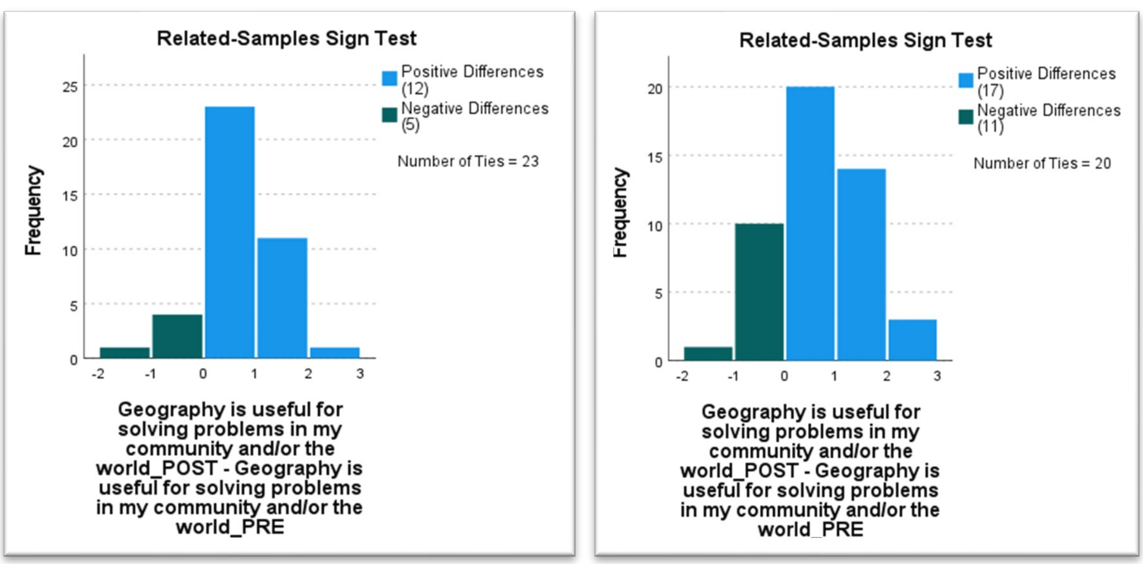

Figure 5: Frequency Distribution of Pre- and Post-responses to Question 2.

Geography has great value in modern society.

Question 3 from the pre- and post-survey asked students how much they agreed or disagreed with the statement, “Geography has great value in modern society.” Results for the related-samples sign test are displayed in Table 9 and Figure 6. Both groups did not experience a statistically significant difference.

Table 9: Statistical Analysis for Question 3: Geography has great value in modern society.

Group	N	Test Statistic	Standard Error	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Exact Sig. (2- sided test)
Experimental	40	12.000	2.236	.671	.502	.503
Control	48	15.000	2.449	1.021	.307	.307

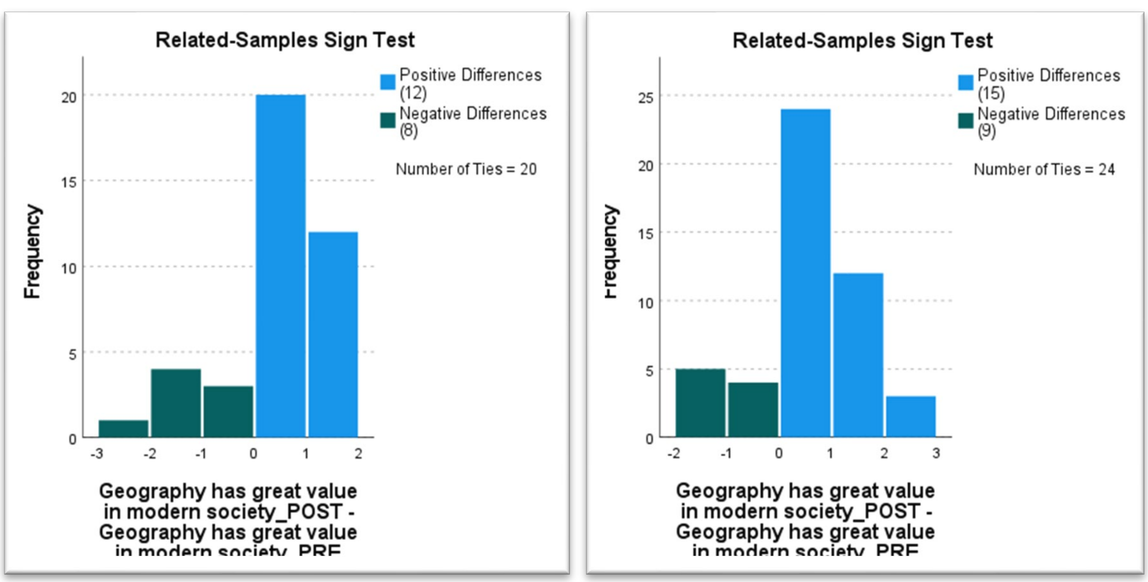

Figure 6: Frequency Distribution of Pre- and Post-responses to Question 3.

I am interested in taking a geography course at the postsecondary (college or university) level.

Question 4 from the pre- and post-survey asked students how much they agreed or disagreed with the statement, “I am interested in taking a geography course at the postsecondary (college or university) level.” Results for the related-samples sign test are displayed in the Table 10 and Figure 7. Although not statistically significant, the experimental group’s responses trended to the positive direction, meaning agreeing with the statement, while the control group responses did to the negative direction.

Table 10: Statistical Analysis for Question 4: I am interested in taking a geography course at the postsecondary (college or university) level.

Group	N	Test Statistic	Standard Error	Standardized Test Statistic	Asymptotic Sig. (2-sided test)	Exact Sig. (2- sided test)
Experimental	40	10.000	2.236	.000	1.000	1.000
Control	48	9.000	2.398	-.834	.404	.405

Figure 7: Frequency Distribution of Pre- and Post-responses to Question 4.

Geography class is useful for my potential career.

