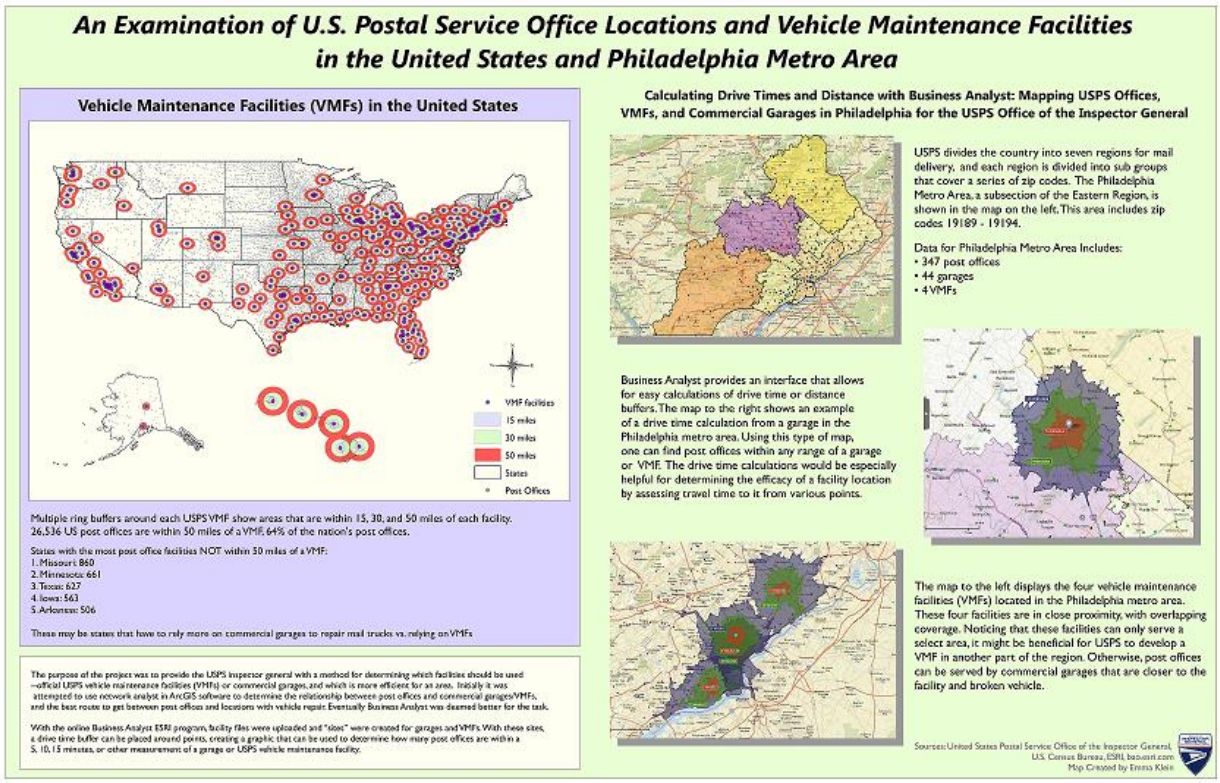
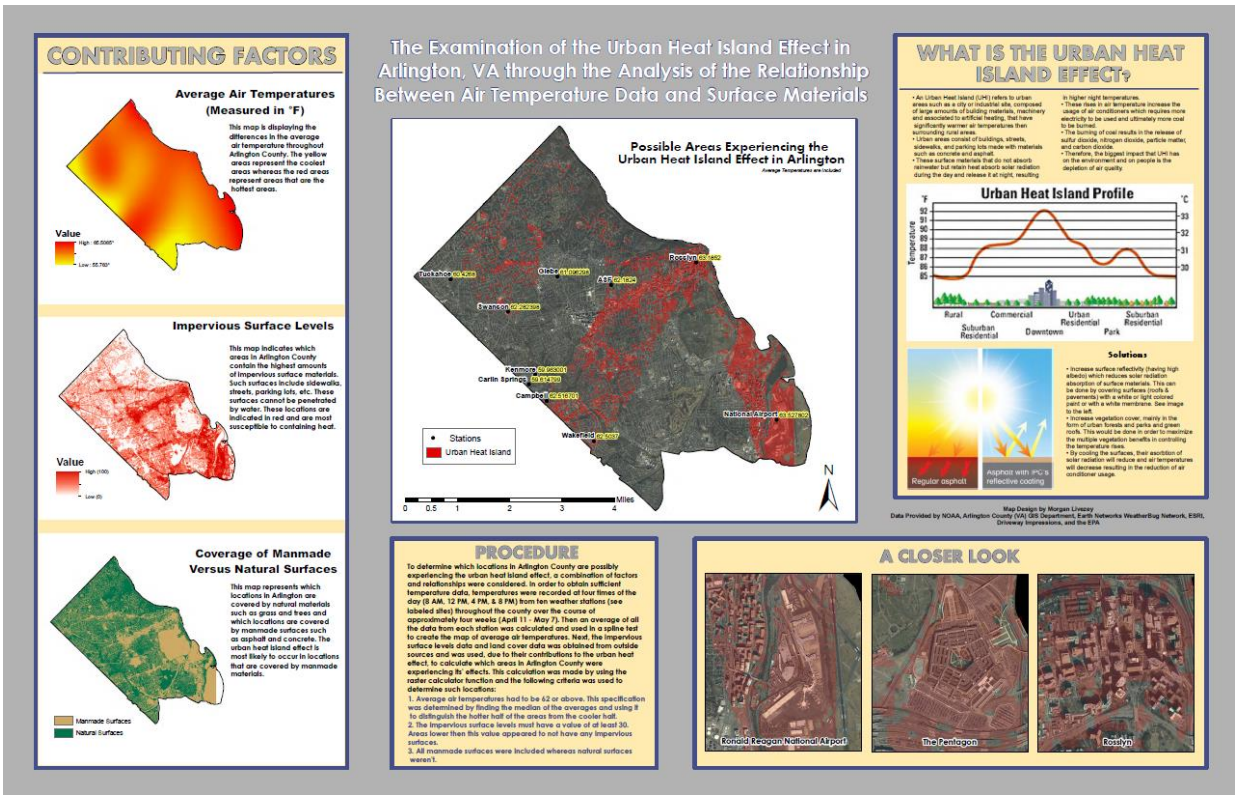
S1. Examples of GSS Student Final Projects





