A Low Cost Approach for Rapidly Creating Demonstration Models for Hands-on Learning

Kristoph-Dietrich Kinzli, Tanya Kunberger and Robert O'Neill
Florida Gulf Coast University

Abstract

Demonstration models allow students to readily grasp theory and relate difficult concepts and equations to real life. One major drawback of using demonstration models is that they are costly to purchase from vendors and that they take a significant amount of time to build. These two limiting factors pose a significant obstacle for adding demonstrations to the curriculum. This article presents an assignment to overcome these obstacles. To date the assignment has resulted in 24 demonstration models being added to the curriculum. The article also presents the results of student performance on course objectives as a result of the 24 demonstration models created being used in the classroom. Overall, significant improvement in student learning outcomes, due to the addition of demonstration models, has been observed.

Keywords

Demonstration models, hands-on learning, visualizing theory, student learning outcomes

Introduction

Numerous engineering courses lend themselves to teaching methods that utilize demonstration models. Demonstration models allow students to readily grasp theory and relate difficult concepts and equations to real life. One of the cornerstones of the highly successful ASCE ExCEED teaching model is the use of physical demonstrations. One major drawback of using demonstration models is that they are costly to purchase from vendors and that they take a significant amount of time to build. Faculty members are generally pressed for time and departments have limited funding for purchasing manufactured demonstrations. These two limiting factors pose a significant obstacle for adding demonstrations to the curriculum. This article presents an assignment to overcome these obstacles. Over the last 3 academic years a "Demo Design Challenge" has been issued to students in a senior level class at Florida Gulf Coast University to address the two major limitations for adding demonstrations to the curriculum. This article presents the "Demo Design Challenge" assignment in detail and discusses the effectiveness of creating models using this assignment.

Background and Justification

The use of physical models has shown to be beneficial in undergraduate education[1-,3] It addresses both the visual and kinesthetic learners in the classroom[4 – 7] however it must be mentioned that learning styles theory has recently come under question[8]. Several articles [9 - 13] have documented activities and benefits of models in the classroom. The American Society of Civil Engineering Excellence in Civil Engineering Education (ExCEEd) Teaching Workshop emphasizes the use of physical models demonstrating effective implementation and encouraging participants to develop and employ models both in their “practice classes” during the workshop and later in classes back at their home institutions [14 - 17]. What is less prevalent in the literature however is how these models can be effectively and efficiently developed. Some textbook publishers provide videos and several companies produce equipment that can be purchased if it falls within a department’s budget; but often it is left to the instructor to locate or develop meaningful course models. This paper presents an alternative to faculty developed models with the creation of an assignment in an upper level course for the fabrication of a model and related instructional presentation.

In addition to the benefits these models confer on students in the class in which they are utilized, the creation of both the model and the associated theory strengthens topic comprehension for the upper level students by supporting a constructivist learning theory[18,19]. The creation of models is considered the highest level of learning in the revised Bloom’s Taxonomy[20] and Meneske emphasizes that the group creation of knowledge is one of the highest levels of active learning[21]. These seniors have seen models throughout the three course sequence in Water Resources, and thus have a basis on which to design an effective product. The familiarity with strong examples and how the work will be used is a critical component in receiving quality submissions [22].

Demo Design Challenge Assignment

The demo design challenge assignment was created in the fall of 2012 to address the lack of physical demos in the water curriculum at Florida Gulf Coast University, during a time of extreme financial duress. The idea was developed after viewing the “demonstration rooms” at West Point during the ExCEEd teaching workshop in the summer of 2012. The actual assignment that is given to students is displayed in Figure 1 and 2.