Question 5 from the pre- and post-survey asked students how much they agreed or disagreed with the statement, “Geography class is useful for my potential career.” Results for the related-samples sign test are displayed in Table 11 and Figure 8 below. The results indicated there was not a statistically significant positive differences for both groups.

Table 11: Statistical Analysis for Question 5: Geography class is useful for my potential career.

Group	N	Test Statistic	Standard Error	Standardized Test Statistic	Asymptotic Sig. (2- sided test)	Exact Sig. (2- sided test)
Experimental	40	10.000	2.550	-.981	.327	--
Control	48	10.000	2.500	-.800	.424	.424

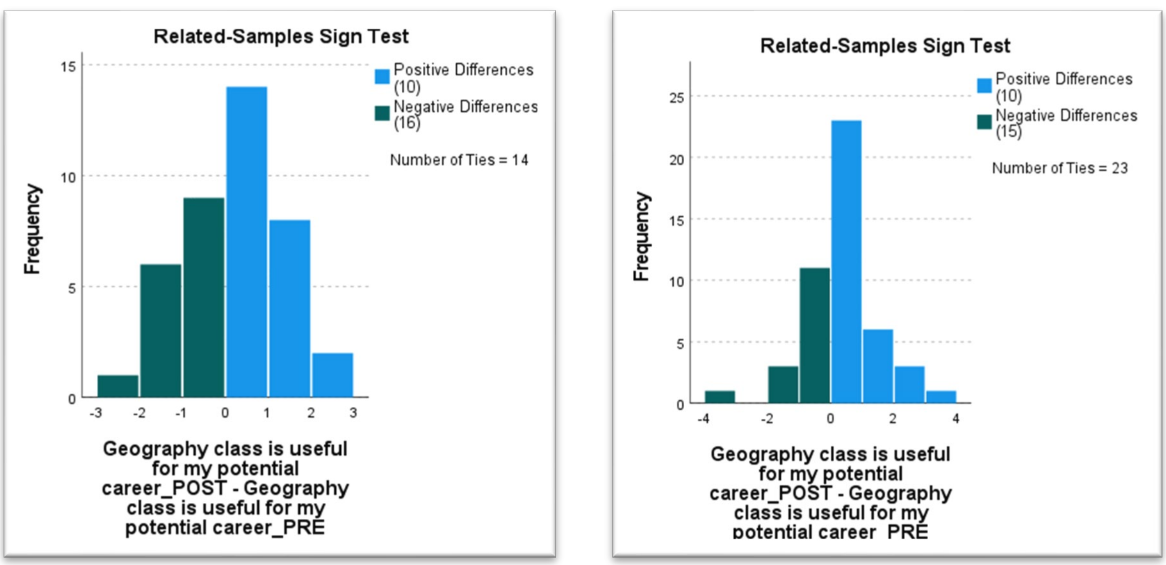

Figure 8: Frequency Distribution of Pre- and Post-responses to Question 5.

Discussion

Based on the results, the research hypothesis is not supported. I hypothesized that using ArcGIS Online would increase students’ spatial awareness and perception of geography. A series of *t*-test results showed that the overall mean score changes from pre- to post-STAT for experimental and control groups were too small to be statistically or practically significant. However, significant changes were observed in some category mean scores. The following section discusses my speculation on the possible reasons for the results. The sign test results showed that the overall median differences in student responses to the pre- and post-survey were not statistically significant. However, I observed interesting patterns in students' responses to each survey item, which I will discuss below.

Overall Changes in Spatial Thinking Ability

While there was a score increase, the experimental group did not show a statistically significant difference. The control group showed a statistically significant increase in the post-test. However, the score increase was too small to be practically significant.

Prior research suggests that using GIS including Web-based GIS increases students' spatial thinking skills (Lee & Bednarz, 2012; Jo et al., 2016). Going into this study, I expected similar results from my research. However, the study results do not support the significant benefit of using ArcGIS Online on a student's spatial thinking skills. One possible reason is the device the experimental group used to access ArcGIS Online. All students used district-issued Chromebooks with an 11-inch screen and a trackpad. The manipulation of ArcGIS Online was difficult for students since they could not access more manageable control mouse devices. Based on my observations during the lessons, the students had challenges zooming in and out the map layers. This caused student frustration and difficulty evaluating and answering the questions because they spent considerable time trying to achieve the correct scale.

A second possible reason could be from the nature and characteristics ArcGIS Online activities used for the lessons. Due to the demands on the students from the campus, their teachers, and limited APHG instructional time, I chose to go with ESRI's GeoInquires (2014), which provide ready-to-use simple, meaningful inquiry-based classroom activities on a variety of concepts and topics in geography. Most of the activities are meant to be completed in 15-minutes without having to creating an ArcGIS Online account. Five out of seven of the ArcGIS Online activities implemented in the study were from GeoInquires. While easy to adopt and well aligned with some of the APHG concepts, the activities were not extensive and encompassing enough to fully utilize the capabilities of ArcGIS Online for my students and to facilitate student practice of thinking spatially.

Another possible and more likely reason is that the implementation time was too short to make substantial changes in students' spatial thinking skills. Spatial thinking is complex cognitive process that takes time for one to develop (Gersmehl & Gersmehl, 2007; Sinton et al., 2013). Exposure to ArcGIS Online over seven weeks at the beginning of the student's freshman year might not be sufficient for practice and develop such complex cognitive abilities. I believe the results would have shown a more significant difference had the study been conducted over the course of the year (Lee, 2005; Jo et al. 2016).

Overall Changes in Spatial Thinking Ability of Special Populations

Special populations with my experimental and control groups were measured. For example, special populations are the at-risk students and minority groups. The results show that the at-risk experimental group (n=15) experienced positive gains in their spatial thinking, but it was not statistically significant. The at-risk control group (n=9) did not experience a positive gain, nor was the difference significant. The sample size was small, so it is hard to gauge whether this finding is noteworthy. I also attempted to break down the group further by ethnicity. ANOVA was used but did not warrant usable results because the sample size was too small and breakdown group numbers were uneven. For example, the ethnic composition for the experimental group was: Black (n=5), Hispanic (n=33), Asian Pacific Islander (n=7), and White (n=15). The composition for the control group was: Black (n=6), Hispanic (n=27), Multi race black, white, Hispanic (n=5), and White (n=21). This measurement could provide valuable data but needs a much larger sample. I suggest conducting this on a larger scale, including many different high schools with a diverse population.

