PLACE-BASED AND STUDENT-LED CLIMATE CHANGE INSTRUCTION IN THE SCIENCE CLASSROOM

by

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of

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in

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ABSTRACT

Climate change is a global problem affecting everyone living on Earth. In Florida specifically, intense hurricanes are becoming a familiar event. In response to this phenomenon, I designed hurricane lessons to help students understand the link between climate change and increased hurricane intensity. I used place-based and student-led lessons. During these lessons, 14 students attended in-person and 16 students attended online, which was an option for students during the Covid-19 pandemic.

In the Hurricane Webquest, students learned about the structure of hurricanes, tracked Hurricane Irma and read about the link between rising sea-surface temperatures and hurricane intensity. For the Thermodynamics PhET Labs, students investigated the links between climate and heat, and energy transfer. In the Thermodynamics Mini-Project, students looked at how thermal energy can be converted into kinetic energy in hurricanes. Finally, in the Hurricane Building Codes Assignment, students investigated local buildings and how they met the Florida hurricane building codes.

Both before and after the hurricane lessons, students participated in the Hurricane Likert Survey and took a Hurricane Knowledge Test. Some students also participated in final interview questions once the lessons were concluded. Students indicated in both pre- and post-surveys that they were aware of climate change. After the hurricane lessons, students reported a greater understanding of the relationship between climate change and hurricanes. After students completed the Hurricane Building Codes Assignment, they were better able to articulate their reasons for evacuating or staying during a hurricane. When in-person and online students were compared, their greatest difference was in-class participation. Students attending in-person participated in classroom discussion, and those who attended from home stayed silent.

BACKGROUND AND INTRODUCTION

Context of Study

Climate change is a global crisis that impacts everyone on the planet. It is also one of the most controversial topics that science educators encounter. In a recent Washington Post article, 20% of Americans polled said that they do not believe in climate change (Dennis et al., 2019). Although this percentage is dropping, some parents and students are still hesitant to agree that climate change is accepted science. This fact is challenging for teachers who must determine the best way to cover the required standards.

Even more troubling is the potential of teacher bias affecting the delivery of the content. Researchers determined through interviews and surveys that personal views of teachers could affect not only their attitudes on climate change, but also the methods and curricula that they use to teach it. The same research also elucidated possible ways that curricula could be designed to reduce bias by teachers, who universally agreed in the study that teaching unbiased science is their professional responsibility. This goal can be reached by emphasizing student-centered education where students are taught to work through their understanding of climate change with scientific reasoning and critical thinking skills. This approach is largely unaffected by teacher bias (Kunkle & Monroe, 2019).

My students and I live in coastal Florida, which experiences a very specific, intense effect of climate change: stronger hurricanes. Since 2015, when I started teaching, we have had three direct hits or near misses by Hurricanes Matthew, Irma and Dorian. All three of these events caused mandatory evacuations for beachside residents as well as

school closures. Following Hurricane Irma in 2017, for example, we lost six days of school, as residents first prepped homes, then evacuated before the storm, and finally cleaned up and waited for power and internet service to resume after the storm. Many of my students, many of them living within walking distance of the beach, do not evacuate. It seems like they do not believe "the big one" will hit them. It was my desire as a science educator for them to truly understand hurricanes and their potential damage as well as the local impacts of climate change.

My physics classes are at Cocoa Beach Jr/Sr High School (CBHS) in Cocoa Beach, FL. This school also serves the city of Cape Canaveral as the population of both these cities is relatively low. In the 1990s, the International Baccalaureate (IB) program was added to the school because enrollment at the school was steadily dropping. Without the addition of this program, the school was in danger of being closed. This program brought academically motivated students from all over Brevard county to Cocoa Beach High. The student population is currently approximately 1000 students in grades 7-12. According to US News & World Report, Cocoa Beach High has 25% minority enrollment and 29% of the student population is considered economically disadvantaged ("Cocoa Beach Jr/Sr High School," 2018).

In response to Covid-19, Florida state guidelines required all schools to be open at least five days a week. Most school districts, including Brevard Public Schools where CBHS is located, allow for an online option that is synchronous to the in-person class, meaning both in-person and online students attend class simultaneously. Approximately one-third of CBHS students are attending school partially or completely online via an

online video platform (Zoom, Microsoft Teams or Google Meet). All of my classes use Google Meet for our online platform. Because the IB program does not require physics, few IB students take physics. Those that do sign up for the course are taking the class as an elective.

Focus Question

The focus question for this study was, How does place-based and student-led learning affect student understanding of climate change in the context of hurricanes?

My sub-questions included the following:

1. How do students perceive the relationship between hurricanes and climate change?
2. How does hurricane instruction impact student attitudes about hurricanes?
3. How does hurricane instruction differ between in-person and online learners?

CONCEPTUAL FRAMEWORK

Inquiry

Inquiry in the science classroom fosters an environment that encourages students to ask questions and find creative innovative solutions. In particular, science inquiry provides students foundational skills that guide students in critical thinking and overall learning. Students are presented with a question or they may have to create one. They then design experiments or investigations that give them qualitative or quantitative data that can be analyzed. The data can help provide support for answers to the questions that the students started with. This method allows students to explore topics they are curious about with evidence that they will also find meaningful (Llewellyn, 2013).

Inquiry has been identified with increased motivation in low-achieving students, in a study in Taiwan. In this semester-long study, middle school students of two achievement levels (low achieving and non-low achieving students) were exposed to two different instructional styles. The experimental group was taught with inquiry-based instruction, while the control group received traditional instruction. The inquiry group was primarily exposed to guided inquiry type lessons, where they were given questions and materials and left to figure out the solution on their own. The researchers found through interviews that students in the inquiry group had a higher rate of motivation and curiosity in learning science. This is especially important for the low achieving students, as lack of interest is seen as a potential roadblock to engaging in academic content. Non-low achieving students also experienced learning gains in the experimental group. Researchers pointed out that these improvements are not statistically significant when

compared to the control group, although a longer study could show measurable gains (Kuo et al., 2019).