Semester Design Challenge

CWR 4540C Water Resources Design

Due 10/14/2014 at the start of class

To be completed in Project Teams of 4

Design and build a demonstration model that can be used to teach a concept from fluid mechanics, hydrology/hydraulics, or water resources. Please think back to your classes and try to identify an area where a demonstration model would have been helpful. Your project constraints are that your budget is not to exceed $60 ($15 per team member). If you already have construction material around the house it must be treated as if you had to purchase it. This is a design challenge and your grades will be based on how well your demonstration model is built and how well it can be used to teach a specific concept. There are no constraints on the material you can utilize. A list of possible ideas is included at the end of this handout. Please check with me and present your idea in detail before you start constructing anything. If you are having difficulties trying to come up with ideas I have a reference in my office that might be helpful. If you need additional resources please let me know.

Figure 1: Demo Design Challenge Description

Deliverables:

1) Complete functioning demonstration model to be used in future classes
2) Board notes including equations and instructions on how the model should be used in class.
3) Demonstration of model for the class

Possible Topics for Demonstration Models:

Watershed (abstraction, CN, antecedent soil moisture conditions, slope, time of concentration)
Rainfall simulator
Hydraulic Rocket Launcher
Buoyancy and Stability
Pressure Head
Hydrostatic Pressure distribution
Pipe Network
Orifice Jet
Pipe Friction
Manning's Roughness in a Channel
Groundwater
Pumps
Pipes in Series or Parallel
Three reservoir problem

Figure 2: Demo Design Challenge Deliverables and Possible Topics

The assignment expects each group of four students to pay the $60 for materials out of pocket and no financial assistance is received from the Environmental and Civil Engineering Department. The department does assist the teams with access to the machine shop and tools but the models must be built by the students themselves. The reference for idea mentioned in the description is "H2Oh! Classroom Demonstration for Water Concepts" edited by Amy Chan Hilton and Roseanna Neupauer and published through ASCE/EWRI. The board notes created by the students are collected in a "demo binder" so that they are readily accessible and using the demos requires minimal lesson preparation.

Demos Developed

Overall the assignment has been highly successful. Using the "Demo Design Challenge" assignment 24 demonstrations have been added to the water engineering curriculum at Florida Gulf Coast University (Table 1). Figures 3-9 display several of the models built by the students.

Table 1: Demonstrations Added to Water Curriculum

Watershed model	Orifice apparatus
Hydraulic rocket launcher	Hydraulic bridge
Manning's channel for roughness	Curve Numbers (CN) plates
Buoyancy demonstration tank	Major and minor headloss
Stability boats	Fire tornado
Rainfall demonstration model	Hydrostatic force demo
Hydrostatic force calculation	Surface tension
Venturi effect in updraft carburetor	Flow lines (laminar/turbulent flow)
Viscosity of 6 fluid types	Vortex cannon
Hydrograph demo	A cubic foot of water
Centrifugal pumps	Multistage pumps
Bernoulli equation	Pressure gages

Figure 3: Watershed Model Capable of Showing Abstraction, Varying Slope and Urbanization Affects