Changes in Different Types of Spatial Thinking Ability

I took the STAT results further by evaluating scores on each of the eight item categories of the STAT (Table 5).

Category 7 encompassed Questions 9, 10, 11, and 12. This category measured the skill of overlaying and dissolving maps. Both groups showed a statistically significant difference in this item category. The increases experienced for both group in this category suggest that the specific activities chosen for the study period enhanced their skills. Jo et al. (2016) study also noted that students scored higher and lower in similar categories based on the activities conducted. For example, during the World Population activity (Appendix I) and the Scale and Distance (Appendix B) both groups needed to compare multiple layers and visualize the movement or turn on/off for each layer. The possible action of turning the layers on/off or visualizing the maps from different angles helped reinforce the skills measured in Category 7.

While both groups experienced statistically significant differences in this category, the control group's mean difference was larger at 0.40. One possible reason for this difference was that the control group was used to evaluate shapes and patterns on physical maps instead of ArcGIS Online. They were able to use the large wall maps for comparison and the paper maps used in the activities were also larger than what was shown on the computer screen. In my opinion, this category was the hardest out of all the spatial questions. It required multiple steps for the students to make decisions. While not measured for the study, I received the most questions from my students in this category. I did not answer the students' questions but encouraged them to evaluate all the information before deciding on their answers.

Changes in Student Perception of Geography

The results from the student perception of geography survey showed that the changes from the pre- to post-survey were not statistically significant. However, upon a closer look at the individual question results, some interesting patterns were observed. Those changes will be discussed by each question below.

Question 1: Geography is an enjoyable subject.

The experimental group (n=40) experienced positive improvements from the pre- to the post-test survey. There were 12 positive changes, meaning that 12 students selected more positive responses to the post-survey, compared to 6 negative changes and 22 ties (Figure 4). I tried to identify possible reasons for each case by looking at the students' optional written comments. One student stated 'strongly disagreed' with both surveys because they struggled with the content. In the post-survey, he stated,

> "I really struggle with this class. I struggle with history in general and I'm not completely comfortable yet with the AP questions."

Based on my knowledge of this student, he has high expectations and is focused on his grades. An interesting aspect is that from the students whose opinion changed from neutral to agree only two of them chose to leave a comment.

> "I think that is fun in this class and learning geography is cool to learn about the world."
>
> "It is because it can help in the future to maybe benefit you."

The students who chose 'disagree' and 'strongly disagree' tend to struggle with the content and the workload. This is a common concern for freshmen taking their first AP class during the first few months of the school year.

The control group showed a statistically significant difference (p=.022) in Question #1 with 15 positive changes compared to 4 negative changes. I focused the most on evaluating any comments from students who went from the 'negative' (neutral or disagree) to a 'positive.' Most students who moved from neutral to agree did not comment on why. However, there was one student who did and stated,

> "I like getting to know the world and the map quizzes can be fun."

The control group used and had access to three large wall maps for their activities. This allowed for more collaboration among the students as they attempted to identify patterns. Another interesting aspect was the students who chose neutral in the post survey. There was a common pattern in the statements, such as:

> "It is difficult for me but it is kinda cool to learn new things about are world."
>
> "It can be fun if it comes easy to you or if you find enjoyment in history."
>
> "I never had an interest in geography but I do not hate the subject."
>
> "The reason I believe geography is neutral because it's not super fun to me but not boring."
>
> "I'm not awful but i'm not good at geography so I'd say I'm neutral."

Many students chose neutral because they had not decided if they liked the class. Again, this could be because it was completed very early in the year.

Question 2: Geography is useful for solving problems in my community and/or the world.

The results from the second question showed overall positive changes but were not statistically significant. The experimental group had 12 positive changes, and the control group had 17 positive changes (Figure 5). The difference between the control group verses the experimental group was relatively large. I could not locate a specific pattern with the experimental group since most students did not comment. Aside from showing that the students can see the impact of geography, they do not address the reason for the change.

> "It teaches us about things going on in the world and other issues that arent talked about"
>
> "By knowing the geography it can help us better understand a place."
>
> "Geography can provide background information about the community and can provide a solution, but I believe with all fairness and respect to the subject not everything can be solved like this"
>
> "I agree with that statement because knowing about geographical money distribution and where poorer areas are important. Having the knowledge of the world around you is very important to how to change the flaws in the community."

The control group experienced a more significant increase with seventeen positive differences. Most students did not comment on this question, so it was difficult to evaluate why there was a larger movement than the experimental group. One pattern that did appear with the control group was in the negative differences. Six out of the eleven differences were movement from 'strongly agree' to 'agree'. Therefore, they remained on the positive side of the question but did not appear to because of the movement down. It is difficult to explain why because the students did not leave a comment. There were comments left by students in the 'strongly agree' category. The pattern here could help explain the movement of other students. They recognize the importance of learning about the world.

> "If you know the state that each country is in and resources it has then it can help others."
>
> "geographic maps can show patterns in an area and help solve a problem"

"Geography can be used in lots of ways to represent the changes in human culture."

Question 3: Geography has great value in modern society.

The experimental and control groups had more positive than negative differences (Figure 6) but the mean difference did not experience statistical significance. The experimental group resulted in 12 positives compared to eight negatives. After evaluating the comments, I conclude that the question is too similar to the previous question in the survey.

It confused a few of the students, as indicated by the comments:

"This is the same answer as the one before."

"I say neutral Because i really don't have an opinion."

"I think that it can be beneficial, but mostly people don't care nowadays."

The control group had a similar type of movement for this question. The control group had 15 positive differences to nine negative differences. Many of the comments were positive comments about geography in the world, but then some comments did not seem to fit, such as:

"With every map that is used."

"I feel like it could but I am not sure."

"I think geography should be more modernized than it is now."