S2: Example Interview Questions

T1: Comparison Group

Transfer Questions presented in counterbalanced order across participating schools and Interviews 1 and 4

Transfer Question A or B is asked at Interview 1 followed by:

Course / Project Questions

What electives are you taking this semester?

- What is your favorite and why?
    - Have you taken courses in that subject before?

Background Information

How often do you use maps?

- What form are those maps usually in?
    - Google Maps (computer or phone) / GPS / Paper Maps
- Do you tend to look at a map before you head out to a new location, or do you consult a map en route to a new location?

What are your post-high school plans?

Outside of school work, what do you use a computer for?

Transfer Question C or D is asked at Interview 1

T1: GSS Group

Transfer Question A or B is asked at Interview 1

Course / Project Questions

Why did you decide to take this course?

Could you describe what your project will be about?

- What are the goals of your project?
    - What are you trying to determine?
- What do you predict will be the findings of your project? Why?

What specific information will you need to answer your project's main question?

- Why those particular pieces of information?
- Has there been any information you have looked at already that you have determined will not be useful for your project? Why?

How did/will you find your information for this project?

- What methods were (do you think will be) the most useful?
- Have there been any methods you found useless so far?

Has there been anything unexpected happen so far during your research process?

Background Information

How often do you use maps?

- What form are those maps usually in?
    - Google Maps (computer or phone) / GPS / Paper Maps
- Do you tend to look at a map before you head out to a new location, or do you consult a map en route to a new location?

