AC 2011-1930: INSPIRING STUDENTS TO LEARN FLUID MECHANICS THROUGH ENGAGEMENT WITH

Diane L. Bondehagen, Florida Gulf Coast University

DIANE BONDEHAGEN is an Assistant Professor of Environmental Engineering in the Department of Environmental and Civil Engineering, U.A. Whitaker School of Engineering, Florida Gulf Coast University. She received a B.S. in Mechanical Engineering from the University of Wisconsin, Madison, in 1983, an M.S. in Civil and Environmental Engineering from Florida International University in 1999 and a Ph.D. in Environmental Engineering Sciences from the University of Florida in 2005. Dr. Bondehagen joined FGCU after a research and teaching position at the University of Florida. Dr. Bondehagen is a member of the American Geophysical Union (AGU), the American Water Resources Association (AWRA) and American Society of Engineering Education (ASEE). Her current research interests are in the area of contaminant transport and remediation.

Inspiring Students to Learn Fluid Mechanics through Engagement with Real World Problems

Abstract

Faculty often experience many challenges in teaching Fluid Mechanics. At Florida Gulf Coast University, this course is taught to combined sections of civil and environmental engineering students. Students often express fear at the course difficulty and a feeling of "wanting to get it over with." The challenge then for faculty is to motivate the students' desire to understand the material and to help the students understand the importance of the material not only to their subsequent coursework but also in becoming "Fluid Mechanics Literate" in a world abounding with scientific challenges related to basic fluid mechanics. To this end, Lifelong Learning is incorporated in the current Engineering Fluid Mechanics course objectives. This is in keeping with one of the ABET outcomes for our students: recognition of the need for, and an ability to engage in Lifelong Learning.

Two lifelong learning projects were assigned which addressed real world engineering problems. Students were required to write a report on the application of fluid mechanics principles learned in the course to these engineering challenges. The professor provided the topics which were chosen to ensure that the fluid mechanics covered in our course would be easily applicable to the assignment. Assessment techniques were employed in this course to evaluate the lifelong learning outcome. Surveys were administered after each report where the students reported on the value of this exercise to their engagement and effective learning in the class. Additionally, testing provided further assessment of learning via directed questions. Survey results showed a distinct improvement in student appreciation of the importance of fluid mechanics principles. Test results showed a higher level of understanding of these fundamentals. Survey responses and test results demonstrated that student engagement and performance in the class improved from identifying fluid mechanics aspects of real world problems via the lifelong learning assessments.

Introduction

The Whitaker School of Engineering (WSOE) was established in 2005 at Florida Gulf Coast University (FGCU) and is now fully accredited. The WSOE teaching mission fosters excellence in teaching by providing innovative lecture-lab classes. Offered in the Fall Semester of the junior year, Fluid Mechanics has proved to be challenging to students. While teaching is "outside" the student's brain, learning is what is going on "inside" the brain. How does the student "get it"? Indeed, as one of the first upper level engineering courses, Fluid Mechanics challenges students to delve more deeply into topics they may not have considered earlier in the curriculum. Labs on topics such as testing of fluid properties and calculating head losses using Bernoulli's Law do aid in understanding, but in recent years with increasing class size and distractions, too many students are "tuning out" evidenced by higher withdrawal and failure rates in Fluid Mechanics in 2009-2010.

One of the principal challenges of teaching fluid mechanics is the level of abstraction that comes with the subject. Students tend to be more familiar with, and have better intuition for, the

behavior of solids. Fluids move in complex and beautiful patterns, but the flow is often difficult to see with the naked eye. Despite the fact that we spend our lives immersed in a fluid (air) and water movement is observed continually, many fundamental fluid behaviors remain unfamiliar to students since the behavior just happens; no reasoning occurs exploring the basic fundamentals of motion. For example, we tell students that air in the classroom is turbulent, yet their acceptance of this is more an act of faith than an act of learning. Videos of fluid movement help, but the learning only occurs with in-depth analysis of the movement. To motivate students to do the in-depth analysis required for effective learning and in keeping with FGCU's mission of innovation to aid learning, two lifelong learning (LLL) assignments were created. These were designed not only to give the students a "jump-start" on self-learning, but also to provide them with the confidence in their ability to independently research and learn [1,2].