Question 4: I am interested in taking a geography course at the postsecondary (college or university) level.

The experimental and control group results were more negative for this question (Figure 7). The mean differences for both groups were not statistically significant. The experimental group had 10 positive and 10 negative differences, while the control group experienced nine positives compared to 14 negative differences. The comments from both groups suggest a reason why.

> "I don't know if I would take it in college because I already took it here and my career is not going to be related."
>
> "I don't exactly know what i want to take for college classes. I'm just taking as many college level courses in high school to benefit me later."

At this early in the year, the students focus on learning to be an AP student. Based on many of the comments, the students do not see a need to pursue any more geography courses. Instead, they plan on passing the AP exam and receiving college credit.

Question 5: Geography class is useful for my potential career.

The results from this question also trended negative instead of positive differences (Figure 8). There was also no statistically significant mean difference for either the experimental or control group. The experimental group experienced 10 positive differences compared to 16 negative differences, while the control group experienced 10 positive changes compared to 15 negative differences. The experimental and control group student comments show they have not seen the connections. I should have used something other than this question since it was outside the scope of my study. Also, based on my experience, students start making connections to other career fields in the spring. The results show that I need to be more explicit about career fields and opportunities at the beginning instead of the middle of the year.

Conclusions

This research aimed to measure ArcGIS Online's impact on students' spatial thinking skills and their perception of geography. Past studies have shown that the benefits of using geospatial technology such as ArcGIS Online in the classroom increased a student's geographic knowledge, including spatial awareness (Kerski, 2003; Lee & Bednarz, 2012; Jo et al., 2016). They also demonstrate the importance of spatial awareness in the classroom. Developing and using spatial awareness skills, such as analyzing spatial patterns, are critical components of the AP Human Geography Curriculum and Exam Design (2020). I chose to measure this effect in my AP Human Geography classes this year.

The study's results showed improvement in students' spatial awareness for the experimental and control groups. The Lee and Bednarz (2012) STAT pre-and post-tests were used to measure the difference in the student's spatial thinking skills for the experimental period. My goal to add to the existing research was successful, but it did not support my hypothesis. I believe the lack of statistical significance in the differences for the experimental group is due to three possible issues.

The first possible issue was the technology used. The students accessed ArcGIS Online by using their Chromebooks. The Chromebooks have limited functionality, but we were able to access AGOL. However, based on my observations, the small screen size and using a trackpad instead of a mouse made it more difficult for the students. In addition, there were challenges loading the app, zooming in/out, and navigation.

The second possible issue was the activities chosen. ESRI's GeoInquires are short inquiry-based ArcGIS Online activities expected to last 15 minutes. Six out of seven of the AGOL activities were GeoInquires. I worry that the lessons may have been too short of having the effect I expected. One lesson regarding John Snow's Cholera mapping was more in-depth and required the entire 45-minute class period to complete it.

The third possible reason is the most significant. The study was at the beginning of the student's freshmen year over seven weeks. Spatial thinking skills develop over time (Gersmehl & Gersmehl, 2007; Sinton et al., 2013). I believe this study would have shown positive results for the experimental group had it been for the whole year instead of seven weeks. Similar to Goldstein and Alibrandi (2013) study which was conducted over the course of a year and received significant differences in a student's academic performance.

Another point that should be considered is the differences notated in the category results of STAT. Spatial thinking skills are complex and consist of multiple abilities (Lee & Bednarz, 2012) which could mean that different types of activities are needed to develop specific types of spatial skills. The activities used in this study were chosen based on relation to the APHG content needs. This possibly resulted in greater mean difference gains in Category 7, overlaying and dissolving maps.

Lastly, the student perception survey showed improvement in questions related to geography and its importance in the world. While the results, overall, were not statistically significant, there were noticeable differences in the student's perception of geography. I believe the short timeframe for the study is another consideration for the lack of statistical significance. I recommend more studies examining the impact that ArcGIS Online has on a student's spatial thinking skills and perceptions of geography in the context of AP Human geography. Spatial thinking skills take time to develop, and the study period needs to be longer. I recommend expanding the study to include other high schools teaching AP Human Geography at the freshmen level to increase the number of participants for a better indication and measurement of AGOL's impact.

Implications of the study for geography teachers are as follows. First, it would be better to add the focus at the beginning of the year on making my students more aware of the potential for career fields in geography. Typically, I add this later in the year as students start making sense of APHG content. This connection needs to be made at the beginning of the year so that the students will see the relevance of the content to their career aspirations. Teachers may use resources from Powerful Geography (Larson et al., 2022). The more connections students make in geography with their career interests, the more engaged they will be with the content throughout the year.

The second implication is that to enhance student spatial awareness, teachers need to implement ArcGIS Online activities that are closely aligned with the specific types of spatial thinking abilities they target. It can be overwhelming for the teacher, but resources are available that make it manageable, even for the novice teacher. For example, ESRI's GeoInquiries (2014) are ready-to-use lessons teaching a variety of geographic concepts and skills to K-12 students in a wide range of subjects, including AP Human Geography, US History, Middle School Earth Science, etc. The GeoInquires do not require the user to create an account. This is a great way to introduce students to geospatial technologies while also helping to develop crucial spatial thinking skills required in the AP Human Geography curriculum.

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Appendix A

Lesson 1: Latitude and Longitude- Experimental and Control Groups

Latitude and Longitude ArcGIS

Instructions: The flip activity should have been completed yesterday. Go here if you didn't to view the lesson. https://nisd.schoology.com/assignment/6257523891/info

- Use the link to answer the questions below. https://learngis.maps.arcgis.com/apps/webappviewer/index.html?id=604cd228714346bea1868956386dafaf

Latitude and Longitude refresher.

- Latitude lines run west-east OR east-west. They start at the equator (0°) and go North OR South.
- Longitude lines run north-south OR south-north. They start at the Prime Meridian (0°).
- The proper way to write coordinates: (Latitude, Longitude)
    - i.e., San Antonio estimated coordinates (29°N, 98°W)

What city, country, or feature is at the following coordinates?

