Advancing Freshmen Engineering Education by Utilizing the Impact of 2017 Storms on U.S Infrastructure

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Abstract

This paper describes the impact of three major hurricanes from 2017, Harvey, Irma and Maria, on the infrastructure and utilizing the knowledge from these events to educate freshmen civil engineering students. The primary focus of this study was to investigate the structural damage, geotechnical failures, transportation, environmental impacts, and social impacts of infrastructure failure on various demographic groups. In 2017, U.S. infrastructure was given a D+ by the American Society of Civil Engineer's infrastructure report card. The states affected by the hurricanes, Texas and Florida, have received C- and C grades, respectively. Inadequate infrastructure design and maintenance may have compounded the death toll from these storms. These events have shown the need to prepare future generations of civil engineers by educating them about the importance and challenges of designing infrastructure to withstand 100-year storms.

Structural damage from these storms destroyed businesses, residential homes, and major highways. Guajataca Dam in Puerto Rico suffered a collapsed spillway endangering 60,000 people in its path during hurricane Maria. In our lectures, we focused on presenting the reasons for structural failure, and used active learning strategies to discuss ideas and intricacies to design resilient structures.

We investigated the fundamental issues that caused geotechnical failures such as landslides, sinkholes, and dam failures. Irma and Maria caused hundreds of landslides, which generated death, destruction, and contamination. Some of Puerto Rico's dams have not been inspected since 2012 and a majority of these dams were built before 1960.

Hurricanes Harvey, Irma, and Maria have all had a devastating environmental impact. Most of the areas affected were contaminated from hazardous waste, superfund sites, and debris. Hurricane Harvey alone brought 60 inches of rain that flooded superfund sites and oil stations. These flooded areas spread pollutants all over eastern Texas and contaminated water supplies, farms, and watersheds. The cities that were impacted by these hurricanes did not have access to safe drinking water and food to eat. It is important to educate and conduct further research in ways that cities can be protected from huge environmental disasters. Future civil engineers can develop ways to contain contaminated areas during devastating storms.

This paper will focus on how the impact of the 2017 hurricanes was incorporated into our freshman Introduction to Infrastructure course. This will include modifications that were made to existing lecture modules and new lecture modules that were specifically developed to address the impact of these hurricanes. Students were assessed through a survey at the beginning and end of the course to determine the significance of these lectures have on student interest in various civil engineering disciplines.

1. Introduction

Infrastructure plays an important role in the nation's sustained economic development. Infrastructure consists of two main types which are "hard" infrastructure and "soft" infrastructure. Hard infrastructure consists of physical networks which include transportation, power, etc. while soft infrastructure consists of institutions and human capital. Inadequate and inefficient performance of "hard" or "soft" infrastructure hinders economic development. In the past decade, a significant increase in the number of natural disasters has had great impact on the infrastructure in the United States. We believe that it is important to train future civil engineers in various infrastructure systems and concepts of sustainable development to adequately prepare them for future challenges due to climate change. In this paper, three major hurricanes of 2017, Harvey, Irma, and Maria in the states of Texas and Florida, and the territory of Puerto Rico were investigated to understand the damage these hurricanes have done to the infrastructure in United States. The lessons learned from these events were used as case studies to developed lessons for an introductory freshmen civil engineering course. The primary topics discussed in this course include geotechnical failures, structural damage, transportation, and environmental issues. In order to measure the impact of these new lessons in the curriculum, assessment was performed using pre- and post-surveys which were done at the beginning and end of the semester, respectively. In the following sections, we will briefly discuss the various types of infrastructure failures caused by the hurricanes. We will present the assessment information obtained from the course during the Spring 2018 semester.

2. Course Description and Modules

The Civil and Environmental Engineering Department at <removed> University has been offering the 2-credit Introduction to Infrastructure freshmen course since Spring 2015. The course consists of two 75-minute periods per week with class size of 40 students per section. During Spring 2018, the course was offered as two separate sections of 40 and 37 students respectively with a total class size of 77 students. The primary objective of the course was to provide a deeper understanding of the various Civil Engineering disciplines. We have used the civil engineering infrastructure to contextualize the material presented in the lectures. Since the students interact with different types of Civil Engineering infrastructure every day, we presented the various infrastructure civil engineers typically design. The pedagogical philosophy for infrastructure education was based on list of definitions provided by Star and Ruleder [1] and the details of this methodology were presented previous study published in Anonymous 2015 (removed for blind reviews). In addition to presenting the different components of civil engineering infrastructure, we have also presented the students with some of the larger challenges that will be encountered by the future civil engineers such as climate change, resilience and sustainable development. This was done by using case-studies to present the current conditions of the U.S infrastructure. Some of the lecture modules used in the course were developed in collaboration with University of <removed> as a part of <removed> grant. We have modified some of the lectures for the Spring 2018 semester to include the case studies from hurricanes Harvey, Irma and Maria.