Place-Based Learning

Place-based learning provides students with the opportunity to connect specific concepts with local environments. Frequently, students experience a disconnect between what they are expected to learn and how those topics actually affect their lives. This disengagement is fairly new. Before the formation of the public school as an institution, all learning was local and immediately relevant to the student because children were educated in small local schools. However, as schools became more standardized, learning became more focused on traditional lecture and reading from textbooks. The overall learning experience has become more generalized. In response to this, some teachers are building lessons about the specific places that both they and their students live in. Children are naturally curious about their personal lives and by emphasizing local areas, teachers bring this interest out in their students. In order to accomplish this task, teachers must create the specific curricula that correlate the standards they are required to teach with the aspects of the phenomena they wish to cover. This process is vital in meeting educational goals by both the teacher and the state or district (Smith, 2002).

When teachers and students engage in place-based learning, they are interacting with both the social and ecological aspects of the place they in. This allows both teacher and student to work together in analyzing local issues and potential solutions and often includes aspects of civic process and project development. Furthermore, place-based learning should rarely focus on controversial topics and should instead enrich the

students' learning process (Smith, 2007). Students in the Tampa Bay area in Florida, for example, use experimental data to extrapolate trends in sea-level rise. Students then compare their calculated predictions to those made by the Intergovernmental Panel on Climate Change (IPCC). This particular activity gives students direct understanding of the effects of global warming on their area. Most of Florida's coastline is less than three meters above sea level (Nation et al., 2015).

Active Learning

Traditional lecture-based education relies on students learning for the sake of assessment, foregoing deeper understanding of the concepts being studied. This does not align with the nature of the scientific process, which relies on active involvement. Traditional education also can cause disconnection and loss of interest in the content being studied. Active learning, however, allows students to have ownership in their education through both individual and social means. Students independently synthesize information and then share that information with their peers. This group work empowers students with the ability to put their thoughts into words which is then evaluated for understanding by their peers (Ueckert & Gess-Newsome, 2008).

In a massive analysis of undergraduate level STEM classes, Freeman et al. (2014) determined that the benefits of active learning were clear. Taking data from universities across the country and Canada, researchers compared active learning with traditional lecture-based courses. Active learning courses used a wide array of techniques. They looked for both reduction in failures and increases in test scores, and found both of these results. Students in a traditional lecture-based course were more likely to receive a D or F

or withdraw from the course. Test scores for active learning courses went up 6% when compared with similar assessments.

Despite the evidence that active learning can have dramatic learning gains, there is sometimes push back from students (Strain & Pearce, 2001). Some students are accustomed to being told exactly what to study and how to answer assessments. These students may be afraid to get incorrect answers or uncertain on how to get started with assignments. One way to overcome this hurdle is to provide support for students as they learn to take agency over their own learning.

Student-Led Instruction

Traditional instruction places the teacher at the front of the classroom, giving students information directly. Student-led instruction, however, allows the teacher to step back while students take control over the learning process. Differentiation between learners can occur as students tailor the material to their own learning styles. This can be especially successful in carefully selected groups called academic teams. Members of these teams are responsible for the learning of the group and engage in rich and challenging content with the support of their peers. At first, teachers take time training the members of the team to have productive, positive academic conversation. As students achieve appropriate dialogue, they can operate as a more effective academic unit. They can begin to tackle concepts and tasks that would be slightly too challenging for one student on their own. They can now bounce ideas and solutions off each other and the overall rigor of the class increases. These teams also build a strong classroom community where students' differences are valued and celebrated. Each student brings unique

viewpoints, enriching the overall team. It is also important that the teacher of these students provides appropriate, challenging work for the teams, while also monitoring and supporting the students (Toth, 2019).

Student-led learning is also effective when used with other teaching styles, although a recent study suggests that pairing it with traditional styles may be most beneficial. Two sections of biology at Ball State University in Indiana were taught differently: one was taught entirely in a student-led approach, while the other section was taught as a traditional lecture-based course. Although the performance of the two sections was nearly identical, there was significant pushback and negative perception of the student-led section. The authors suggest that a hybrid of both teaching styles would be more effective. They suggested three reasons why pure student-led instruction may not be the best single source of educational information. First, the amount of preparation that goes into each class causes a great deal of stress for the instructor. Second, because this type of education is not widely known or used, students had a difficult time adjusting to the change in learning styles. Finally, the loss of lecture meant the loss of sharing the professor's curiosity and joy in the subject, which is vitally important to share with the students. The authors reiterated that student-led learning itself was still an effective learning strategy (Bernot & Metzler, 2014).

METHODOLOGY

Demographics

In this study, three physics classes with 11th and 12th grade students learned about hurricanes, which are becoming a greater threat locally due to climate change. Instruction was accomplished through place-based learning and student-led learning. One class was taught in the fall block semester and two classes were taught in the spring block semester. Data was collected through quantitative and qualitative means. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

All students received the same treatment and were compared based on their chosen method of instruction: in-class or online. In our local school district, students were given the option of attending class in person or online due to Covid-19. The two groups were compared to determine if instruction was equally effective. In the fall block semester, 60% of students attended class in-person during the period of treatment while 40% attended via Google Meet (N=15). In the spring block semester, 33% of students attended class in-person during the period of treatment while 67% attended via Google Meet (N=15).

Treatment

In the first lesson, students completed the Hurricane Webquest, which was written for this project (Appendix B). The Webquest asked students to sketch a model of a

hurricane based on their current knowledge. Then, students watched a YouTube video produced by National Geographic entitled “Hurricanes 101,” that explained the structure and dangers of hurricanes. In this section of the Webquest, students drew the correct model of a hurricane, explained the most dangerous feature of hurricanes and described the role of hurricanes in the global climate. In the third part of the Webquest, students described the track and timeline of Hurricane Irma using an official NOAA synopsis as well as a humanitarian website. This hurricane was chosen because of its direct impact in the Cocoa Beach, Florida area in 2017. In the fourth part of the Webquest, students read the Geophysical Fluid Dynamics Laboratory page, which has a section entitled “Global Warming and Atlantic Hurricanes.” Students were directed to specific sections of the website where they looked at overall trends of hurricanes and their relationship to sea surface temperatures. They also read the official likelihood statements that are used by the IPCC (Intergovernmental Panel on Climate Change). To conclude the Webquest, students drew a final diagram or model of a hurricane including how the environment impacts its development. Students were expected to include rainbands, eye and eyewall as well as their understanding of the environment’s impact on the development of the hurricane.