1. (0°, 0°) ___________ What is the closest continent? _______
2. (30°N, 90°W)_____________ (country)
3. (49°N, 2°E)______________ (major city)
4. (50°N, 31E°) ______________ (large city)
5. (23S°, 43W°)______________ (large city)

Practice writing coordinates for the following locations. Estimations are okay and you are able to use the search bar on the map.

6. Atlanta, GA/USA ______________
7. Kigali, Rwanda ______________
8. Beijing, China ______________
9. Melbourne, Australia ____________
10. London, England ______________

What lies closest to 0° degrees latitude?

- Singapore, Philippines, Vietnam, or Cambodia?

Which is located at the highest latitude:

- Tierra del Fuego, Argentina; Melbourne, Australia; Reykjavik, Iceland; or Anchorage, Alaska?

Latitude and Longitude

Instructions: The flip activity should have been completed yesterday. Go here if you did not view the lesson. https://nisd.schoology.com/assignment/6257523891/info

- Use the Atlas or the wall map to answer the questions below.

Latitude and Longitude refresher.

- Latitude lines run west-east OR east-west. They start at the equator (0°) and go North OR South.
- Longitude lines run north-south OR south-north. They start at the Prime Meridian (0°).
- The proper way to write coordinates: (Latitude, Longitude)
    - i.e., San Antonio estimated coordinates (29°N, 98°W)

What city, country, or feature is at the following coordinates?

1. (0°, 0°) ___________ What is the closest continent? _______
2. (30°N, 90°W)_____________ (country)
3. (49°N, 2°E)______________ (major city) *(pg146)*
4. (50°N, 31E°) ______________ (large city) *(pg148)*
5. (23S°, 43W°)______________ (large city)

Practice writing coordinates for the following locations. Estimations are okay and you are able to use the search bar on the map.

6. Atlanta, GA/USA ______________ *(pg73)*
7. Kigali, Rwanda ______________*(pg129)*
8. Beijing, China ______________*(pg155)*
9. Melbourne, Australia ____________*(pg173)*
10. London, England ______________*(pg146)*

What lies closest to 0° degrees latitude? *(pg13)*

- Singapore, Philippines, Vietnam, or Cambodia?

Which is located at the highest latitude:*(pg13)*

- Tierra del Fuego, Argentina; Melbourne, Australia; Reykjavik, Iceland; or Anchorage, Alaska?

Appendix B

Scale and Distance ArcGIS Activity

Instructions: Use the link to answer the questions below. Follow in order.
http://esriurl.com/humanGeoInquiry1

Ask: Are all miles “equally” distant?

1. Why might distances of the same length feel longer or shorter?

____

Acquire: How far can you get?

→ Click the details button (top left corner)
→ Click on Content
→ Check the box to the left of the layer name,
Drive Time from Boston (60, 90, 120 minutes).

2. Which major city in **New Hampshire** can you reach in less than 90 min’s?_________________
3. Approximately how long would it take to get to Providence, R.I.?

Explore: Are we taking the long way around? Both Manchester and Worchester are at the outer edge of the 60-minute drive time zone. But, as the crow flies, it is 38 miles to Worchester and 48 miles to Manchester.

4. Why might driving a longer distance take the same time? __
____

→ Use the measure tool on the top center bar. → Select distance
Click once to start measuring and double click to stop measuring on the map

5. What Mass. city is located less than 50 miles from Boston (as the crow flies) but cannot be accessed in a 120-minute drive. _________________
(hint: water contributes to the time. May need to zoom in/out to see detail)
6. Why is the travel time so long? ___________________________
7. What other forms of transportation might change the travel time and accessibility? _______________________

Analyze: How is population density related to travel time?

→ Click the button, Bookmarks (top right).

→ Select BOS_MHT/WOR
→ Turn on the layer, 2020 Population Density (whole states)
→ Compare the Population Density and Drive Time layers by turning them on/off

8. What is the relationship between the drive time and population density?
____

Scale and Distance Activity

Instructions: Use the maps to answer the questions below. Follow in order.

Ask: Are all miles “equally” distant?

1. Why might distances of the same length feel longer or shorter?

____

Acquire: How far can you get?

→ Look at Map 1

2. Which major city in **New Hampshire** can you reach in less than 90 min’s?
____
3. Approximately how long would it take to get to Providence, R.I.?

Explore: Are we taking the long way around? Both Manchester and Worchester are at the outer edge of the 60-minute drive time zone. But, as the crow flies, it is 38 miles to Worchester and 48 miles to Manchester.

4. Why might driving a longer distance take the same time?
____

→ Use the scale in the bottom left corner of the map to measure the distance. (Map 2)

5. What Mass. city is located less than 50 miles from Boston (as the crow flies) but cannot be accessed in a 120-minute drive. __________________
(hint: water contributes to the time.
6. Why is the travel time so long? _______________________
7. What other forms of transportation might change travel time and accessibility? ________________________

Analyze: How is population density related to travel time?

→Look at Map 3 to answer the following questions.

8. What is the relationship between the drive time and population density?
____

ArcGIS – page 2

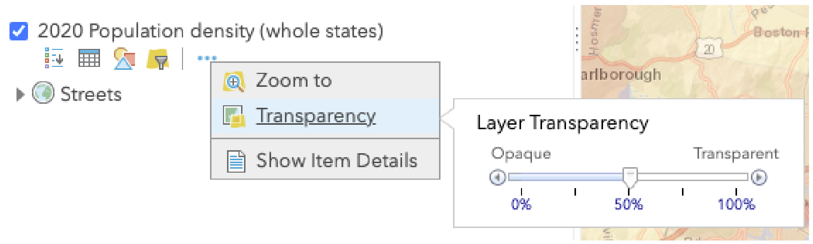
Act: How do highways affect travel time?

→ Turn off the layer, Drive Time from Boston (60, 90, 120 minutes).

→ Change the transparency of the 2020 Population Density layer to 50%

→ From the Details pane, click the Content button

→ Click the three small blue dots and hover your pointer over the word "transparency" to open a drop-down list.