What other electives are you taking this year?

- Which elective is your favorite?

What are your post-high school plans?
Outside of school work, what do you use a computer for?
Transfer Question C or D is asked at Interview 1

T 2 & 3: GSS Group Only

General questions about the Geospatial Semester course
Are you enjoying the class?

- What about it do you like?
- What about it don't you like?

Description of the project
Could you describe what your project is about?

- Is this the same idea as the last time we spoke?
    - If not, what has changed?
    - Why did you change your project? → What specific things made you decide to change your project?
- What are your expectations for your project?
    - What are you trying to determine?
- What do you predict will be the findings of your project?
    - Why do you predict that?

What specific information will you need to answer your project's main question?

- Why those particular pieces of information?
- Has there been any information you have looked at already that you have determined will not be useful for your project?
    - Why was that information not useful?

How did/will you find your information for this project?

- What methods were (do you think will be) the most useful?
- Have there been any methods you found useless so far?

Has anything unexpected happened so far during your research process?
Difficulties

- What has been the most difficult part of the project? What was difficult about it?
    - How did you solve that difficult part? Please discuss the process on how you reached a solution."

Changes

- Has your project changed throughout the semester?

    - How did it change?
    - Why did it change?

Questions about software

Do you enjoy using the ArcGIS software?

- Do you run into many technical difficulties with the software?
    - Could you describe one of those technical difficulties for me and tell me how you solved the problem?

T4: Comparison Group

Transfer Question A or B is asked at T4

Course Questions

Same as T1.

Background Information

Same as T1.

Transfer Question C or D is asked at T4

T4: GSS Group

Transfer Question A or B is asked at T4

Description of the project

Same as T2 & 3.

Reflection

- If you had a chance to start over, what would you do differently?
- What have you learned about how to do a project of this scope?

Did anything unexpected happen so far during your research process?

Background Information

Same as T1.

Transfer Question C or D is asked at T4

S3. Example of Transcript Processing.

Transcripts of students' responses to each of the four hypothetical questions were analyzed using LIWC 2015. First, non-fluencies (e.g. umm, hmm) were edited to the nearest form recognized by LIWC. Next, spatial words were color-coded using LIWC and duplicate spatial words were removed. An example transcript with spatial words and duplicate word removal is below (spatial words are in bold, and removed words are indicated with a strikethrough).

> "Why do I think it differ…or, well, why do I think it differs? I want to say…there's like, there's a combination of factors that go **into**, like, milk price. Like, transportation and stuff, and…but, like, I…maybe the **biggest** one is, like, the consumers…I mean, sorry, the producers, like, you know, the people **at** Walmart, the people ~~**at**~~ Costco, they actually get to choose their own price, I'm pretty sure. So, you know, they're just trying to make the ~~**biggest**~~ profit. So, I mean, predicting that, I'm not really sure. But, like, I mean, I just know that the milk prices vary like, you know, **there**, a lot…a ton of factors. So, you'd probably have to, like, get information from all those factors, and, like, look ~~**at**~~ it, you know, and make a decision **on** that if you wanted to predict. But I don't know how I would do that personally."

In the example transcript, three duplicate spatial words were removed. Next, the edited transcripts (with duplicate spatial words removed) were analyzed using LIWC 2015 including the spatial dictionary from Cannon et al (2011). LIWC produced a total word count (154 for the example transcript) and a percent of spatial words for the spatial dictionary (3.25% spatial words). A count of spatial words was then generated by dividing the percent spatial words by 100 and multiplying the result by the total spatial words used in each instance. The count of spatial words for the example transcript is (3.25/100)* 154 = 5. This count of spatial words was used in our subsequent analyses.

S4. Context: Contrasting the GSS group and the Comparison Group on Transfer Questions.

The following examples help to contextualize the work and to show changes over the course of the GSS. Answers to the Transfer Questions provide specific evidence of students' STEM-relevant problem solving, and were the basis of our analysis of students' scientific reasoning. Here we present examples from the GSS Group and the Comparison Group that demonstrates differences in thinking regarding the Transfer Questions.