In the second hurricane lesson, a modified 5E Lesson was used to explain how the rapid intensification of Hurricane Michael was caused by warm ocean waters. In the 5E lesson, students are exposed to a phenomenon in the Engage state of the lesson. This exposure encourages students to ask questions and wonder what is causing the phenomenon. In this particular instance, students watched a video of Hurricane Michael

on a loop. Students could see how Michael quickly went from a tropical storm to a strong hurricane. During the video, students are informed that Michael hit the Florida Panhandle as a Category 5 storm. In the second phase of the 5E lesson, Explore, students are given the opportunity to explore the phenomenon, allowing students to informally experiment with different concepts related to the phenomenon. For this section of the 5E, students worked with two PhET lab simulations, The Greenhouse Effect and Energy Forms & Changes, where students were asked to test out different scenarios to experimentally determine how solar energy could be converted to other forms of energy, including thermal energy (Appendix C). In the third section of a 5E lesson, Explain, students begin learning the vocabulary and concepts that explain the phenomenon. In this case, a PowerPoint of a traditional thermodynamics lesson was used to provide the background for thermodynamics.

In the last two sections of a 5E lesson plan, Elaborate and Evaluate, students are given a chance to go into further detail and demonstrate their overall comprehension. For this lesson, students were asked to complete a Thermodynamics Mini-Project to explain the different ways heat transfers, as well as how this heat transfer could affect the formation of hurricanes like Michael (Appendix D).

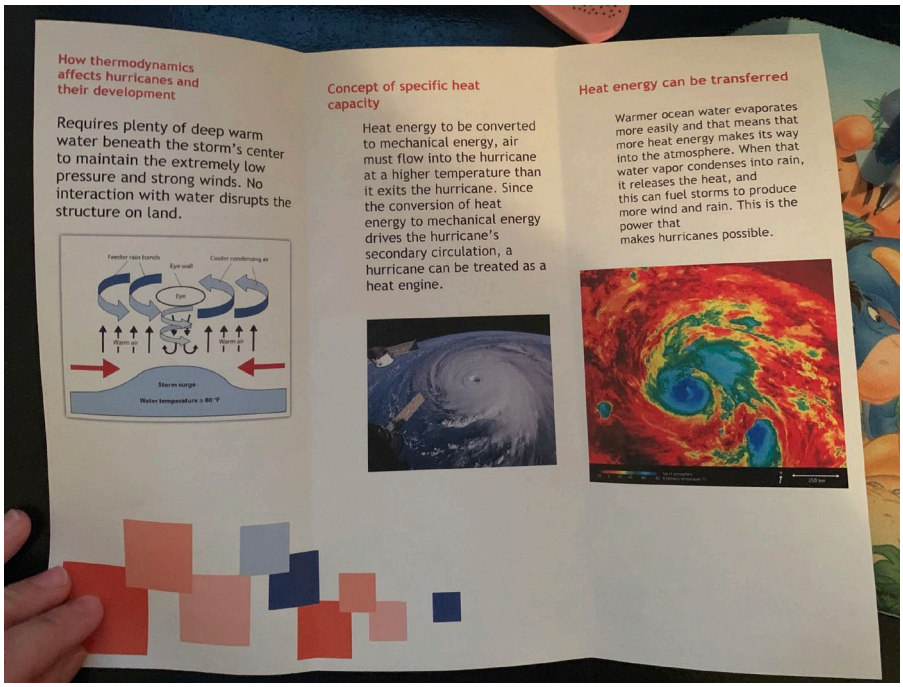


Figure 1. Online student's thermodynamics mini-project.

In the final hurricane lesson, students researched the hurricane building codes for two properties of their choice in the Hurricane Building Codes Project (Appendix E). Students were asked to choose two buildings and analyze their hurricane preparedness using the Florida Building Codes as a guide. Students were also asked to plan for a potential Category 3 hurricane coming to their buildings. They had to decide if they would evacuate the building or not, rationalizing their choice. They also had to plan for the aftermath of the hurricane. A few days after the project was assigned, an article from a local newspaper was given out detailing the fact that the last time Cocoa Beach experienced hurricane force winds was in 1979 with Hurricane David.



Figure 2. Online student's work on the Hurricane Building Codes Project.

Throughout the hurricane lessons, Hurricane Bellwork was also used to supplement the other lessons (Appendix F). This led students to discuss the Coriolis Effect. When students found this to be a confusing concept, an Edpuzzle video lesson with prediction-type questions was assigned.

Data Collection and Analysis Strategies

Before and after treatment, various instruments were used to answer the focus questions. Students took the Hurricane Knowledge Test and the Hurricane Likert Survey. Some students volunteered to be interviewed individually after all hurricane lessons were completed. A teacher reflection journal was maintained before, during and after the research.

The Hurricane Knowledge Test was given to all students as a pre-test and a post-test (Appendix G). Scores were converted into percentages and analyzed using normalized gains. To calculate normalized gains, the percent difference scored between the post-test and the pre-test is divided by the percent difference scored of the pre-test. Gains of less than 0.3 percent were considered low, 0.3-0.7 percent considered medium and above 0.7 percent considered high (Hake, 1998). Percentage scores were also sorted into the following categories: 90-100% highly proficient, 70-89% proficient, 60-69% nearing proficient and 0-59% not proficient. The overall scores were also analyzed by quartiles and a box-and-whiskers plot was used to visualize the results.

Students also took the Hurricane Likert Survey before and after the hurricane lessons (Appendix H). The survey asked the students what they thought about the likelihood of different intensities of tropical storms hitting the Cocoa Beach area. Students were also asked about their thoughts regarding climate change. Finally students were asked about their own evacuation plans and what they thought was the biggest issue for beachside residents in regard to hurricanes. The Likert-type results of this survey were converted into percentages, as well as shown in a stacked bar chart. The free response portions of the survey were used to enrich the overall importance of the data.

Once the hurricanes lessons were concluded, several students in each class volunteered to be interviewed about two main topics: the hurricane lessons themselves and students' thoughts on climate change and how it affects hurricanes (Appendix I). Responses were grouped based on general tone and topic and used to supplement the quantitative data. In the fall semester, students in class were verbally asked if they would

like to volunteer. Students online were asked to volunteer by email. Due to low participation in the fall semester, the interview questions were added to the Google Classroom as an optional assignment for all students for the spring semester classes.