→ You can modify transparency to see an active layer below the top layer. Set it to 50%.

→ Click the button, Bookmarks. Select Traffic

9. How are major roads and population distribution related?
(hint: zoom in/out for detail)

____

____

10. Would travel be faster through a more densely populated or less densely populated area? Explain

____

____

____

____

Paper and Pen: Page 2

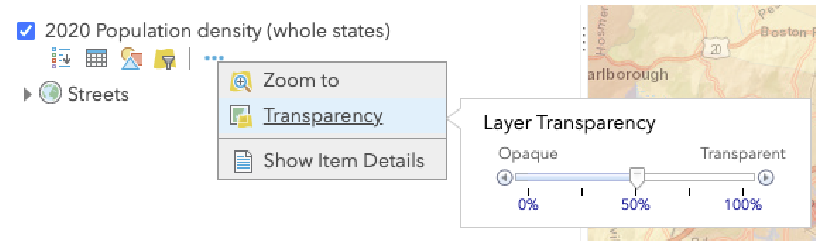
Act: How do highways affect travel time?

→ Turn off the layer, Drive Time from Boston (60, 90, 120 minutes).

→ Change the transparency of the 2020 Population Density layer to 50%

→ From the Details pane, click the Content button

→ Click the three small blue dots and hover your pointer over the word "transparency" to open a drop-down list.



→ You can modify transparency to see an active layer below the top layer. Set it to 50%.

→ Click the button, Bookmarks. Select Traffic

9. How are major roads and population distribution related?
(hint: zoom in/out for detail)

____

____

10. Would travel be faster through a more densely populated or less densely populated area? Explain

____

____

____

____

Appendix C

London's Cholera Outbreak Map – ArcGIS Online

In the mid-1800's, a deadly outbreak of the Cholera disease hit the city of London. The dead bodies are piling up and the authorities don't know what to do! We will use the ArcGIS Map of the outbreak to evaluate how Dr. Snow discovered the source of the disease. [*ArcGIS Map - to be used to answer the questions*]

In August of 1854, one of the most terrifying outbreaks of disease in the history of the western world occurred in London, England. Within a single week, 10% of the population of Soho had succumbed to Cholera, and the outbreak only subsided as residents fled in fear.

The predominant "Miasma Theory" held that the disease was spread through the air, and given the state of London's olfactory environment in 1854, it is not difficult to see why this theory held sway, even within the scientific community of the time. But one man, Dr. John Snow, had a different theory. He believed that the danger was in the water.

Snow had already risen to prominence in the medical community with his innovations in the field of anesthesiology. He had even served as an anesthesiologist to the Queen during the birth of her eighth child. But his rising star was not enough to convince others that his theory of the transmission of Cholera was correct.

Dr. Snow's map of the Cholera outbreak of 1854, and the reports that it accompanied, eventually won over the medical community of the day, as well as the burgeoning public health system in London, and by the time London saw another outbreak of Cholera, most had been convinced. Residents were warned to boil their water, and so ended the last Cholera outbreak London has seen.

The data in this map is taken directly from John Snow's map. This dataset is used in the second of three workshops on the use of Geographic Information Systems (GIS), taught by The Yale Map Department at Sterling Memorial Library. Using **GIS**, several measures of spatial central tendency have been applied to the dataset, revealing that the **Spatial Mean** (the geographic center of the distribution of deaths) of the outbreak lies within 35 meters of the Broad Street Pump, identified as the source of contamination in the 1854 outbreak. Also shown is the **Standard Distance** (similar to the Standard Deviation in statistics), which shows the radius around the Spatial Mean that contains 68% (or one Standard Deviation) of the deaths in the outbreak.

CED Topics:

- 1.2 Geographic Data -
  - May be gathered in the field by organizations or by individuals.
  - Geospatial technologies include geographic information systems (GIS), satellite navigation systems, remote sensing, and online mapping and visualization.
  - Spatial information can come from written accounts in the form of field observations, media reports, travel narratives, policy documents, personal interviews, landscape analysis, and photographic interpretation.
- 1.3 The power of geographic data
  - Essential Knowledge: Geospatial and geographical data, including census data and satellite imagery, are used at all scales for personal, business, and organizational, and governmental decision-making purposes.

Instructions: Use the Map (link) and the CED Topics above to evaluate the Cholera outbreak. The answers should go in the boxes provided.

1. How many layers are in this ArcGIS Map? Hint - Use the layers function to click through the various options.

2. What is the **distribution** of the dead? Are they **evenly dispersed all over the city**, or are there **clusters** of dead in certain areas? If clustered, what are they next to? Explain

3. Are there any clear **spatial patterns** to the phenomena? Do you see any **linear patterns** (in a line)? Any **circular patterns** (radiating out from a point/node)?

4. From your **spatial analysis**, what do you think is the **absolute location** of the origin of the disease (specific building), and explain in detail why you think so?

5. Where are the **outliers** (exceptions) that possibly challenge your suspected source? These are places where "people should have died, but didn't, and places where people shouldn't have died, but did."

6. There are two outliers to the correct source. Try to possibly explain the two **anomalies**. How could people close to your suspected source avoid dying? How could people die far away from your suspected source?

7. What type of map is this? ie. choropleth, isoline

8. Zoom out on the map - What do you notice about London by viewing the original map on top of the modern-day map? Explain. *Hint- there is no 1 answer to this question, but I'm looking for a detailed explanation.*

9. How could mapping technology of field research be applied to our modern-day situation?

Appendix D

London's Cholera Outbreak Map - Paper Map

In the mid-1800's, a deadly outbreak of the Cholera disease hit the city of London. The dead bodies are piling up and the authorities don't know what to do! We will use the ArcGIS Map of the outbreak to evaluate how Dr. Snow discovered the source of the disease. *ArcGIS Map - to be used to answer the questions*

In August of 1854, one of the most terrifying outbreaks of disease in the history of the western world occurred in London, England. Within a single week, 10% of the population of Soho had succumbed to Cholera, and the outbreak only subsided as residents fled in fear.