The lectures were covered by two instructors, Instructor1 and Instructor2. During the first half of the semester, Instructor1 covered the topics related to the Environmental and Water Resources

part of the course and Instructor2 covered the topics related to structural, geotechnical and transportation. The course materials consisted of PowerPoint slides during the first 30-40 minutes of the course and the remainder of the class time was used to complete a group class activity related to the lecture topic. The PowerPoint slides for each lecture and the class activities are available at the Instructor's website. A complete list of lectures is given in Table 1. The list of topics covered in the first half of the semester by Instructor1 are presented in left column and the topics covered during the second half of the semester by Instructor2 are presented in right column.

Table 1: List of lecture topics covered in the "Introduction to Infrastructure" course during Spring 2018.

Environmental/Water Resources	***Geotechnical, Structural and Transportation***
Introduction to Infrastructure*	Geotechnical Infrastructure I and II – Introduction and Characterizing Soil
Public Financing and Economics*	Geotechnical Infrastructure III – Shear Strength and Retaining Walls
Social Impacts of Infrastructure*	Geotechnical Infrastructure IV – Retaining Wall Problems
Ethical Considerations	Impact of Hurricanes on Geotechnical Infrastructure*
Environmental/Water Resources I – Hydrology*	Structural Infrastructure I – History
Environmental/Water Resources II – Water Treatment & Water Quality*	Structural Infrastructure II – Materials and Deflection
Environmental/Water Resources III – Stormwater Management*	Structural Infrastructure III and IV – Bridge Types and Inspection
Environmental/Water Resources IV – Green Infrastructure	Impact of Hurricanes on Structural Infrastructure*
Environmental/Water Resources V – Coastal Systems*	Transportation Infrastructure I and II – History and Traffic Control
Environmental/Water Resources VI – Sustainable Considerations*	Construction Infrastructure I and II – Road Construction and Pavement Distress
Environmental/Water Resources VII – Environmental Contamination and Remediation*	Transportation III and Construction III – Route Selection and Construction
	Impact of Hurricanes on Transportation Infrastructure*

Note: The symbol * indicates that the case-studies for the hurricanes were included in the lecture module.

During the first four lectures, the students were presented with lectures topics to broaden their understanding of the term infrastructure. During the finance and economics, the students were presented with the challenges and competing needs for investing in infrastructure. For example:

the budgets of each county affected by the hurricanes and their spending allocations were presented to the students to show how the tax dollars were being utilized. In addition, the students were also tasked to identify the ways to secure more income as a part of the class activity. The lecture on "Social impacts of infrastructure" presented the demographics affected by the three hurricanes Harvey, Irma and Maria.

In the following sections, we will discuss the different types of damage that was caused due to the hurricanes and some of the learning outcomes for different disciplines.

3. Environmental Impacts & Water Resources

The lectures about water resources focused on the stormwater management, structures used for stormwater conveyance and regulations. The students were also presented with Green infrastructure and best management practices for stormwater conveyance. The environmental portion of the lectures focused on the infrastructure for water and wastewater treatment, environmental pollution and remediation due to the hurricanes. Erosion of the beaches was discussed as a part of coastal systems and the different types of structures, man-made as well as green, used for flood mitigation were also presented.

3.1 Stormwater Management

Hurricane Harvey caused heavy, widespread rainfalls throughout the week following its landfall, with an average of 20 – 40 inches of rain across the region. The record amount was recorded at 49.6 inches near Clear Creek in Houston [2]. The rainfall led to severe flooding, impeding rescue efforts and damaging an estimated 136,000 structures in Harris County [2]. There were several other counties that were heavily affected by Hurricane Harvey. In Fort Bend County, major flooding occurred with both the Brazos and San Bernard Rivers experiencing record floods. Major flooding also occurred along the Brazos River from Richmond to Rosharon. It was emphasized that most of the flooding in Houston has occurred due to the lack of zoning and regulations [3]. Hurricane Irma caused great impact across the eastern part of Florida and has received significant amount of rainfall most notably in Jacksonville and three-day rainfall totals ranged from 10-18 inches across the state. [4] Hurricane Maria was one of the most devastating hurricanes to make landfall in Puerto Rico and the three-day rainfall totals were between 18-24 inches. [5]