Finally, a teacher reflection journal was maintained throughout the project to keep track of the development of the project and immediate student feedback. Qualitative observations from the reflection journal were used to supplement the quantitative data. (Table 1).

Table 1. Data Triangulation Matrix.

Research Questions	Data Source 1	Data Source 2	Data Source 3
How does place-placed and student-led learning affect student understanding of climate change in the context of hurricanes?	Hurricane Knowledge Test	Hurricane Likert Survey	Teacher Reflection Journal
How do students perceive the relationship between hurricanes and climate change?	Hurricane Knowledge Test	Hurricane Likert Survey	Final Interviews
How does hurricane instruction impact student attitudes about hurricanes?	Hurricane Knowledge Test	Hurricane Likert Survey	Final Interviews

DATA ANALYSIS

Climate Change Attitudes

The results of the Hurricane Likert Survey indicated that, before the hurricane lessons, 46% responded that they strongly agreed, 38% responded that they agreed and 15% had a neutral opinion (*N*=26). After the hurricane lessons, 50% of students strongly agreed, 44% agreed and 6% were neutral (*n*=16). Students mentioned several global events that are commonly attributed to global warming. One student said climate change "triggered an increase in extreme weather events such as floods and droughts" and another said, "it is seen in the arctic with the melting of icebergs." Students also cited temperature data saying, "there is evidence of the globe warming" and "temperatures are always going up and beating records." Other students also offered possible causes of temperature rise, stating, "I think it is because of all the gases … and its pollution" and "the greenhouse effect won't stop anytime soon."

Students were then asked if they thought climate change was causing stronger hurricanes. Before the hurricane lessons, 31% of students strongly agreed, 42% of students agreed and 26% of students had a neutral opinion (*N*=26). After the hurricane lessons, 50% of students strongly agreed, 38% agreed and 13% were neutral (*n*=16). In interviews one student stated, "I didn't think about how climate change could make the ocean warmer but it makes sense of how that can affect the hurricanes." Other students said that they generally had previously understood the relationship between climate change and hurricanes but they have "gotten more evidence" (Figure 3).

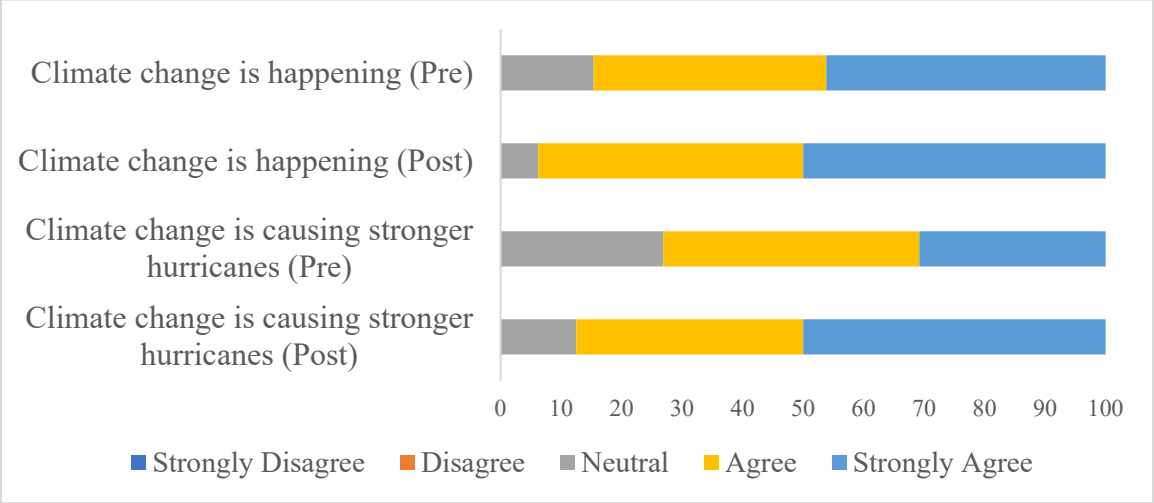


Figure 3. Likert survey results regarding climate change, (Pre *n*=26, Post *n*=16).

Hurricane Attitudes

In the Hurricane Likert Survey, students were asked if they felt like they could be prepared for hurricanes. Before the hurricane lessons, 38% of students strongly agreed, 38% of students agreed, 19% of students were neutral and 6% of students disagreed (*N*=26). After the hurricane lessons, 31% of students strongly agreed, 63% agreed and 6% were neutral (*n*=16).

In an open-ended question, students were asked if they evacuated or not for hurricanes. Before the hurricane lessons, students who evacuated often cited flooding as their reason for leaving: “I live right next to the beach and we are always afraid it may possibly flood” and “we tend to evacuate if the storm surge is supposed to be too much because I live close to the beach.” Another factor in whether students stayed or evacuated was the predicted intensity of the hurricane, with a student saying, “I would evacuate for a Category 3-5 but would stay for the rest.” Some students expressed their confidence in

their safety in staying home, saying, “I know I can survive a few days without electricity and I know my house can survive.”

After the hurricane lessons, students generally maintained the same viewpoints, but expanded on their reasoning, often mentioning specific features of their homes. One student who was planning to ride out the storm said, “I have a very strong house with hurricane proof windows, doors and sliding glass doors. Also we have a built-in generator and lastly we have shutters.” Another student wrote, “My parents don’t deem it necessary based off our home’s build” (Figure 4).

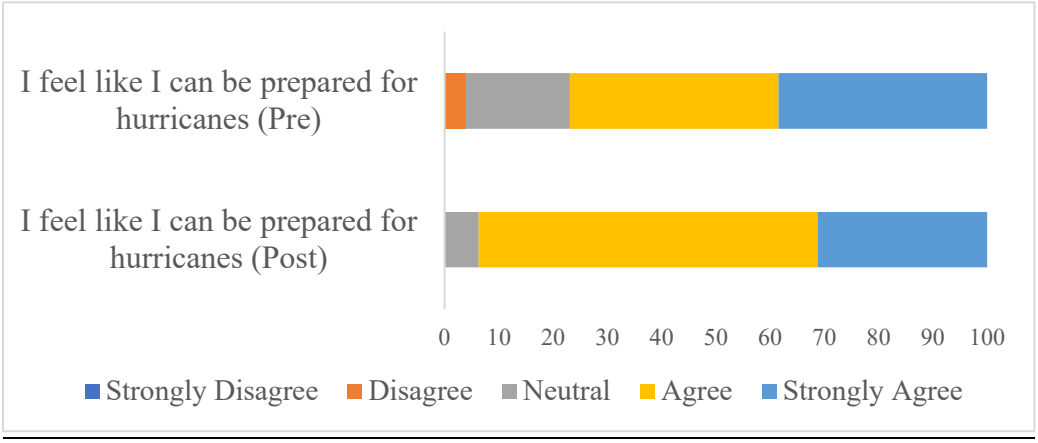


Figure 4. Likert survey results on student attitudes on hurricane preparedness, (Pre *n*=26, Post *n*=16).

