Hurricane- & Pandemic-Resilient Instructional Engineering Labs Enabled Via Portable Kits

Devangi S. Gaikwad, Sean R. Niemi and Matthew J. Traum
University of Florida/ University of Florida/ Engineer Inc.

Abstract

In 2005, Hurricane Katrina caused the four-month closure of Tulane University and displaced about 100,000 Louisiana students. Despite Tulane's physical shuttering, its distance learning programs persisted. The global pandemic of 2020 and spontaneous switch from in-person to online instruction forced engineering laboratory classes to adopt multi-modal content delivery platforms for experiments. Natural disasters such as hurricanes, which strike the U.S. Gulf and Atlantic coasts annually, similarly necessitate students to evacuate or seek shelter when universities are in a hurricane's path. As Katrina showed, hurricanes can cause university closures of days, weeks, or even months. After campus reopening, damage to the infrastructure might make classes and laboratories inaccessible to students. The multimodal flexibility of instructional kits developed in response to the pandemic can be leveraged to make hands-on lab-based instruction resilient against natural disasters and even future pandemic lockdowns. On July 7, 2021, Hurricane Elsa made landfall on Florida's Gulf Coast prompting University of Florida (UF) to close. Elsa also caused significant flooding in Gainesville, FL which trapped residents (including students) in their homes. That summer semester, Fluid Mechanics teaching lab kits engineered for remote instruction, hybrid instruction, and/or in-person instruction were deployed to replace the brick-and-mortar Fluids lab setup. Despite being trapped in their homes due to hurricane induced flooding, students were able to successfully conduct Fluids lab experiments and submit class deliverables on time by using the lab kits by running experiments from home. Anecdotal comments from students who took this Fluids laboratory class demonstrate effective implementation of kits and student enablement to continue without delay toward academic goals despite UF being shuttered by a hurricane.

Keywords

disaster, resiliency, hurricane, instructional, kits

Introduction

In 2005, Hurricane Katrina displaced about 100,000 Louisiana college students and caused the four-month closure of Tulane University. Despite Tulane's physical shuttering, its distance learning programs persisted. Along similar lines, the COVID-19 pandemic forced a near-instant switch from in-person to online instruction. Institutions teaching engineering laboratory classes had to adopt content delivery platforms to facilitate remote instruciton.[1] Flexible, multimodal distance learning instructional practices that developed in response to the pandemic can be leveraged to make hands-on lab-based instruction resilient against natural disasters and even future pandemic lockdowns. This paper tells of the first time, to our knowledge, that educational kits were deployed in response to a hurricane to keep an engineering lab course running by capitalizing on remote learning best practices pioneered during COVID-19 lockdowns.

On July 7, 2021, Hurricane Elsa made landfall on Florida's Gulf Coast, as shown in Figure 1, prompting University of Florida (UF) to close. Elsa caused significant flooding in Gainesville, FL, Figure 2, which trapped residents, including students, in their homes. That summer semester, Fluid Mechanics teaching lab kits created for remote, hybrid, and/or in-person instruction were deployed as an experimental pilot to replace the brick-and-mortar Fluids lab. Despite being trapped in their homes due to hurricane-induced flooding, students were able to successfully conduct Fluids lab experiments remotely and submit class deliverables on time. Anecdotal comments from students who took the class demonstrate the kits were implemented effectively and students were able to continue on-track toward academic goals despite UF being shuttered.

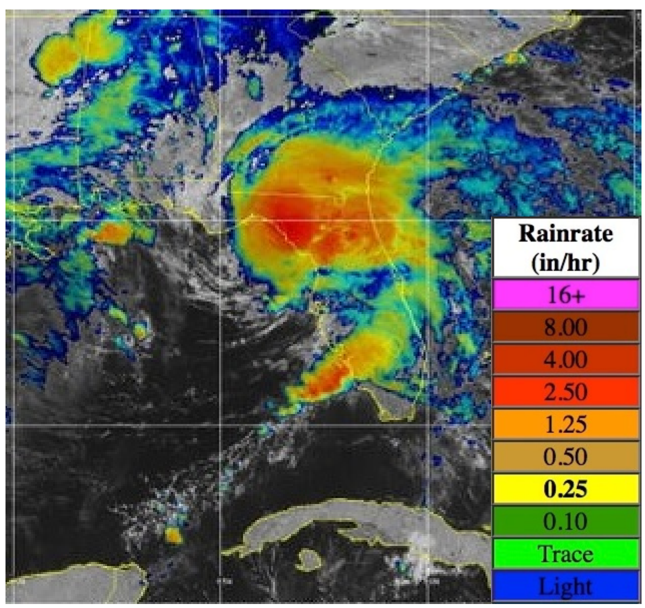

Figure 1. Radar image centered on North Florida as Hurricane Elsa passed over Gainesville.