3.2 Environmental Contamination

Due to the severe rainfall during Hurricane Harvey, 13 of the 41 Superfund sites located in Texas were flooded, and several were completely under water and were inaccessible. While Superfund sites contributed to contamination in the floodwater, an additional source was raw sewage, which is an environmental risk and a human health hazard. An estimated 20.7 million gallons of raw sewage contaminated the floodwaters, containing high levels of Coliform bacteria [6]. Reports of lead, arsenic, and other metals were also found in the sewage. This surface runoff not only contaminated the surrounding communities, but the northern estuary of Galveston Bay, impacting the health of the ecosystem. [7]

Hurricane Irma had a strong impact on Floridian coastlines and on islands in the Caribbean. From such extreme conditions, the Florida Keys experienced harsh flooding, which exposed roads and beaches to Coliform bacteria. The rise of Coliform bacteria was not from contaminated groundwater, but from runoff contaminated from debris in waste staging areas [8].

Hurricane Maria severely damaged the 18 superfund sites in Puerto Rico. The most prolific Superfund site is the Dorado Groundwater Contamination Site, which is part of a drinking water system serving 67,000 people. The water quality was deteriorated by the modifications to the land-surface due to the high winds and the sediment that was washed through the rivers into the coastal waters. [9]

3.3 Erosion of Coastal systems

Hurricane Irma generated strong winds accompanied by the resultant tides heavily impacted the extensive seagrass meadows, which house shrimp, lobsters and conch, and is a natural barrier for the shoreline. Sediment was also lifted from the seafloor, affecting turbidity levels of the water and affecting the integrity of aquatic plants. Florida is also home to the Florida Reef Tract, which is more than 300 miles long and provides shelter for many species of marine life. The Florida Reef Tract suffered damage from rolling waves, and due to increased sediment and pollutant runoff from the mainland, stressed the coral and caused some of it to die [10].

Hurricane Maria increased surface heat flux, enhancing runoff and estuary turbidity. Following the rainfall, there was an increase of sediment traveling into streams and rivers from coastal waters. Coastal sediment content increased by 2.2 times after the storm, increasing turbidity as well. Sediment was also lifted off reef shelves, being pushed closer to shore. Hurricanes thrive off warm water on top of the ocean, and their swells push up the colder water on the ocean floor. Offshore reefs were not heavily damaged, but shallow shore reefs were damaged by waves, debris, and temperature fluxes [11].

4. Geotechnical Failures

As shown in Table 1, the geotechnical portion of the lectures covered basic concepts such as the soil characterization, shear strength and retaining walls. Subsequently the students were presented with the geotechnical failures due to the heavy rainfall during hurricanes. These lectures focused on the landslides, dam failures, sink holes and erosion of soil.

4.1 Dams and Levees

During Hurricane Harvey, there were fifteen private, non-regulated dams that did fail or suffered significant damage. Levee Improvement Districts (LIDs) built and maintained levees that protected their districts from riverside flooding. However, interior flooding occurred within several LIDs where rainfall accumulation and pumping against high riverside pressures overwhelmed LIDs stormwater management facilities. Numerous shallow slide failures were observed along drainage channels associated with the LIDs. These shallow slides were solely due to infiltration of water into the cracks, softening of the clay, and increased loading. [12]

The Guajataca dam collapse endangered over 70,000 people located downstream. The failure was exacerbated by fallen radio towers, which made it difficult for the local police to inform the residents to prepare for evacuation. The dam failure was caused by seepage and internal erosion which was expected to be caused by small depth of embedment and affected by historical landslide movements [13].