Hurricane Knowledge

Students were given Hurricane Knowledge Test both before and after the implementation of the hurricane lessons. For the pre-test, scores ranged from 22 to 61 percent, with a median score of 33 percent. For the post-test, scores ranged from 22 to 72 percent. The median for the post-test was 44 percent. The results from the pre-test (M =

34.68, SD = 10.1) and post-test (M = 45.26, SD = 14.9) indicate that there was a statistical difference between the two sets of scores, t(18) = -2.56, p = .015. When normalized gains were calculated for the two sets of scores, 26% of students had a medium gain and 74% of students had a low gain, including 7 students who had a score change of zero (Figure 5).

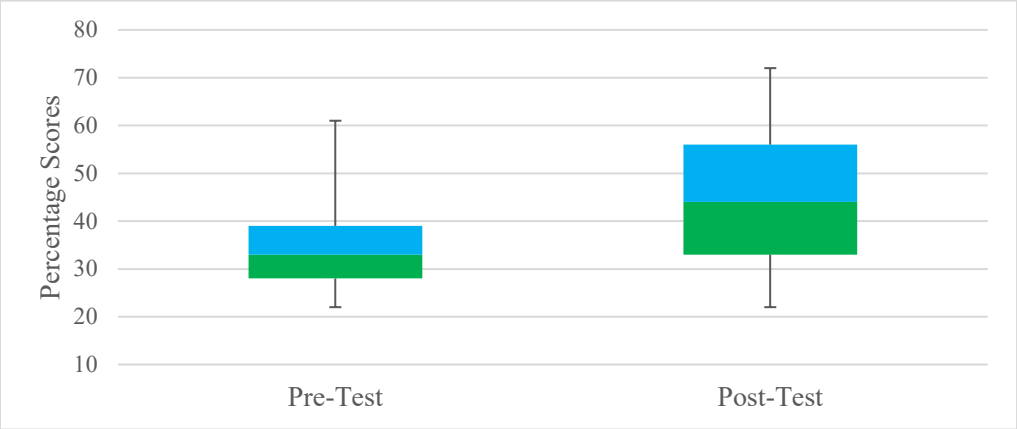


Figure 5. Hurricane Knowledge Test scores before and after treatment, (*n*=19).

As part of the hurricane knowledge test, students were asked to draw and label a hurricane. In the pre-test, most students drew some kind of spiral shape with an eye. Once students completed the hurricane lessons, students added details such as the eyewall and rainbands.

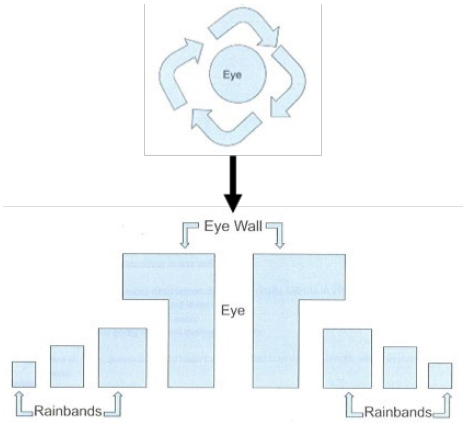


Figure 6. Pre- (on top) and post-test (on bottom) diagrams of hurricanes from an online student.

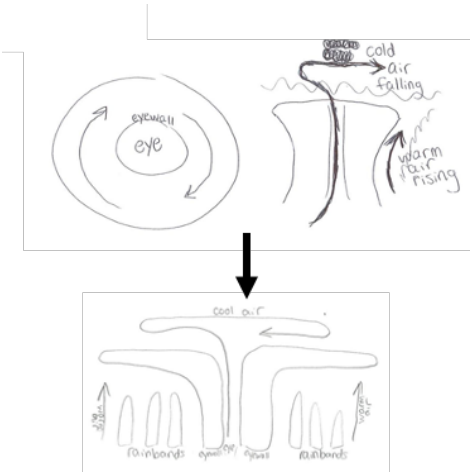


Figure 7. Pre- (on top) and post-test (on bottom) diagrams of hurricanes from an in-person student.

In the Hurricane Likert Survey that the students completed before and after the hurricane lessons, students were asked how well they understood the structure of a hurricane. Before the hurricane lessons, 12% of students strongly agreed that they understood the structure, 35% of students agreed, 46% of students were neutral and 8%

of students disagreed. Following the hurricane lessons, 38% of students strongly agreed, 56% agreed and 6% were neutral (Figure 8).

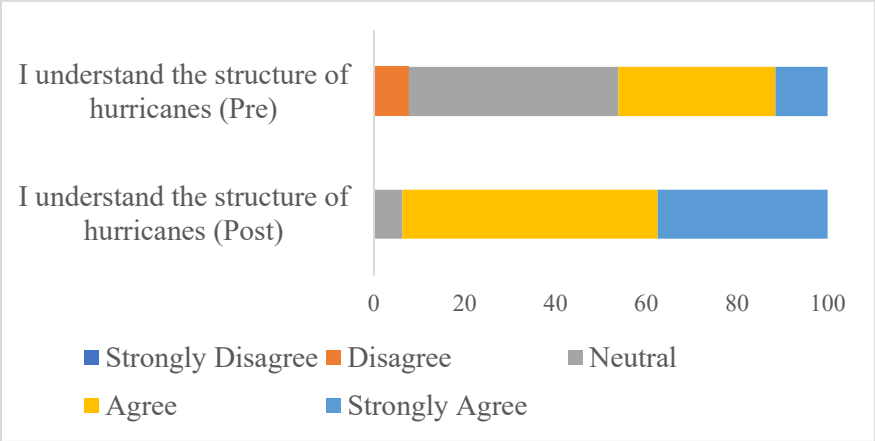


Figure 8. Likert survey results of student familiarity with hurricane structure, (Pre *n*=26, Post *n*=16).