Methods

The first assignment involved the application of Fluid Mechanics fundamentals to oil spills/leaks in deep water. In light of 2010 events, the real world example suggested was the Deepwater Horizon Oil Spill which occurred in the Gulf of Mexico[3]. In our region of the country, this problem resonates deeply with students. The students were asked to write a 2-3 page report with reference to the application of Fluid Mechanics fundamental principles to oil spills (quantifying mass, capping the wells, clean-up practices). These principles included hydrostatic forces on submerged plane/curved surfaces, surface tension, and the Bernoulli/energy equation[4]. Therefore, suggestions and examples given to students as a starting point of research included looking at hydrostatic forces, considering surface tension effects and the use of oil dispersants, and evaluating pressure-velocity-elevation heads and head losses. Further motivational direction was given in the assignment text: "Actually, everything you have learned so far is applicable. Be as creative and innovative in your approach to this assignment as you would like."

The second assignment also required a minimum 2-3 page report instructing students to consider and apply fluid mechanics principles to the capture of tidal and wave energy (potential energy) and the use of new technology turbomachinery (kinetic energy) to generate electrical energy. The Bay of Fundy and Rance River examples were provided as starting points for research. The students were also given the option to consider water transport energy losses (provided example: modeling a reach of a river and the analysis of possible required parameters to include energy losses). No restrictions were placed on how to approach topic analysis; instructions again designed to motivate included: "Everything you have learned so far is applicable. Be as creative and innovative in your approach to this assignment as you would like."

The raison d'être of these lifelong learning assignments was to cultivate in the students the practice of self-learning required for true lifelong learning [5,6]. The students were required to access new material and demonstrate they can learn this material on their own and apply this knowledge to the course assignment. In order to evaluate and focus student efforts, an evaluation rubric (Table 1) and specific instructions were provided by the professor for both assignments [7,8,9]. In the assignment instructions, the professor directed the students to write a clear, succinct analysis of their research and chosen applications of Fluid Mechanics principles. In fact, throughout our course, written and communication skills were evaluated and feedback provided. The continuing development of technical writing skills is emphasized in our curriculum, and

therefore the written reports provided an evaluation of the progress of this writing development (technical report format guidelines along with a sample report were provided).

Table 1. Rubric to Evaluate Lifelong Learning Assignment #1 and #2

	Competent(10-9)	Developing (8-7)	Beginning (6-5)
Ability to learn	Demonstrates ability to learn independently	Requires guidance as to expected outcome of assignment.	Requires explicit instructions to complete assignment
Assignment Completion	Goes beyond what is required to complete assignment and researches outside sources for information	Completes only what is required	Demonstrates difficulty in completing assignment
Independent thinking	Demonstrates ability to think for oneself	Does not take whole responsibility for own learning	Assumes that all learning takes place in the confines of the class.
Analytical ability	Is able to understand broad (ambiguous) topic and see relationships. Able to use information researched to address problem.	Has difficulty in understanding relationships of fundamentals to "real life" problems.	Is unable to recognize need to analyze problem – think creatively.
Transfer of class/learned materials to assignment	Is able to apply learned materials and concepts in a different format than that taught in class (different nomenclature, different form of equation than that taught in class)	Has trouble using materials and concepts that are in a different format than presented in class.	Cannot use materials outside of what was explained in class

Results and Assessment

Assignment 1: The primary goal of the first assignment was to encourage students to consider application of fluid mechanics principles to engineering solutions used to address oil spills. The salient learning points included fluid properties (viscosity, surface tension effects) as well as hydrostatic forces and the application of the energy equation to clean-up of the oil. In fact, the predominant points of discussion of submitted student papers for lifelong learning assignment #1 included buoyancy effects, surface tension, flow fields, and hydrostatic pressure. A survey was conducted where students were asked the following questions:

> **1.** Did this assignment improve your understanding of some basic fluid mechanics principles? If so, how did it help? Please provide specifics.
> **2.** A goal for this assignment is to enhance your engagement in and understanding of real life engineering challenges using fluid mechanics principles you learned so far in the course. Do you believe you became or are more interested in these engineering applications as a result of an assignment like this? Did this assignment help you appreciate the importance of fluid mechanics in your future engineering work?