Figure 4: Boats to Illustrate Stability and Center of Gravity

Figure 5: Infiltration and Abstraction

Figure 6: Buoyancy and Displacement

Figure 7: Fire Tornado and Bernoulli Equation

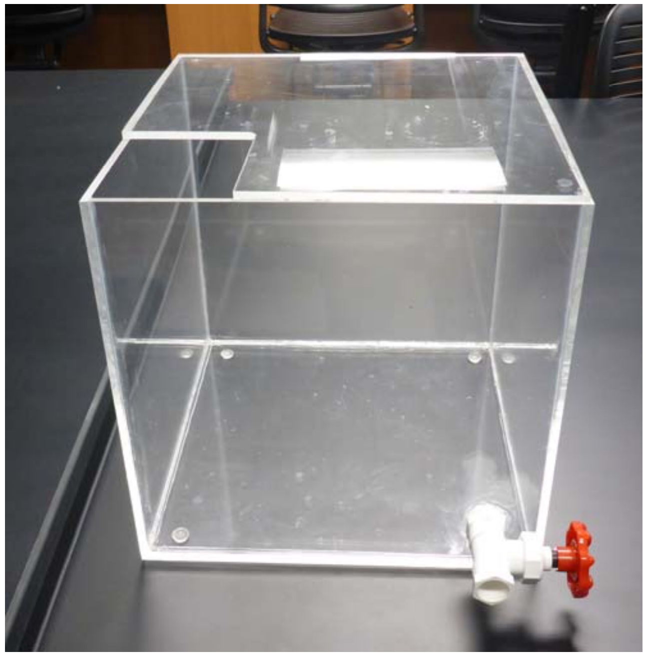

Figure 8: Cubic Foot of Water

Figure 9: Major and Minor Headloss

The assignment has resulted in the creation of high quality models. The knowledge that these models would become a permanent part of the curriculum inspired the students and gave them the feeling that they were leaving a legacy for future students. The assignment also gives students a sense of empowerment as they are asked to address deficiencies in the curriculum that they observed.

The assignment has been introduced to colleagues in the U.A. Whitaker College of Engineering so that it can be utilized across our curriculum. In the summer of 2014 the assignment was presented at the ASCE ExCEEd teaching workshop hosted at Florida Gulf Coast University. It was well received and hopefully it can be utilized across the country in numerous engineering and science disciplines.

Measurement of Demo Effectiveness

To culminate each semester all courses in the Environmental and Civil Engineering Program at Florida Gulf Coast University are assessed and revised to continuously improve each offering. This detailed assessment allows for a direct measure of the effectiveness of models added through the demo design challenge assignment. For example one of the learning objectives for the fluid mechanics class is to solve buoyancy problems. In Fall 2011 students were given class instruction and homework problems as well as a test question. In Fall 2012 and Fall 2013, a buoyancy demonstration (Figure 6) was utilized. Table 2 summarizes the results of student proficiencies on the related test question for 2011, 2012, and 2013. The proficiency levels were jointly determined by the faculty to provide a standard for ABET assessment. The numbers indicate that a greater percentage of students achieved all levels of competency for this objective due to the addition of the buoyancy demonstration.

Table 2. Student Proficiency Comparison for Solving Buoyancy Problems

Proficiency Levels	% of Students Meeting Proficiency Level 2011	% of Students Meeting Proficiency Level 2012	% of Students Meeting Proficiency Level 2013
$\geq$ 85%	21%	48%	53%
$\geq$ 70%	76%	90%	89%
$\geq$ 65%	76%	90%	89%

One of the learning objectives for the hydrology/hydraulics class is to explain the hydrologic cycle and define a watershed. In Spring 2012 students were given class instruction and homework problems as well as a test question. In Spring 2013, a watershed model was added to the course (Figure 3). Table 3 summarizes the results of student proficiencies on the related test question for 2012, 2013, and 2014. The numbers indicate that a greater percentage of students achieved all levels of competency for this objective due to the addition of the model watershed.

Table 3. Student Proficiency Comparison for Explaining the Hydrologic Cycle and Defining a Watershed

Proficiency Levels	% of Students Meeting Proficiency Level 2012	% of Students Meeting Proficiency Level 2013	% of Students Meeting Proficiency Level 2014
≥ 85%	21%	65%	92%
≥ 70%	49%	87%	100%
≥ 65%	53%	89%	100%

One of the learning objectives for the fluid mechanics class is to identify proper units for fluid volumes. In Fall 2012 students were given class instruction and homework problems as well as a test question. In Fall 2013, a model of a cubic foot of water (Figure 8) was utilized. Table 4 summarizes the results of student proficiencies on the related test question for 2012 and 2013. The numbers indicate that a greater percentage of students achieved all levels of competency for this objective due to the addition of the model watershed.