4.2 Sinkholes and Landslides

Hurricane Irma caused a lot of sinkholes in Central Florida because the region is primarily made up of sand and clay overlying limestone. The rain caused the granular sand to relocate inside the existing fracture which resulted in ground loss, forming a sinkhole [4]. Roads near South I-75 and SR-26 reported several sinkholes whereas Timberry Lake Retention Pond reported five different sinkholes in the retention area. These sinkholes near the roads caused erosion in areas up to a width of 10 m, a height of 3 m, and lengths of almost 150 m. This erosion could have possibly caused the landslide between the Dream Lake and the retention basin

Hurricane Maria caused over 400 different landslides w causing a disruption to earth retaining system in the state. Most of these landslides occurred in the center of Puerto Rico, which is primarily a mountainous area with steep slopes. These steep slopes combined with the rainfall that occurred with immense wind speeds could have been the cause for these landslides. Specifically, the road adjacent to the river Blanco had a landslide that damaged over 200 m of roadway. PR-357 was also damaged due to landslides and this section had experienced two different landslides only meters away from each occurrence. This landslide damaged over 150 m of the road. This type of damage would take Puerto Rico several months to access and repair. They can also have lasting impact on the geotechnical stability even after the repairs. In certain instances, it was observed that the soil was pushed away from its natural position and eroded into the rivers causing fluvial sediment loads to remain high for a long time after the hurricane occurred. [14]

5. Structural Failures

As shown in Table 1, the first three lectures of the structural portion covered general topics such as material properties and their deflection as well as different types of bridges and their inspection. Subsequently, the damage caused by the hurricanes to different types of structures such as homes, businesses and other major infrastructure components was discussed.

5.1 Structural damage to businesses and homes

Hurricane Harvey caused over $125 billion in damages according the report by National Oceanic and Atmospheric Administration (NOAA). Over 300,000 structures and up to 500,000 cars were reported flooded, and an estimated 40,000 flood victims were evacuated and took refuge in shelters across Texas or Louisiana. The structural damage resulted in several oil and gas refineries in the Golden Triangle area going offline for days, and consequently gas prices in the United States spiked to their highest levels in two years. Record water levels were observed at Pine Island Bayou, the Lower Neches River, and Cow Bayou. Houses were flooded in areas of

Simonton, Richmond, Rosenburg, and Thompsons, where nearly 200,000 people were evacuated due to levee concerns and restrictions.

Due to Hurricane Irma, the structural damage in Brevard County was more than $157 million [15]. The general breakdown for the damage types for each category such as private homes and businesses that was compiled by FEMA county-wide is as follows:

- Destroyed: Four single-family homes, two multi-family housing units, 37 mobile homes and two businesses.
- Major damage: 257 single-family homes, 24 multi-family housing units, 89 mobile homes and 30 businesses.
- Minor damage: 417 single-family homes, 70 multi-family housing units, 171 mobile homes and 118 businesses.
- Affected but not considered minor damage: 3,883 single-family homes, 398 multi-family housing units, 1,251 mobile homes and 378 businesses.

Hurricane Maria caused major damage to the weather systems such as radars and electricity generating devices. A major solar field as well as a wind turbine field were destroyed in Humacao and Puerto Rico needed to find an alternative source to provide power for their citizens. The entire city of Naguabo was devastated due to flooding and the city houses were destroyed by the massive increase of water. A few turbines still stand with all three blades having been torn off, while others have been torn off their main column completely [16]. NQS-San Juan NEXRAD radar, a structure that was used to forecast upcoming storms and the weather, was destroyed during the hurricane.

6. Transportation

As shown in Table 1, the first three lectures of the transportation part of the lectures were used to teach basic concepts about traffic control, road construction and pavement failure. Subsequently, the damage caused to roads and bridges were discussed as a part of infrastructure failures

6.1 Roads

During Hurricane Harvey, sensors recorded water levels of eight feet higher than the canal banks in the west and southwest along Interstate 610. On the north side, particularly along Spring Creek, water topped channel banks by more than 10 feet. Outside of I-610 and along the Hardy Toll Road, the water overflowed nearby bayous by as much as six feet. Texas Governor Greg Abbott opened all the interstate highways after the storm and at least 118 other roadways remained closed because of high floodwaters. [12]

Due to the damage from Hurricane Irma, Florida's DOT received $25 million in Federal funding for relief efforts from Federal Highway Administration (FHWA). As Irma moved on and the rain waned, Florida transportation officials had warned the residents and visitors to stay off the roadways. Road conditions were unsafe in parts of the state and crews cleared dangerous debris, examined bridges and roads to ensure that they were safe for travel. Across the state, officials were clearing debris and signs blown from highways during the storm, residential streets

remained impassable due to fallen trees and branches, and authorities had to respond to hundreds of reports of objects on local roadways. In central Florida, a portion of the interstate highway washed away during Hurricane Irma. [4]Some of the damage to transportation was also covered in geotechnical damage.