Online vs. In-Person Learners

Throughout the hurricane lessons, 16 students attended class online via Google Meet and 14 attended class in-person. The most notable difference between the two groups was the level of in-class participation. In one particular case in the first semester physics class, the entire in-person class (including myself) got confused about the direction hurricanes turn and we puzzled it out at as a group. In my reflection log I wrote, "ALL of these discussions took place in the classroom. Students online did not participate in the classroom discussion. I'm not even sure if they heard it." This theme repeated during our Thermodynamics PhET Lab: "Noticed that the kids online don't mention snow being reflective, even though I said it aloud in class. How much are the online kids

paying attention to what I say…?" In final interviews, an in-class student cited the in-class discussions as the activity that had the highest impact on him.

Many students, regardless of learning situation, found the assignments themselves to be the most helpful activity. Three of the seven students who agreed to be interviewed listed the Hurricane Building Codes Project as the most helpful. One student, an eLearner, said, "I had no idea about hurricane building codes before that assignment and it was interesting how building codes varied."

Overall, the rate of turned-in assignments was similar between the two groups despite the lack of class participation. Of students that completed both the pre- and post-tests, 42% were online learners and 58% were in-person learners, which is fairly close to the split between the two groups (n=19). The biggest project students did, the Hurricane Building Codes Project, had slightly more online learners turn in the project at 88% than in-person students at 71%.

CLAIM, EVIDENCE, AND REASONING

Claims From the Study

When students were asked if they thought climate change was happening, most students responded that they did. Before the hurricane lessons, 84% of students strongly agreed or agreed and after the percentage rose to 94%. Overall, students appear to agree that climate change is happening and cited many global examples of climate change including flooding, droughts, melting icebergs and record-breaking temperatures. As the evidence mounts, most students surveyed concluded that the climate is changing (15 out of 16).

In the Hurricane Webquest, students read an article that showed the link between warming sea surface temperatures and the increasing intensity of hurricanes. They also looked at the transfer of heat energy from the atmosphere to the oceans. Before these lessons, 73% of students strongly agreed or agreed that climate change was causing stronger hurricanes. After the lessons, 88% of students strong agreed or agreed. Due to the smaller sample size for the post-test, there may not be enough data to conclude that there was a sizeable gain in understanding, although the percentage of students who were neutral fell. However, this reduced percentage could be because of a lack of participation.

The Hurricane Knowledge Test scores resulted in very modest gains, with the average going from 33% up to only 44%. Several different gaps in knowledge resulted in a low overall gain. Surprisingly, a high number of students were still under the impression that Brevard county had experienced hurricane force winds recently, despite the article that was given out during the Hurricane Building Codes project. This article

was not required reading, but was supplied as a possible source of information. Either students didn't read the article or didn't internalize it. Second, when drawing their hurricane diagrams, students did incorporate more details into their hurricane drawings, adding rainbands, but neglected others like the direction of windspeed and where the weakest and strongest winds were located. The diagram that students copied from the National Geographic video "Hurricanes 101," did not have these three features. Finally, students were still convinced that hurricanes crossed the equator and spun because of warm air rising, despite the Coriolis Effect preventing hurricanes from crossing the equator and giving hurricanes their spin. These deficiencies in increased knowledge resulted in the low gains for the Hurricane Knowledge Test.

Students who completed the Hurricane Buildings Code assignment appeared to gain more confidence in their families' evacuation plans, as well as overall understanding of how building construction is affected by Florida hurricane building codes. Many students talked with their parents and neighbors to better understand how hurricane windows, doors and roofs were able to protect them from hurricanes. Students often chose their own homes as their first building. Other buildings they decided to analyze included the school, a neighbor's house, a hospital, a clothing store and a church. This activity allowed students to see how physics intersects with their personal lives and community.

In-person and online learners had significant difference in their level of class participation. Online learners have rarely asked questions in class or commented on any assignments this year, including those in the hurricane lessons. During the first semester,

where two-thirds of the class attended in person, students would ask questions and get feedback from peers and the instructor. Online students would not participate in these discussions despite encouragement. In the second semester, class discussion greatly tapered off as one-third of the students attended class in person, with three attending in third block and two attending in fourth block. However, even as classroom participation dwindled, students in both groups turned in assignments and participated in completing the optional treatment activities.

Value of the Study and Consideration for Future Research

Students were able to connect physics concepts like thermodynamics and forces to events happening in their world. Although students were already aware of the reality of climate change, they had not always connected global warming to intensifying hurricanes. Here in Cocoa Beach, we have seen the new reality of terrifyingly strong hurricanes as we have experienced effects of Hurricanes Matthew, Irma and Dorian, the last two of which were Category 5 hurricanes at some point in their development. The hurricane lessons allowed students to connect climate change to these stronger storms.

The Hurricane Knowledge Test had modest gains, possibly because the lessons focused far less on the hurricanes themselves than on their development and impact on communities. Although the average of the post-test was still less than 50%, there was still a significant increase in test scores.

Sometimes it was hard to determine exactly how opinions changed before and after the lessons. When the post-survey was given out, only 62% of the original number

of participants did the survey again. It was difficult to come to any conclusion on the results with confidence.

Impact of Action Research on the Author

During the course of working on this project, I used a local phenomenon and built a unit around it. This is the first time that I've done something like this and I think it was not only more interesting for the students but enriched the content so it became more meaningful for them. I plan on doing this with more units, as we also have NASA and Kennedy Space Center nearby, as well as the Indian River Lagoon.

I also realized that a fact that I find fascinating doesn't always resonate with my students in the same way. When I read the article about our county not experiencing hurricane force winds in forty years, I was astounded! I have been in so many hurricanes, so I feel like I know what's coming. After reading the article, I started to realize that maybe I *don't* know what's coming. I really thought my students would be similarly surprised. Because I didn't require my students read the article, I'm not sure how many students read it. I did get a few comments from students about it in their Hurricane Building Codes Project.

