AC 2012-4480: SIX HANDS-ON ACTIVITIES DESIGNED TO IMPROVE STUDENT ACHIEVEMENT IN AND ATTITUDE TOWARDS LEARNING FLUID MECHANICS

Ms. Lynn Albers, North Carolina State University

Lynn Albers received her B.S. in mathematics with a minor in music from the Massachusetts Institute of Technology in 1992 and her M.S. in mechanical engineering with a concentration in nuclear engineering at Manhattan College in 1996. After working for Nortel Networks and the North Carolina Solar Center, Albers matriculated at North Carolina State University, where she is a Ph.D. candidate in mechanical engineering. Her dissertation spans the Colleges of Engineering and Education and will be the first of its kind at NCSU.

Dr. Laura Bottomley, North Carolina State University

Laura J. Bottomley, Director, Women in Engineering and K-12 Outreach programs and Teaching Associate Professor, College of Engineering, North Carolina State University, received a B.S. in electrical engineering in 1984 and an M.S. in electrical engineering in 1985 from Virginia Tech. She received her Ph D. in electrical and computer engineering from North Carolina State University in 1992. Bottomley worked at AT&T Bell Laboratories as a member of technical staff in Transmission Systems from 1985 to 1987, during which time she worked in ISDN standards, including representing Bell Labs on an ANSI standards committee for physical layer ISDN standards. She received an Exceptional Contribution Award for her work during this time. After receiving her Ph D., Bottomley worked as a faculty member at Duke University and consulted with a number of companies, such as Lockheed Martin, IBM, and Ericsson. In 1997, she became a faculty member at NC State University and became the Director of Women in Engineering and K-12 Outreach. She has taught classes at the university from the freshman level to the graduate level and outside the university from the kindergarten level to the high school level. Bottomley has authored or co-authored more than 40 technical papers, including papers in such diverse journals as the IEEE Industry Applications Magazine and the Hungarian Journal of Telecommunications. She received the President's Award for Excellence in Mathematics, Science, and Engineering Mentoring program award in 1999 and individual award in 2007. She was recognized by the IEEE with an EAB Meritorious Achievement Award in Informal Education in 2009 and by the YWCA with an appointment to the Academy of Women for Science and Technology in 2008. Her program received the WEPAN Outstanding Women in Engineering Program Award in 2009. Her work was featured on the National Science Foundation Discoveries website. She is a member of Sigma Xi, Past Chair of the K-12 and Pre-college Division of the American Society of Engineering Educators and a Senior Member of the IEEE.

Six Hands-On Activities Designed to Improve Student Achievement In and Attitude Towards Learning Fluid Mechanics

Abstract

Six, hands-on activities were designed to supplement an existing mechanical engineering curriculum for fluid mechanics with the goal of creating a new instructional method centered around activity based learning. Replacing lecture time with activity based learning positively affects university students by reinforcing concepts learned during lecture, visually teaching new concepts and providing an outlet where the students are free to interact more casually with the instructor and their peers. Results of this are higher student achievement, a more thorough understanding of the material and a more positive attitude towards learning

The four activities titled *Rainbow Layer Cake* ©, *Marshmallow Madness* (Control Volume Analysis) ©, *Twist and Turn* (Fluid Flow) ©, and *Construction Function* (Pipe Flow) © were original ideas developed for the class by the author. The activity, *Foil Boat, Float, Float* was an original idea created through North Carolina State University's GK-12 Outreach Program and modified for use in the junior level class. *Sink or Swim* (Bowling Balls and Soda Cans in Water) was a demonstration borrowed from the physics department and augmented with a worksheet.

To assess whether the activities resulted in higher student achievement, a control group and experimental group were created. Students in the experimental group performed the activities while students in the control group did not. Both groups received the same assessments and a comparison of exam scores was performed to assess the impact on student achievement. The experimental results and effectiveness of the activity, *Rainbow Layer Cake* © are presented to show that hands-on activities do result in higher student achievement.