During Hurricane Maria, the roads in Puerto Rico were flooded causing transportation problems and the people were stranded on their roofs if they did not have access to a boat. Several intersections were also closed due to downed traffic lights. The state of New Jersey has sent over 200 law enforcement officials to help with traffic control and to deliver supplies. The officers helped deliver over 2,500 pounds of supplies to aid the locals [17]. Along with Roosevelt Roads, San Juan International Airport and six other airports in Puerto Rico are either fully open or open with daylight only operations.

6.2 Bridges

During Hurricane Harvey, a bridge collapse occurred at the Highway 96 Bridge over Village Creek near Silsbee, and flood waters inundated parts of I-10 in Rose City, Vidor, and near the city of Orange. Historic flooding was also reported in several cities across these counties, including Port Arthur, Lumberton, Warren, Groves, Bevil Oaks, Sour Lake, Hamshire, Fannett, China, Silsbee, Lakeview, Mauriceville, and northeastern Beaumont [18]. Texas is one of the best states in the United States for maintaining its large share of bridges and roads, but rain and flooding in the wake of Hurricane Harvey undermined bridges and roads in and around Houston. Texas has a larger-than-average share of bridges: 53,488 out of the country's 614,387. The state also takes above-average care of them, according to a review by the American Society of Civil Engineers (ASCE): Only 900 or 1.7% are rated structurally deficient by federal inspectors. For comparison, 9% of bridges nationwide are rated deficient. The problem for most of these bridges is the fast-moving flood waters washing away the foundation of bridges and roadways, a process known as bridge scour. Bridge scour is the removal of sediment such as sand and gravel from around bridge abutments or piers. As the foundation erodes, columns supporting bridges collapse or roads simply wash away. The most pressing concern is the scouring of the foundations of the southbound Interstate 69 bridge at the San Jacinto River, where water passed through with tremendous force and washed away the supports of the concrete pillars.

6. Assessment

The course assessment was done by pre- and post-surveys at the beginning and the end of the course. A screenshot of the complete survey is presented in Appendix-A. The questions were developed in collaboration with the University of <removed> as a part of the <removed> grant. The questions 1-8 are similar as this will allow us to compare the responses across various universities collaborating on the project. We have added the questions 9-11 to check the interest of the students in various disciplines as well as the overall interest of students in the Civil Engineering discipline (Question 10). Since some of the questions posed in the survey are subjective, we believe it is beyond the scope of the conference paper to present the details of all questions asked in the pre- and post-survey.

These questions were designed to check the understanding of some core concepts, such as sustainability, that were taught during the class. In addition, multiple choice questions were asked to measure the interest in Civil Engineering discipline during the semester to ensure retention. The total number of responses for the pre-surveys at the beginning of the course was 72 whereas the total number of responses for the post-surveys at the end of the course was 76. In this paper, we discuss the results from three different questions: Questions 1, 2 and 10.

Question 1

Sustainable design concepts were taught to combat the effect of climate change and we wanted to ensure that these concepts were grasped by the student. The first question asked about the definition of sustainability as a multiple-choice question. The correct answer for this question was choice B, "meeting the needs of the present without compromising the ability of future generations." Figure 1 shows the results from the pre- and post-surveys and it can be seen from the figure that 12 students knew the correct answer at the beginning of the semester and by the end of the semester a total of 73 students knew the correct definition. This shows the percentage of students who knew the correct definition of sustainability increased from 16.9% to 96% after taking the course. This shows that the lessons have done their part in imparting the concept of sustainable development.

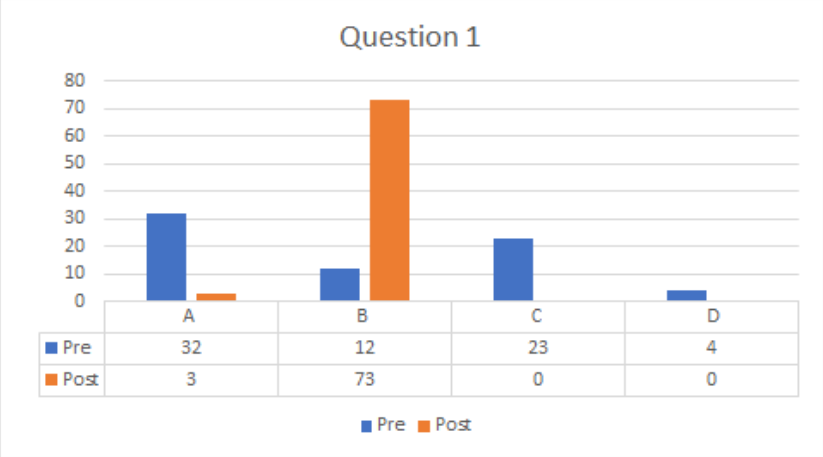

Figure 1: Bar graph showing the results from pre and post surveys for Question 1 (Note: the correct answer is B)