A sizeable challenge this year was completing my capstone research during a pandemic. With so many of my students distance learning as well as the constant threat of infection and quarantine for my in-person students, it was essentially impossible to do group activities and hands-on labs. This school year was only my second year teaching physics and I was looking forward to letting my students explore concepts together while

developing their own labs and experiments. Covid absolutely affected what I could actually do with my students and inevitably limited my research.

Teaching in the time of Covid has been challenging, terrifying and exhausting. There were days when I didn't know how I was going to get my capstone done. It felt like I didn't see my fellow teachers for weeks as no one wanted to hang out in the teacher's lounge, and I sorely missed their input and support. The past 18 months has given me an appreciation for both my students and colleagues. I'm hopeful that in the coming school year I can complete more action research projects more in line with my original vision.

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APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD WAIVER

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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MEMORANDUM

TO: Elexa Rendla and John Graves

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

DATE: November 12, 2020

RE: *"Place-Based and Student-Led Climate Change Instruction in the Science Classroom" [ER111220-EX]*

The above research, described in your submission of November 12, 2020, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

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

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

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

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

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

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

APPENDIX B

HURRICANE WEBQUEST

Hurricanes and Climate Change

In this activity, we are going to explore the structure of hurricanes and how climate change can influence its impact.

Part 1: Hurricane Modeling

In the space below, make or draw a model of a hurricane using your current level of knowledge. Label and explain as much as you can on how the hurricane functions as a weather system and how its environment impacts its development.

Part 2: Watch Hurricanes 101 | National Geographic

Go to https://www.youtube.com/watch?v=LlXVikDkyTg or Google "National Geographic Hurricanes 101" and answer the following questions.

1. Sketch the anatomy of a hurricane.

2. What is the most dangerous part of a hurricane? How is this feature more dangerous than others?

3. What is the role of hurricanes in the global climate?

Part 3: Hurricane Irma Tracking

Go to https://www.weather.gov/tae/Irma_technical_summary (NOAA's Detailed Meterological Summary on Hurricane Irma) and fill out the timeline, paying special attention to the development of Irma, as well as surrounding weather conditions. Then go to https://www.worldvision.org/disaster-relief-news-stories/2017-hurricane-irma-facts (a humanitarian organization's breakdown of the storm's impact on different areas. Add any affected areas and additional facts to your timeline.

STAGE OF DEVELOPMENT	DATA
1. EARLY START | AUGUST 22, 2017	• Low pressure tropical wave • Disorganized thunderstorms • Near west African coast
2. IRMA'S RAPID INTENSIFICATION| AUGUST 30-31, 2017	
3. IRMA GROWS STRONGER | SEPTEMEBER 4-5, 2017	
4. IRMA BLOWS THROUGH CARIBBEAN | SEPTEMBER 6-8, 2017	

5. IRMA STARTS TO TURN NORTH | SEPTEMBER 9, 2017	
6. IRMA APPROACHES FLORIDA| SEPTEMBER 10, 2017	
7. IRMA HEADS INTO GEORGIA | SEPTEMBER 11, 2017	
8. THE STORM WINDS DOWN | SEPTEMBER 12-13, 2017	

1. Based on the data that you've collected, what do you think were the most important factors for the development of Hurricane Irma?

Part 4 – GFDL: Global Warming and Hurricanes

Go to the Geophysical Fluid Dynamics Laboratory page on global warming and hurricanes: https://www.gfdl.noaa.gov/global-warming-and-hurricanes/ Answer the following questions:

1. Rewrite the questions asked in the Summary Statement in your own words.

2. Explain what the likelihood statements mean.

3. Scroll to "Global Warming and Atlantic Hurricanes." In part B, which trend does the article say is not significantly distinguishable from zero? Why?

4. Scroll to part D and read the first 3 paragraphs. How will sea surface temperatures change during the 21st century when analyzed using current climate models?

5. How is hurricane number and intensity expected to change during the 21st century?

Part 5 – Hurricane Model: Final Version

On another sheet of paper, draw a diagram or model of a hurricane. Label and explain as much as you can on how the hurricane functions as a weather system and how its environment impacts its development.

APPENDIX C

HURRICANE THERMODYANMICS PhET LAB

Thermodynamics PhET Labs

Name

Keeping in mind the Hurricane Michael video, experiment with two PhET labs – The Greenhouse Effect and Energy Forms & Changes.

The Greenhouse Effect

https://phet.colorado.edu/en/simulation/legacy/greenhouse

1. Explore the controls in the Greenhouse Effect tab.
2. Describe in detail the different time periods. Include as much information as possible.

3. Go to the Photon Absorption tab and experiment with the controls, including the part labeled "Build Atmosphere."
4. How does this tab relate back to the Greenhouse Effect tab?

Energy Forms & Changes

https://phet.colorado.edu/en/simulation/energy-forms-and-changes

1. Click on the Systems tab and explore the lab controls.

APPENDIX D

HURRICANE THERMODYANMICS MINI-PROJECT

Hurricane Thermodynamics Mini-Project

In this assignment, you will describe thermodynamics and how it affects hurricanes and their development. Make sure you include the concept of specific heat capacity, as well as different ways heat energy can be transferred.

You can choose any product you choose. Suggestions are Google Slides, PowerPoint, a short story, a comic, a song, an essay, a poster, etc.

CATEGORY	4	3	2	1
Content Knowledge	The facts regarding thermodynamics are clearly present and well-explained.	The facts regarding thermodynamics are present and explained.	The facts regarding thermodynamics are present and poorly explained.	The facts regarding thermodynamics are not present.
Required Elements	The project includes all required elements as well as additional information.	The project includes all required elements,	The project includes all but one of the required elements	Several required elements were missing.
Accuracy	95% or more of the assigned information is accurate.	94-75% of the assigned information is accurate.	74-50% of the assigned information is accurate.	Less than 50% of the information is accurate.
Creativity	The project is exceptionally creative in terms of design, layout, and neatness.	The project is creative in terms of design, layout, and neatness.	The project is acceptably creative in terms of design, layout and neatness.	The project is distractingly messy or very poorly designed. The project is not creative.