Survey Question 1:
Sample responses to question 1 were mostly affirmative (n=54, 4 students answered no) and included the following comments:

- This assignment led me to see how fluid mechanics plays a role in many topics across engineering.
- …very good in opening my mind to how fluid mechanics plays a part in many topics of engineering.
- …involved different conceptual thoughts that I did not realize.
- Did improve my understanding of the some basic fluid mechanics. It really showed me how the basic properties of a fluid are studied to design the clean-up of oil spills.
- It is a good tool to improve our understanding of fluid mechanics.
- It was hard for me to do the paper because I have problem seeing the whole picture. But, it was worth it.
- …because it applies it to the real world. I think that most of us just look at the concepts learned as just another equation for some plug and chug.
- The study of basic fluid mechanic principles gave me a better understanding on how to solve engineering problems and also on how to prevent potential catastrophes
- It made me actually think about the topics we had covered and how they could be used and applied.
- It did help me understand. While researching for the LLL, I could see how the different principles used in the class applied to real world situations

Survey Question 2:
Sample responses to question 2 were all affirmative (n=54) and included the following comments:

- …broadens one's spectrum of engineering and can also make you explore more ideas that could potentially change your profession. LLL should be offered in more classes at FGCU.
- …assignment definitively made me appreciate the importance of fluid mechanics, especially when it comes to a huge natural disaster like the oil spill.
- …doing this paper, I became more interested in these engineering applications and it helped me to appreciate the importance of fluid mechanics
- It made me actually think about the topics we had covered and how they could be used and applied.
- …assignment did make me appreciate the importance of fluid mechanics because there is so much good you can do which can have an impact on the entire world and save species of fish when there are wide spread disasters such as an oil spill.
- This assignment helped me relate fluid mechanics to problems happening in the real world.
- I do believe I became more interested in fluid mechanics after this assignment. Because of the importance of solving such a disaster I feel that the importance of fluid mechanics was greatly improved in my mind after performing this assignment.

- It helped me understand how the principles we were learning in class applied to the real world.
- This assignment helped me consider what actually went into oil spill clean-up.
- It very well showed me the importance of fluid mechanics in the real world. I can definitely see how this material will come into play in my future career.
- …good way to show how these fluid mechanic principles are used in everyday life. It is a good way to get away from the examples from the text book and focus on real world situations.
- This assignment allowed me to more relate the principles of fluid mechanics to everyday life. Fluid mechanics is important in everyone's life whether they may know or notice it or not.

Besides a survey, midterm and final test questions were structured to assess the learning of basic fluid mechanics principles germane to each assignment. The questions directed at the first lifelong learning assignment included a hydrostatic pressure problem on a submerged surface, a problem involving buoyancy (submerged sphere floating in oil and water interface), and a classic capillary action surface tension problem including the use of a surfactant to reduce surface tension in the problem. The hydrostatic pressure problem average score was 86 with almost 75% receiving full credit. The buoyancy problem average score was 80 with about 68% receiving a perfect score. The surface tension problem average score was 85 with almost 78% receiving a perfect score. Comparing this to the previous year's class performance on similar problems, scores were very much improved with previous performances averages of 72, 70 and 69 on respective submerged surface, buoyancy and surface tension test questions. This confirmed the professor's perception of the students exhibiting improved understanding with a more intuitive sense of these concepts. Also, it is important to note that although no data was collected to support this, the students appeared motivated by the enormity of the Gulf Oil Spill and long-lasting effects on the regional economy.