Question 2

The second question in the survey is another multiple-choice question that discussed the grade of U.S infrastructure from the report. The students were presented with the ASCE report on the US infrastructure during the first class, and the specific infrastructure components and their grade was discussed during the semester as individual case studies were presented. The course emphasized the fact that infrastructure grades for different components such as roads, bridges, railways etc., was mostly C's and D's. The correct answer for this question was C: "Mostly C's and D's". Figure 2 shows the results of the pre and post surveys for question 2 and it can be seen that 28 students knew the correct answer at the beginning of the semester and by the end of the semester, this number increased to 70 students. This shows that the percentage of students that knew the correct grade of US infrastructure increased from 38.9% to 92.1% after taking the course.

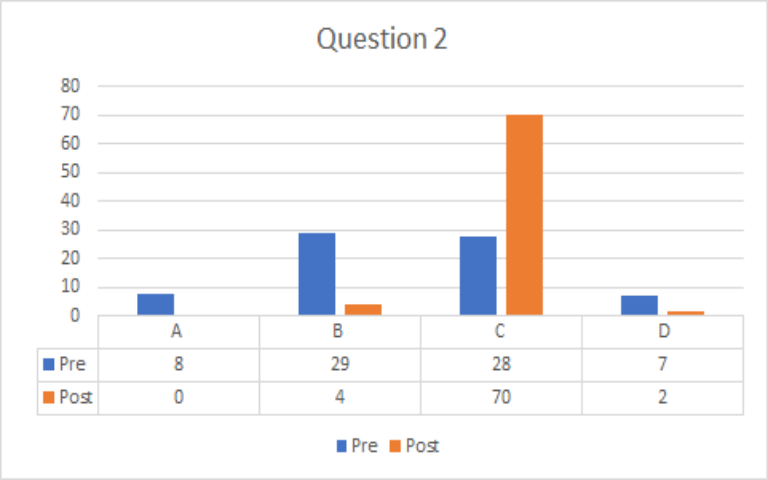

Figure 2: Bar graph showing the results from pre and post surveys for Question 2 (Note: the correct answer is C)

Question 10

This question was used a means to measure the interest of students in civil engineering discipline as a career. We wanted to observe if the course was able to sustain the interest in the civil engineering discipline. The choices for this question were: "A – Very high, B – high, C – Moderate, D – Low" Interest. Figure 3 shows the results from the pre and post surveys.

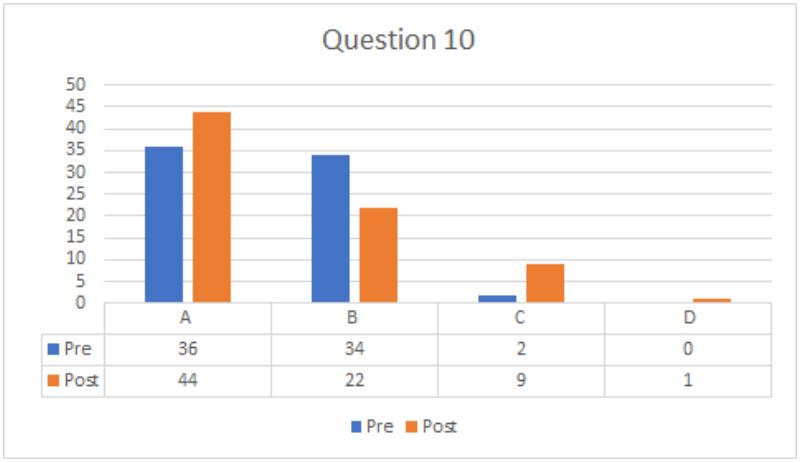

Figure 3: Bar graph showing the results from pre and post surveys for Question 10 (Note: A, B, C and D options denote "Very High Interest", "High Interest", "Moderate Interest" and "Low Interest" respectively)