The predominant "Miasma Theory" held that the disease was spread through the air, and given the state of London's olfactory environment in 1854, it is not difficult to see why this theory held sway, even within the scientific community of the time. But one man, Dr. John Snow, had a different theory. He believed that the danger was in the water.

Snow had already risen to prominence in the medical community with his innovations in the field of anesthesiology. He had even served as an anesthesiologist to the Queen during the birth of her eighth child. But his rising star was not enough to convince others that his theory of the transmission of Cholera was correct.

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The data in this map is taken directly from John Snow's map. This dataset is used in the second of three workshops on the use of Geographic Information Systems (GIS), taught by The Yale Map Department at Sterling Memorial Library. Using **GIS**, several measures of spatial central tendency have been applied to the dataset, revealing that the **Spatial Mean** (the geographic center of the distribution of deaths) of the outbreak lies within 35 meters of the Broad Street Pump, identified as the source of contamination in the 1854 outbreak. Also shown is the **Standard Distance** (similar to the Standard Deviation in statistics), which shows the radius around the Spatial Mean that contains 68% (or one Standard Deviation) of the deaths in the outbreak.

CED Topics:

- 1.2 Geographic Data -
  - May be gathered in the field by organizations or by individuals.
  - Geospatial technologies include geographic information systems (GIS), satellite navigation systems, remote sensing, and online mapping and visualization.
  - Spatial information can come from written accounts in the form of field observations, media reports, travel narratives, policy documents, personal interviews, landscape analysis, and photographic interpretation.
- 1.3 The power of geographic data
  - Essential Knowledge: Geospatial and geographical data, including census data and satellite imagery, are used at all scales for personal, business, and organizational, and governmental decision-making purposes.

Instructions: Use the Map (link) and the CED Topics above to evaluate the Cholera outbreak. The answers should go in the boxes provided.

1. How many layers are in this map? Hint - Each different color or icon is a different layer
2. What is the **distribution** of the dead? Are they **evenly dispersed all over the city**, or are there **clusters** of dead in certain areas? If clustered, what are they next to? Explain

3. Are there any clear **spatial patterns** to the phenomena? Do you see any **linear patterns** (in a line)? Any **circular patterns** (radiating out from a point/node)?

4. From your **spatial analysis**, what do you think is the **absolute location** of the origin of the disease, and explain in detail why you think so?

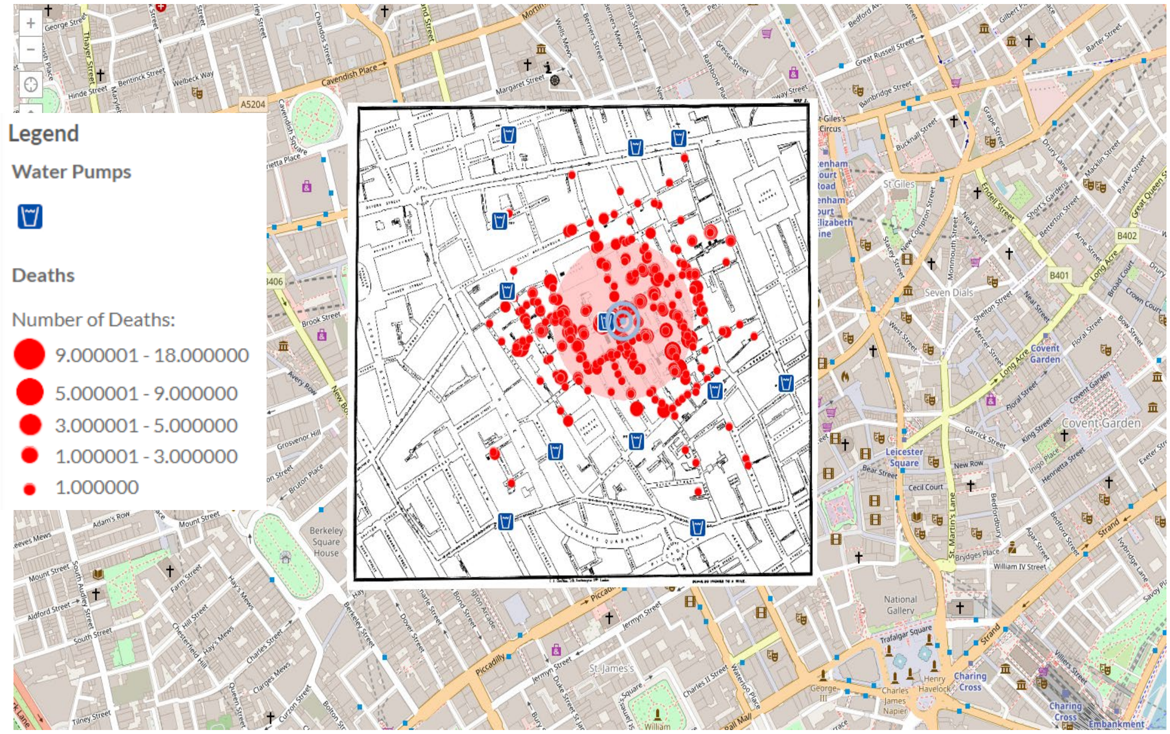
5. Where are the **outliers** (exceptions) that possibly challenge your suspected source? These are places where "people should have died, but didn't, and places where people shouldn't have died, but did."

6. There are two outliers to the correct source. Try to possibly explain the two **anomalies**. How could people close to your suspected source avoid dying? How could people die far away from your suspected source?

7. What type of map is this? ie. choropleth, isoline

8. What do you notice about London by viewing the original map on top of the modern-day map? Explain. *Hint- there is no 1 answer to this question, but I'm looking for a detailed explanation.*

9. How could mapping technology of field research be applied to our modern-day situation?


Legend
Water Pumps
Deaths
Number of Deaths:
9.000001 - 18.000000
5.000001 - 9.000000
3.000001 - 5.000000
1.000001 - 3.000000
1.000000

Appendix E

ArcGIS Online: Comparing Country Development

Use the data from ArcGIS to compare the country's HDI scores.