Active Learning

> *"Active learning is anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes." Dr. Richard Felder*[4]

Dr. Felder does not propose to entirely eliminate the act of lecturing however, highly encourages that active learning be incorporated into the classroom experience. Dr. Felder proposes that teachers engage students in relevant activities involving problem solving that last 30 seconds to a minute. He proposes the following activities which all involve problem solving with paper and pencil to give the students practice and feedback: Think-Pair-Share; Concept Tests; and Thinking-Aloud Pair Problem Solving (TAPPS).[4]

> *"Only what we experience is the best guide to explain what we cannot experience or measure directly. In this way, I persuade myself, I can go from what I know to what I do not know, but want to, through the connections I can make between experiences and experiences, concepts and concepts." Marc Belth*[2]

The type of active learning in this research project differs from that of Dr. Felder in that it involves the use of hands-on activities. The hands-on activities are models that give a three-dimensional shape to the experiences and concepts that we know. The models allow the student to touch, feel and play so that they can first solidify their knowledge of the concept and then connect it to a potentially new experience and concept. The hands-on activities were designed for use in the fluid mechanics classroom to have the student move; first by getting up to get the materials and second by having them build the model.

The inspiration for creating hands-on activities for an undergraduate Fluid Mechanics course came from working with North Carolina State University's GK-12 Outreach Program where hands-on activities were designed to teach math and engineering to children in grades 3-8 under the guise of having fun. The Program followed Dr. John Dewey's philosophy that learning can occur through everyday activities[3]; for example math can be learned while cooking. Therefore, common items found in the home were used to create several, original activities. For example, toothpicks and marshmallows are used for both a Kindergarten and a Fifth grade activity where the students build 2D and 3D shapes respectively. Another very popular activity called, *Diaper Hold'em*© teaches students about liquid volume in the SI and English metric systems using kitchen turkey basters, yellow colored water and diapers.

Following a pragmatist approach, it is believed that active learning is a fun and feasible teaching style that replaces words with activities as the means of communicating new concepts. This often takes the "fear-factor" out of learning for those who feel overwhelmed or intimidated about learning math or engineering. The Program creates opportunities for active learning through many out of classroom learning experiences such as afetr school clubs, tutoring, assistance with science fair projects and family STEM nights for which no fewer than six activities were created per grade level K-8.[1]

A pilot study was done during the 2010-2011 academic year to measure the impact of family STEM nights. Participating students in grades 3-5 at two elementary schools (ES1 and ES2) and students in grades 6-8 at one middle school (MS1) were given a pre and post survey to measure any change in awareness of and any increased likeability in the four STEM disciplines after having played with the activities for approximately an hour and a half. There was a 24%, 9% and 21% improvement in awareness of engineering at ES1, ES2 and MS1 respectively through participation in the Family STEM Night. Upon performing a paired t-test on each sample, ES1 ($p < 0.05$, 28 df) and MS1 ($p < 0.05$, 18 df) were significant for improvement in awareness of engineering. There was an 11%, 9% and 16% increase in likeability of science and a 47%, 16% and 21% increase in likeability of engineering at ES1, ES2 and MS1 respectively through participation in the Family STEM Night. Upon performing a paired t-test on each sample, ES1 ($p < 0.05$, 28 df), ES2 ($p < 0.5$, 17 df) and MS1 ($p < 0.05$, 18 df) data were significant for increases in science and engineering likeability. MS1 also showed significant gains in math likeability: a very positive result for this age group.[1] While only a pilot study, these results are positive indicators that hands-on activities are helpful in improving awareness and likeability of STEM disciplines, which can lead to a more pleasurable learning experience.

Given the positive results of the pilot study and upon observing the students' success in grasping concepts while playing, it was decided to try a similar approach with university students. Thus was born the idea of using activity-based learning in an undergraduate fluid mechanics course. The original intent of this paper was first to describe the activities in detail however, the author is currently investigating having the activities published and is uncertain at this time if inclusion in this paper is permitted. Therefore, the paper will just contain a brief mention of some of the activities. The second part of the paper will show the experimental results and effectiveness of the activity, *Rainbow Layer Cake* ©.

The Hands-On Activities

The four activities titled *Rainbow Layer Cake* ©, *Marshmallow Madness* (Control Volume Analysis) ©, *Twist and Turn* (Fluid Flow) ©, and *Construction Function* (Pipe Flow) © were original ideas developed for the class by the author. The activity, *Foil Boat, Float, Float* was an original idea created through the university's GK-12 Outreach Program and modified for use in the junior level class. *Sink or Swim* (Bowling Balls and Soda Cans in Water) was a demonstration borrowed from the physics department and augmented with a worksheet. Students were given approximately 30-40 minutes to perform each activity during class time. They were encouraged to work in pre-determined groups of 2 or 3.