The Episode 2 below, demonstrates that students in the GSS and Comparison groups gave similar answers to the Transfer Questions at T1. The students' answered the question, "If you were running a campaign for a local political office, how would you go about running your campaign?" The answers illustrate that neither group provided rich, spatially-based answers to the questions. The following answers are presented directly from the transcripts.

Episode 1:

> **GSS Student A:** Right. Um, well, I'd use the media, obviously, I'd have signs. Um, like, when I'm driving down the road, I always see signs, um, saying who's running, and letting you know what they're running for. Uh, I'd go to public events, um, and try to help out and just be noticed by the, uh, public. [sic]
>
> **Comparison Student B:** Um, I would try to market it, um, like, get a campaign. [sic]

Neither student takes a particularly spatial approach to solve the problem. They each make a low-level claim regarding how they would begin to campaign, such as using signs or posters to get a message out. However, they do not consider gathering data to determine the best locations for the signs, nor do they consider past voting habits. Finally, as neither student provided sufficient evidence (or data) to support their claim, they also did not attempt to reason about their claim statements. For instance, Student B stated that s/he would try to place signs

and go to public events but does not elaborate of where to place the signs or the benefit of doing so.

Episode 2 comes from the same two students at T4. The students were asked, "If your city needed to add an additional landfill, and you were in charge of the process, how would you go about determining where it should be?" Consider the differences in how each student approached solving the novel problem. The following answers are presented directly from the transcripts.

Episode 3:

> **GSS Student A:** Okay. Um, well first you'd find populated areas, areas of population density, high and low population, because landfills, everyone knows, don't want trash trucks or garbage trucks driving by all the time, with the smell. It'd be awful. If it was in a town, you could, uh, do a buffer in a certain area, find, um, real low population somewhere, that's not near, uh, a water source either because when you, when certain things are dropped…uh, dropped in landfills like batteries and things like that could possibly get into the water source. Pollute the water. Um, you could look at, uh, jobs. People might need a job and this would make some. Uh, that could be something you could do. Uh, it needs to be accessible because lots of garbage trucks will be coming in and out all the, all day, every day. Um, lots of people just come and do their own type of, uh, recycling, things like that. Uh, you got to have someone regulating it, making sure no one's coming there, dropping anything bad, so you have to, uh, make it's not a bad area, because people would be, uh, dumping, uh, harmful things, so it is good to have a big buffer. [sic]

> **Comparison Student B**: Uh, I'd definitely talk to, I guess, our Governor, or, like, the people who know our land the best, and start from there, I guess If people don't mind, and, you know, where it's located. [sic]

While the GSS student gives longer answers in both instances, the response length alone is not evidence that the GSS improved students' STEM-relevant spatial thinking. Rather, these examples suggest that GSS Student A has begun to consider a new approach to solving this novel problem, in comparison to the approach he or she used at the first interview. Several aspects of this student's response are noteworthy. Student A now makes a strong claim that motivates the

search for data (evidence) to test the claim statement; in this case, the data would be the population density for certain areas and water supply sources and accessibility. Moreover, Student A considers the calculation of the buffer for the area around the landfill and provides a justification linking evidence (population density, water sources) to reasoning (large buffer to protect population and water) when determining a landfill location. Student A also reasons about gathering data on traffic flow and accessibility of the landfill, and the data inform his or her selection of a location.

In contrast, Student B does not consider gathering data from multiple sources. While this student briefly ponders the idea that a landfill could be disruptive, she or he does not provide a reason for that disruption or a solution that involves gathering data to limit the possible disruption. Student B claims that he or she will speak to the Governor or other professional regarding a location choice; however, the student does not elaborate on why speaking to the Governor would help or what kind of data the state government might be able to provide.

These vignettes provide context for the course and examples of the ways in which the GSS may have influenced students' STEM-relevant spatial thinking and problem solving.