It can be seen from the Figure that there was a net gain of 8 students in the "Very high" interest. However, we lost a few students from the high to moderate and low columns. So, we cannot conclusively say whether this course was able to create interest in the civil engineering discipline and increase retention. It should be noted that the number of responses for the post-survey are higher than the pre-survey. In addition, the loss of students from the B column may not be due to the course content alone. Based on conversations with some of the freshmen students, it was observed that there were changes to the way the course was taught by Mathematics department that had affected the confidence of some of the freshmen students. We believe that the results from this question cannot be taken in isolation as other courses that have no connection to the

course content can affect the student's overall interest in the program. In the future, we will ask the student to explain their answer which will help us figure out if the course content had affected their interest.

7. Conclusion

In this paper we present the details of an introductory freshmen civil engineering course. The lectures for this course were updated during Spring 2018 to includes the case-studies discussing the impact of three different hurricanes in 2017 that caused a devastating impact on the US infrastructure. We presented the different types of infrastructure failures that were caused due to geotechnical, structural, transportation, and environmental issues. In addition to the lectures, the students also participated in inclusive class-activities at the end of the lecture period.

We discussed sustainable design ideas to combat climate change during the course. The results from course assessment using the pre- and post-surveys at the beginning and the end of the course respectively, show that there was a marked increase in students understanding the concepts presented in the course. We also identified that there was an increase in the students expressing "Very High Interest" in the civil engineering discipline when compared between the total number of students at the beginning and end of the semester. Our assessment results indicate that the lectures have helped the students understand the concepts of sustainability as well the current US Infrastructure rank. However, we do note that the assessment questions need modification to correctly understand the reasons for students varying interest in Civil Engineering discipline.

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APPENDIX – A

1. Which is the most appropriate definition of "sustainability" as used by engineers (circle one).
   a. Constructing infrastructure systems to ensure maximum durability with minimal need for maintenance and/or rehabilitation.
   b. Meeting the needs of the present without compromising the ability of future generations to meet their own needs.
   c. Designing structures and other components of infrastructure so that they can sustain expected loading over the entire lifecycle.
   d. Constructing infrastructure systems that can be reused and/or recycled.

2. If you were to characterize the state of the nation's infrastructure (roads, bridges, sewers, water supply, etc.) using a typical grade scale, what grades do you think would be most appropriate (circle one)?

   a. mostly A's and B's
   b. mostly B's and C's
   c. mostly C's and D's
   d. mostly D's and F's

3. Explain the basis for your answer to question 2. That is, specifically, what factors led you to select the answer you chose?

4. Select an example of an infrastructure project that civil engineers would work on. State at least two subdisciplines of civil engineering that would be involved. Explain how the subdisciplines would work together on the project.

5. Choose an example of a project that civil engineers would work on (it could be the same example as question 5 or you could choose a different example). Explain how civil engineering professionals would interact with *non-civil engineering professionals*? List at least two examples of interactions.

6. Choose one of the considerations listed below (circle one) and *using a single infrastructure example* (a road, bridge, water treatment plant, retaining wall, etc.) state why the this consideration is important and explain how engineers would incorporate this consideration in the design of that example.

   Constructability Risk
   Aesthetics Economy
   Sustainability

7. Select one of the infrastructure components below (circle one) and list the considerations that would be necessary to conduct a field assessment of the component:
   a) Stormwater drainage system for a city block.
   b) Road pavement for a stretch of county highway.
   c) Substructure of a bridge crossing a small creek.
   d) Retaining wall along a highway cut.

8. The following is a recent quote from the Transportation Secretary in regard to the $50 billion infrastructure investment plan proposed in September 2010: "We know that upgrading our nation's infrastructure is vital to our economy and our future competitiveness." Explain briefly why you think this statement is true or not true (circle one). Cite any examples that you can think of to support your argument.
   True False

9. Which area of civil engineering are you most interested in working in (circle one)?
   a. Environmental Engineering
   b. Water Resources Engineering
   c. Geotechnical Engineering
   d. Structural Engineering
   e. Transportation Engineering
   f. Other – Explain:_____

10. What is your current level of interest in pursuing a career in civil engineering (circle one)?
    a. Very High
    b. High
    c. Moderate
    d. Low
    e. Very Low

11. What grade do you expect to receive in this course (circle one)?
    A A- B+ B B- C+ C C- D+ D D- F

Figure A1: Screenshot of the Pre- and Post-class surveys used for assessment