Table 4. Student Proficiency Comparison for Defining a Watershed

Proficiency Levels	% of Students Meeting Proficiency Level 2012	% of Students Meeting Proficiency Level 2013
≥ 85%	43%	69%
≥ 70%	48%	91%
≥ 65%	48%	93%

In addition to the higher levels of student competency observed on learning outcomes due to the inclusion of models, a significant amount of positive feedback has been received from students and colleagues. The comments from students indicate that the models allow them to actually see the concepts being taught in class. They feel that the hands-on nature of the physical models teaches concepts in a way that relates to their own experiences and addresses their need for visual learning. The students also feel that the models connect the theory taught in class to the physical world around them. Comments from students also indicate that the models break up the lecture into more time appropriate sections and allow for maximum attention from the students.

Building the models also has some significant benefits for the students. The major benefit commented on by students is that they gain an understanding about the process of design and gain valuable skills about the construction process in a group environment. An additional benefit of model construction is that the students gain experience using a variety of materials and tools that they have not been previously exposed to.

The final benefit for students from the "Demo Design Challenge" comes from putting together board notes and presenting the model to the class. Student comments indicate that putting together the board notes reinforces the theory behind the model. The comments also indicate that the student gain valuable public speaking experience when they present their model and board notes to the class.

Conclusions

The benefits of having demonstration models and visual tools to illustrate engineering theory are enormous and are well documented. The drawback to having models in the classroom is that they are expensive to purchase and time consuming for a faculty member to build. The assignment presented here addresses a gap in the literature and presents faculty with a tool to efficiently and effectively create classroom demonstrations on a limited budget. The preliminary data collected about student learning outcomes indicates that the "Demo Design Challenge" has substantially improved student learning. The comments from student indicate that the assignment is well received and has several aspects that increase student learning. It is the authors' great hope that the Demo Design Challenge is adopted in programs across the country and enhances student success and the effectiveness of engineering educators

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Kristoph-Dietrich Kinzli

Dr. Kinzli is an Assistant Professor in the Department of Environmental and Civil Engineering in the U. A. Whitaker College of Engineering at Florida Gulf Coast University. Dr. Kinzli received his B.S.(2003), M.S.(2005), and Ph.D.(2010) in Civil Engineering from Colorado State University. Dr. Kinzli also received a M.S.(2008) in Fish, Wildlife and Conservation Biology from Colorado State University. Dr. Kinzli is the ASCE student chapter faculty advisor and has serves as an ASCE ExCEEd assistant mentor. His research interests include open channel hydraulics, river mechanics, stream rehabilitation, agricultural water use, fisheries biology, and ecological restoration.

Tanya Kunberger

Dr. Kunberger is an Associate Professor in the Department of Environmental and Civil Engineering in the U. A. Whitaker College of Engineering at Florida Gulf Coast University. Dr. Kunberger received her B.C.E. and certificate in Geochemistry from the Georgia Institute of Technology and her M.S. and Ph.D. in Civil Engineering with a minor in Soil Science from North Carolina State University. Her areas of specialization are geotechnical and geo-environmental engineering. Educational areas of interest are self-efficacy and persistence in engineering and development of an interest in STEM topics in K-12 students.

Robert J. O'Neill

Dr. O'Neill is a Professor and Chair of the Department of Environmental and Civil Engineering, U.A. Whitaker College of Engineering, Florida Gulf Coast University. He received a B.S. from the United States Military Academy in 1975, an M.S. in Structural Engineering and an M.S. in Geotechnical Engineering from Stanford University in 1984 and a Ph.D. in Structural Engineering from Kansas State University in 1993. Dr. O' Neill is a retired Lieutenant Colonel, U.S. Army Corps of Engineers. He has been active at the national level with ASCE's Technical Council on Computing and Information Technology (TCCIT), Committee on Faculty Development (CFD) and Excellence in Civil Engineering Education (ExCEEd) initiative. He is an American Society of Civil Engineering Fellow (ASCE), a member of the American Society for Engineering Education (ASEE), and Phi Kappa Phi National Honor Society.