Prior Work

The only previous instance we found in the peer-reviewed literature of a STEM instructor sending experiments home to remote learners to perpetuate a course against the backdrop of a foreseen disaster is the work of Hoxha and colleagues. Here the Spartan physical resources of the authors' war-time Albanian chemistry classroom necessitated development of lab experiments students could perform with items acquired from their households. The chemistry class itself was not offered remotely online, but the labs had to be completed by students at home to provide hands-on learning given lack of physical classroom resources.[2]

Figure 2. Hurricane Elsa flooded Gainesville, FL streets in summer 2021. The red arrow shows where a Hogtown Creek tributary washed out a road leading to apartments preventing students living there from attending their Fluids lab class.

Methods & Results

The units deployed in UF's summer Fluids course were @HOLM™ Viscid & Inviscid Flows lab kits[3] commercially available from Engineer Inc., a social enterprise based in Gainesville, FL. Each kit comes in a 40-quart tote for portability and can be mailed to students via UPS. Kits are reusable each new semester and contain the following 20 experiments 1) Similitude & Nondimensionalization, 2) Experimental Uncertainty & Pythagoras Cup Siphon, 3) Pressure Transducers & Barometry, 4) Manometry, 5) Mass Conservation, 6) Jet Flow Visualization, 7) Binary Mixture Viscosity Measurement, 8) External Flow Over Spheres & Stokes Flow, 9) Hydrostatic Column, 10) Torricelli's Fountain, 11) Unsteady Bernoulli Drain,[4] 12) Pitot-Static Velocity Probe,[6] 13) Velocity Profile Interrogation,[7] 14) Microfluidics & Contact Angle, 15) Potential Flow Vortex, 16) Major Pipe Losses, 17) Minor Pipe Losses, 18) Pipe Flow Development Length, 19) Pump Curve Measurement, and 20) Fan Curve Measurement.

This paper is underpinned by written anecdotes taken from open-ended surveys (see Appendix) answered by three students enrolled in the Fluids class affected by Hurricane Elsa. Survey responses were gathered via Email and coded based on kit characteristics including 1) portability, 2) modularity, 3) accessibility, 4) use ease, 5) prolonged use, 6) applications, and 7) student attitudes. Under each of these topics, we provide one or more student survey comments linked and coded to that topic.

<u>1. Portability and 2. Modularity:</u> Student A: "The kits are lightweight and compact. Any student with access to a vehicle would be able to transport it with ease in the event of an evacuation."

<u>3. Accessibility:</u> Student B: "Performing the experiment at home was surprisingly simplistic and accessible. The lab kit structure was easily set up and stored in a manner similar to the experimental methods performed in lab."

Student C: "The lab kits were largely accessible during hurricane Elsa. Everything from the instructions to the actual set up was easy using everything from the lab kit and had no difference to my experience with them in lab."

4. Use ease outside class: Parts from the lab kit were employed by students to aid in everyday activities as well as a relief response to flooding caused by the hurricane. This feature is in junction with accessibility and yielded the following responses.

Student A: "Hurricane Elsa brought even more water to our thoroughly saturated back yard. I detached the water hoses from the house, waded into the back yard, and placed the first end of the hose at the deepest point of the back yard. After priming the hose, water flowed quickly and easily uphill and then down the driveway, emptying the backyard in a couple of hours! This process was repeated with a second hose, nearly doubling the initial volume flow rate. I'm not exaggerating by saying that a basic understanding of Fluid Mechanics saved our house. The siphon works without an external power source and works nonstop until the water runs out; something that is difficult to come by with no electricity and on a college student budget.
I am able to explain, in excruciating detail, how fluid flow works in wind instruments to broaden the understanding of my students. I can also make a Bernoulli siphon at any time in order to drain our back yard, which has become a necessity."

Student C: "The experiment which uses a fan along with paper tubes and meshes to diffuse the airflow vortices is used every day for me. I have a computer that utilizes around 8 fans to cool the interior component, however dust buildup was a huge problem since the fans all had vortices that moved dust to the bottom corner of the computer casing. Using a similar design to the hexagonal shaped mesh on the fan intakes improved the dust buildup inside the computer. The hexagonal mesh negates most of the circulation from the fan, allowing for a more steady and straight airflow, leading to a direct path through the computer case."

5. Prolonged use: Student A: "If lab kits similar to those used in Fluids were available, I would absolutely take the courses distanced if coming back to campus were difficult. It would do nothing but improve the learning environment; after taking many distanced courses, this is the only course that could offer a complete grasp of course material. That is due entirely to the development and use of the lab kit."