- Go to link: https://www.arcgis.com/home/webmap/viewer.html?webmap=6cabf90871f7425abe3fa66f94e52efb
- Choose "Content," turn on all 3 Layers
- Click on the country to view its data

Measurement	Germany	China	Mali
2019 HDI Rank			
Life Expectancy			
School: Years Expected			
Avg. Years in School			
GNI per Capital			

Describe the difference in the data between a high level of development versus a low level of development. FRQ Format

Appendix F

Control Group: Comparing Country Development

Use the map image and table below to answer questions related to development.

Measurement	Germany	China	Mali
2019 HDI Rank	4	85	184
Life Expectancy	81.2	76.7	58.9
School: Years Expected	17	13.9	7.6
Avg. Years in School	14	7.9	2.4
GNI per Capital	$46,946	$16, 127	$1,965

1. Describe the difference in the data between a high level of development versus a low level of development.

   ____
   ____
   ____
   ____

2. Out of the countries shown, which are:
   a. High developed: ________________________
   b. Mid developed: _________________________
   c. Low developed: _________________________

3. How is mean (avg.) years of schooling used to assess development?
   ____

4. How is Life expectancy used to asses development? ______
   ____

5. Describe the general location of MDCs and LDCs ________
   ____
   ____

6. Which region has a great number of MDCs?

Appendix G

Experimental Group: The Human Development Index

https://www.arcgis.com/home/webmap/viewer.html?webmap=9e70b7f72c0f415dbf0be6b08c628eb3

1. What statistics are used to create the HDI? ______________ ____
2. Click on the U.S., Brazil, and Pakistan to access their HDI score
   a. U.S. __________
   b. Brazil _________
   c. Pakistan________
3. Which regions are the
   a. Most developed? ________________________
   b. Least developed? ________________________
4. Turn off the HDI 2019 layer
5. Turn off all layers. Then turn on Total Fertility Rate layer.
   a. What regions have the highest Fertility Rate? _______ ____________________________________
   b. Click on the country to complete the chart

Country	Fertility Rate -2018	Fertility Rate -1990
Chad		
Afghanistan		
Cote d'Ivoire		
South Sudan		
Russia		
Singapore		
U.S.A.		

What do you notice about the differences between countries AND the years? What is happening to the total fertility rate?

Appendix H

The Human Development Index

Use the provided maps and data to answer the questions.

1. What statistics are used to create the HDI? _____________
   ____
2. What do you notice about the difference between the country's HDI? Use the Key to compare the levels
   a. U.S. _________
   b. Brazil ________
   c. Pakistan (west of India)_______
3. Which regions of the world are the
   a. Most developed? ______________________
   b. Least developed? ______________________
4. Total Fertility Rate map
   a. What regions have the highest Fertility Rate? *Hint -the lighter the color the higher the rate* ________________
   ____

Country	Fertility Rate -2018	Fertility Rate -1990
Chad	5.75	7.31
Afghanistan	4.47	7.47
Cote d'Ivoire	4.65	6.62
South Sudan	4.7	6.76
Russia	1.57	1.89
Singapore	1.14	1.83
U.S.A.	1.73	2.08

What do you notice about the differences between countries AND the years? What is happening to the total fertility rate?

What is the relationship between the total fertility rate and a country's development?

Appendix I

World Population: Modified GeoInquires

ArcGIS Online: World Population
Tape to WarmUp Section 1/ pg 41 - where it opens up
https://www.arcgis.com/home/webmap/viewer.html?webmap=f899e111a098487180db38e180beb39b

1. What type of map? ______________________________
2. How many people does the largest symbol represent?
   ____
3. Turn on only the layer, Total Fertility Rate (TFR). Close other layers.What pattern is observed? ________________________
   ____
4. Turn off TFR layer. Turn on Infant Mortality Rate (IMR) layer. What is the relationship between IMR and TFR patterns?
   ____
   ____
5. Turn all layers off except for Natural Increase Rate (NIR). Which region has the highest NIR? ___________________
6. Which regions have the lowest NIR? Hint: lightest colors ____

World Population
Tape to WarmUp Section 1/ pg 41 - where it opens up
Use the class set of maps to answer the questions

1. What type of map? ______________________________
2. How many people does the largest symbol represent?
   ____
3. On the Total Fertility Rate (TFR) map. What pattern is observed?
   ____
   ____
4. On the Infant Mortality Rate (IMR) map. What is the relationship between IMR and TFR patterns?
   ____
   ____
5. On the Natural Increase Rate (NIR) map. Which region has the highest NIR? ___________________
6. Which regions have the lowest NIR? Hint: lightest colors ____

Appendix J

ArcGIS Online: Standard of Living
Tape to WarmUp Section 1/ pg 41 - where it opens up
http://esriurl.com/worldGeoInquiry7

1. Click the layer name, SOL-Population 65 Years Or Older/Percent. Click the Show Table button. Name two countries with the highest % of population over 65.
   ____
2. Close the open table and turn off all SOL layers. Individually, turn on and explore the two layers, SOL – GDP Per Capita and Workforce In Services %. Where are the countries with the lowest GDP per capita? What is the lowest GDP? *Hint: look in the Middle East and Sub-Sahara Africa*__________ ________________________________
3. What are the highest GDP countries? __________________
   ____
4. Turn off all SOL layers. Turn on layer SOL-Literacy. Where are the countries with the lowest literacy rates, and what is the lowest percentage? _______________________________
   ____
5. Where are the countries located with the highest literacy rates, and what is the highest percentage? __________________
   ____

Standard of Living
Tape to WarmUp Section 1/ pg 41 - where it opens up
Use the Class Set of Maps to answer the questions

1. Look at the map with SOL-Population 65 Years Or Older/Percent. Name two countries with the highest % of the population over 65.
   ____
2. Look at SOL – GDP Per Capita map. What regions have the lowest GDP per capita? ________________________________
3. What regions have the highest GDP per capita? ____
   ___
4. Look at the SOL-Literacy map. Where are the countries with the lowest literacy rates? Name three of them
   ____
5. Where are the countries located with the highest literacy rates?
   ____