APPENDIX E

HURRICANE BUILDING CODES PROJECT

Hurricane Building Codes

Florida has the most hurricanes of any other state. After Hurricane Andrew in 1992 and the 2004 hurricanes, building codes in Florida were strengthened to prevent destruction of property. These building codes have varying affects on buildings based on their distance from the coast.

Create an informative product that describes the hurricane building codes for two different buildings, as well as potential risks. Suggestions are the school, your home or buildings in the community. This should be a high-quality, thoughtfully designed product that will serve as an example to other local citizens. The format is up to you: Google Slides, podcast, poster, etc.

What to include:

a) A detailed, written explanation of the Florida building codes as they apply to hurricanes. Consider where your two buildings are located and how the building code applies in those locations. Include an analysis on what makes a building able to withstand the relevant the listed wind speeds.
b) Information on how your specific buildings meet the Florida building codes with hurricane-resistant features. What are your buildings made from? Do they have special windows or doors? How does the roof meet the building codes?
c) Include a scenario where a category 3 hurricane is approaching your buildings. What kinds of preparations are required for your buildings? Should occupants evacuate? Consider the aftermath of the storm as well. Should your building have a generator, solar panels, etc.? Also consider the water supply.

Rubric:

Part A

Correct Florida hurricane building codes are chosen for each buildings' location	0 1 2
Analysis of a minimum of 3 building features that help withstand hurricanes	0 1 2 3

Part B

Analysis of Building 1 of how it meets Florida hurricane building codes	0 1 2 3 4
Analysis of Building 2 of how it meets Florida hurricane building codes	0 1 2 3 4

Part C

Appropriate preparations are detailed	0 1 2 3 4
Evacuation plans are clear OR rationale for not evacuating	0 1 2 3
Aftermath for hurricane is thoughtfully laid out	0 1 2 3 4

Overall

All writing is legible	0 1 2
Creativity is evident	0 1 2 3
Organization is clear	0 1 2 3
APA citations are correctly completely for all sources	0 1 2 3

/35

APPENDIX F

HURRICANE BELLWORK

BELLWORK

1. What direction do hurricanes in the Northern Hemisphere spin? What about the Southern Hemisphere?
2. What do you know about the Coriolis effect?
3. How would this phenomenon influence hurricane structure?

BELLWORK

1. What was the significance of the yellow and red dots in The Greenhouse Effect PhET lab?
2. What kinds of things were different in each of the 3 time periods?
3. If you could pick any object for the Energy Forms and Change simulation for hurricanes, what would you pick?

BELLWORK

1. A 5.10 kg cast-iron skillet is heated on the stove from 295 K to 373 K. How much thermal energy had to be transferred to the iron?
2. A 100 g metal block at 100°C is placed in 100 g of water at 10.0°C. The final temperature of the mixture is 26.0°C. What is the specific heat of the metal? What is the metal?

APPENDIX G

HURRICANE KNOWLEDGE TEST

Hurricane Knowledge Test

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

1. What caused the most destruction during Hurricane Katrina in 2005?
    a. Floods due to breaking levees
    b. Houses being blown away
    c. People going outdoors during the storm

2. True or false: Brevard county hasn't experienced hurricane-strength winds in over 40 years.

3. How often do hurricanes cross the equator?
    a. Often
    b. Sometimes
    c. Rarely
    d. Never

4. Which of the US states is most likely to be hit by a tropical storm or hurricane?
    a. Florida
    b. Texas
    c. North Carolina
    d. Louisiana

5. Current Florida building codes require all buildings on the Space Coast to sustain
    a. Category 1 winds
    b. Category 2 winds
    c. Category 3 winds
    d. Category 4 winds
    e. Category 5 winds

6. The elevation of Cocoa Beach is
    a. 0 feet above sea level
    b. 5 feet above sea level
    c. 10 feet above sea level
    d. 20 feet above sea level

7. The storm surge of a major hurricane is typically
    a. 5 feet
    b. 10 feet
    c. 15 feet
    d. 20 feet
    e. 25 feet

8. Atlantic hurricanes are primarily powered by
    a. A strong humid effect from El Nino
    b. Warm ocean waters
    c. Lightning storms occurring over water
    d. High pressure systems over the continental US

9. Climate change is linked to
    a. An increase in the number of tropical systems
    b. An increase in the intensity of tropical systems
    c. Neither of these answers
    d. Both of these answers

10. Which month has the highest average number of hurricanes?
    a. July
    b. August
    c. September
    d. October

11. What causes hurricanes to spin?
    a. Warm air rising while cool air sinks
    b. The Gulf Stream rotating the storm as it moves west
    c. The circulation of thunderstorms present in the hurricane
    d. The rotation of the Earth

12. What is the “dirty side” of a hurricane?
    a. The side that first makes landfall
    b. The area that has hurricane force winds
    c. The side where the direction of the hurricane matches the direction of the winds
    d. The area around the eyewall

13. Draw a diagram of a hurricane. Make sure to include the main parts of a hurricane, being at detailed as possible.

APPENDIX H

HURRICANE LIKERT SURVEY

Hurricane/Climate Change Survey

*Note: Survey will be given using Google Forms

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

1. I believe it's likely that Cocoa Beach could be hit by a TROPICAL STORM while I live in the area.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

2. I believe it's likely that Cocoa Beach could be hit by a HURRICANE while I live in the area.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

3. I believe it's likely that Cocoa Beach could be hit by a MAJOR HURRICANE while I live in the area.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

4. I understand the structure of a hurricane.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

5. Climate change is happening.

a. Strongly agree
b. Agree
c. Neutral
d. Disagree
e. Strongly disagree

6. I feel like I can be prepared for hurricanes.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

7. Climate change is causing stronger hurricanes.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

8. Distinguish between “tropical storms,” “hurricanes” and “major hurricanes.”

9. Do you evacuate for hurricanes? Why or why not?

10. What’s the biggest issue regarding hurricanes for beachside residents?

11. Is there anything else you want me to know?

APPENDIX I

FINAL INTERVIEW QUESTIONS

Final Interview Questions

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

1. How has your understanding of hurricanes changed throughout the hurricane lessons?
2. Which activity impacted your knowledge the most?
3. Do you think climate change is happening? Why or why not?
4. Did you have any ideas about the relationship between hurricanes and climate change before the hurricane lessons? Have your ideas changed?
5. Is there anything else you would like me to know?