Student B: "The kits were simple yet contained all the essentials and working with the kit for hours on end would be a breeze."

Student C: "Taking classes online due to the coronavirus pandemic hindered my experience in lab settings that would have been beneficial to my learning. Having a lab kit available to me for various classes would be very convenient, especially since all the materials would be in one place."

6. Application and 7. Student Attitudes: Students were provided context of three approaches for remote lab instruction: (i) take home lab kits, (ii) remote equipment access where students perform experiments via an internet control panel and record data, and (iii) faculty member runs experiments on video and all students get the same data.

Student A: "Absolutely the first method - for many students, there is no replacement for hands-on learning. The process allows not only for ease of conceptualization, but also for further discovery and curiosity. This helped immensely for the development of further labs and further understanding of topics."

Student B: "The in-person lab kit experiment is truly irreplicable. Learning the general physics and kinetics of fluids through take home lab kits is the best option as many students benefit from hands-on experience."

Student C: "The best option is the take home kits. It provides actual experience for the students to gather the data and run the experiment, which you don't get with option 3, and it provides an easier way to run the lab without all the control and communication issues apparent with option 2. The take home kit is a simpler way to run the experiments, with the only risks being someone having faulty equipment, which could be solved by testing the equipment before running labs to ensure they are properly functioning."

Discussion, Conclusions, & Future Work

Despite being trapped in their homes due to Hurricane Elsa flooding, UF engineering students successfully conducted Fluids teaching lab experiments and submitted class deliverables on time by using lab kits engineered for remote instruction, hybrid instruction, and/or in-person instruction. Anecdotal comments from students who took the Fluids laboratory class in summer demonstrate that effective kit implementation enabled students to continue learning and meeting course learning outcomes without delay despite UF being shuttered by a hurricane.

The lab kits are being tested to further reduce cost and develop a more compact configuration. Kit implementation and analysis of student attitudes and response to kit use are being actively incorporated into pedagogical studies at UF to discover best engineering education practices.

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Devangi S. Gaikwad

Devangi Gaikwad is a post-graduate research associate at the University of Florida MERGE Lab and earned her honors baccalaureate degree in Mechanical Engineering. Her research includes experimental and pedagogical analysis of instructional laboratory kits using principles of Fluid mechanics, and testing course resiliency of the kits. She has worked on developing and testing sensors to determine curve-metrology of a Tesla turbine.

Sean R. Niemi

Sean Niemi is an Assistant Instructional Professor and founding PI of the MERGE Lab in the Department of Mechanical & Aerospace Engineering at UF. His teaching and research focus is centered around team-based, hands-on, design and manufacturing courses, primarily capstone and sophomore level design. Sean is active in fostering experiential learning opportunities and integrating modern enterprise productivity solutions in the classroom. Sean received his Ph.D. in Mechanical Engineering from the University of Florida in 2018.

Matthew J. Traum

Dr. Matthew J. Traum is a Senior Lecturer and Associate Instructional Professor of Mechanical & Aerospace Engineering at the University of Florida. He is also founding CEO at Engineer Inc., a Florida-based STEM education social enterprise. Dr. Traum is an experienced educator, administrator, fund raiser, and researcher with co-authorship of over 70 peer-reviewed journal and conference papers. Prior to UF, Dr. Traum was an Associate Professor and Director of Engineering Programs at Philadelphia University. He previously served at MSOE and co-founded the Mechanical & Energy Engineering Department at the University of North Texas – Denton. Traum received Ph.D. and M.S. degrees in mechanical engineering from MIT.

Appendix

The following survey was sent to students' anecdotes from the answers were highlighted in the methods & results section.

- What was your motivation behind taking the fluids laboratory course?
- Please describe your knowledge about fluids before the laboratory experience.
- What were some interesting observations while performing the lab?
- Please describe about your experience about accessibility to lab kits during Elsa.
- If there was an evacuation initiated, would it be feasible for students to take lab kits with them? What is your opinion and suggestion about it?
- Would you be comfortable continuing courses with the lab kits for a prolonged period?
- If the university reopened after a natural disaster, and there was an option to select either in-person and online instruction, would you prefer taking courses remotely? For this question, please take into consideration that evacuation measures might be in effect or infrastructural damage might be a hinderance for some students.
- There are three approaches for remote lab instruction: (i) take home lab kits, (ii) remote equipment access where students perform experiments via an internet control panel and record data, and (iii) faculty member runs experiments on video and all students get the

same data. Having the 'take-home lab kit experience', what in your opinion is the best option and why? Do you have any suggestions for other methods?
- Were you able to implement experiments from the lab kit in everyday life? Please explain in detail.