Foil Boat, Float, Float was designed for middle school students. However, it could easily be adjusted to teach elementary school students as well as college level students the concepts of geometry, weight and buoyancy. During this activity, students were given an equal size piece of aluminum foil and were given the freedom to design the shape of the boat and test it in a tub of water. Glass beads were used as weight and the goal was to design a boat that would hold as many beads as possible. Students of all ages enjoy this activity because they like to mold the aluminum foil sheet into many different shapes in order to hold the greatest number of glass beads. Surprisingly, the record for holding the most glass beads is held by a second grader whose boat held 175 beads.

Experiment

In order to statistically measure the effectiveness of the hands-on activities, two sections of a fluid mechanics class were used during the same semester. One section was designated a control group (N=21) while the other was designated the experimental group (N=23). The course material was compartmentalized by basic concepts; resulting in eight sections. To assess the students, a quiz was given at the end of each section. Both groups were exposed to the same lectures while the experimental group also partook in the hands-on activities. Since there were only 6 activities and 8 sections, not all sections had an activity associated with it.

The students were assessed via quizzes containing six multiple choice questions with five choices each. The same quiz was administered to both groups who were given equal time to complete the quiz. The questions were set up as multiple choice questions with five choices each in order to eliminate instructor bias while grading. For the statistical analysis, each correct answer was equal to 1 while each incorrect answer was equal to 0. Then the percent of the control class answering the problem correctly was compared with the percent of the experimental class answering the problem correctly. A test for significance was performed using a two-tailed t-test.

Statistical Results

Figure 1 shows the students in the experimental group partaking in the activity, *Rainbow Layer Cake* ©. During this activity, students used Jello™ to simulate the layers of a fluid undergoing deformation due to shear stress.

Figure 1. Students in the control group performing the activity *Rainbow Layer Cake* ©

Table 1 shows the statistical results of the quiz assessing the effectiveness of the activity, *Rainbow Layer Cake* ©. Both groups received the same lectures, completed the same homework assignments and took the same quiz on the same day. The six problems on the quiz covered the material taught during that section of the course. The problems marked with an asterisk were considered relative to both the lecture notes and the activity and therefore it was expected that the experimental group would perform better on these problems.

Table 1: Quiz 1; Activity = Rainbow Layer Cake©

Problem #	Control Group	Experimental Group	P-value (2-tailed)
Average (out of 6)	2.14	3.70	.000
1	52%	57%	.789
2*	10%	35%	.047
3	52%	70%	.252
4*	14%	70%	.000
5*	43%	74%	.037
6	43%	65%	.143

The maximum possible score on the quiz was 6. The average (mean) on quiz 1 for the control group was 2.14 and 3.70 for the experimental group. While the experimental group did take the quiz approximately four hours after the control group, it was not believed that students from the two groups collaborated as it was too early in the semester for them to know each other.

Figure 2 is a picture of problem 5 taken from quiz 1 of a student in the experimental group. Note that the activity was performed using a Cartesian coordinate system while the problem was based on a cylindrical coordinate system which they had not seen prior to the quiz. Also note the comment by the student on the right side that begins, “Think like Jello…” This student used the three dimensional model from the activity to visualize how the fluid would flow in this coordinate system in order to solve the problem.

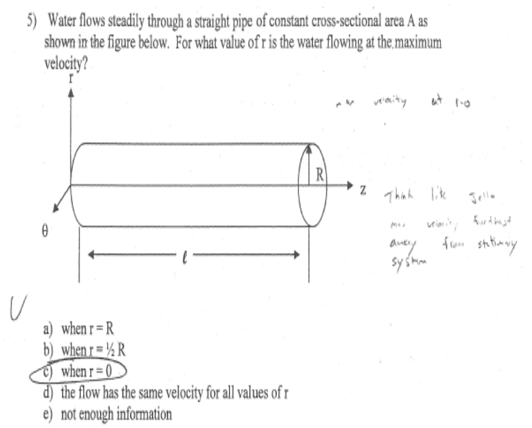

Figure 2. Problem Number 5 on Quiz 1

Conclusion

The *Rainbow Layer Cake* © activity was created to help teach the concepts of fluid layers, their deformation under shear stress and the no-slip condition. Overall the students enjoyed the activity with one student stating on an end-of-semester survey, “Trying to stack the Jellos™ was fun and seeing the no-slip condition at work was interesting. I had not really thought of that before.” Problems 2, 4 and 5 of quiz 1 were all related to fluid flow and used to assess the effectiveness of the activity. The experimental group outperformed the control group on all three problems with statistically significant results (according to a simple t-test).

Quizzes were given and statistical analyses were performed to assess the effectiveness of the other activities with varying results.

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