Assignment 2: The primary goal of the second assignment was to ensure that students fully understood the energy equation and the concept of energy loss. This assignment directed students to explore turbine and wave energy and the application of fluid mechanics principles to the capture of energy. The predominant points of discussion of student papers included new turbine design to increase efficiency, energy equation applications and the inefficiencies due to energy loss. Again, a survey was conducted where students were asked the following questions:

> **1.** Did this assignment improve your understanding of some basic fluid mechanics principles? If so, how did it help? Please provide specifics.
> **2.** A goal for this assignment is to enhance your engagement in and understanding of real life engineering challenges using fluid mechanics principles you learned so far in the course. Do you believe you became or are more interested in these engineering applications as a result of an assignment like this? Did this assignment help you appreciate the importance of fluid mechanics in your future engineering work?

Survey Question 1:
Sample responses to question 1 were all affirmative (n=53) and included the following comments:

- …specifically the application of energy equation towards real life problem like generating energy through waves and analysis of how to generate electricity through waves.
- This assignment led me to research various topics with fluids and waves and how they relate to fluid mechanics.
- It gave me a realistic representation of the Bernoulli Equation.
- This assignment improved my understanding of real life applications of the energy equation.
- This assignment went into great details of the principles of fluid mechanics in energy recovery.
- I learned a great deal of how pumps and turbine energy is harnessed from tidal energy and the natural tide changes of the ocean.
- … improved my understanding by helping me realize how turbines work.
- The assignment allowed me to see how fluid mechanics was used in building the panama canal.
- This LLL assignment helped me understand the principles of energy and work that we had discussed in class. Seeing how the tides and waves could be used to generate energy was interesting.
- I thought it was very interesting. It sparked my interest which in turn made me want to learn more.
- LLL 2 assignment improved my understanding of how tidal waves and tidal energy are captured. While doing research on the web, I found a great deal of material about wave energy that for some people might be confusing, but with the good background about fluid principles that we had with Dr. Bondehagen everything made sense.

Survey Question 2:
Sample responses to question 2 were all affirmative (n=53) and included the following comments:

- I became more interested in engineering problems because you can actually apply what you learn in solving a specific problem
- …led me to research various topics with fluids and waves and how they relate to fluid mechanics.
- I believe that this assignment made me more interested in the topic of fluid mechanics and how it relates to wave energy. This also made me more appreciative of the use of fluid mechanics in all engineering applications
- Understanding real life engineering challenges like new turbines that produce energy from the currents made me a little more interested about working in the future with new engineering applications like this one
- I definitely became more interested in fluid mechanics because I am extremely interested in energy from renewable sources… have a large appreciation for the importance of fluid mechanics in my future engineering work because of my pursuit in the field of energy.
- I find it fascinating to see theories and formulas learned in class being applied in technical articles and discussions.

- I didn't realize how much of what I'm learning at this level is applicable to practical situation in the engineering field
- I learned a great deal of how pumps work and turbine energy is harnessed from tidal energy and the natural tide changes of the ocean
- Technology does not stop. Understanding real life engineering challenges like new turbines that produce energy from the currents made me more interested about working in the future with new engineering applications like this one.
- This assignment made me much more interested in turbines and how renewable energy can be harnessed…I now understand how it all works.
- I didn't realize how much of what I'm learning at this level is applicable to practical situations in the engineering field.
- This assignment did spark my interest more …. It was interesting to see how the principals we learned in class applied to tidal energy.

The questions directed at the second lifelong learning assignment included an energy equation application involving a turbine to generate power, and an additional problem addressing energy losses. The turbine energy problem average score was 84 with almost 78% receiving full credit. For the problem including energy losses, the average score was 78 with about 69% receiving a perfect score. Comparing this to the previous year's class performance on similar problems, scores were very much improved with previous performances averages of 74 and 72 respectively for turbine and energy losses questions. This second assignment was much appreciated by many students who are interested in alternative energy. Again, with heightened student interest in these topics, assessment results suggested an improved motivation to learn and increased understanding. Renewable energy is a current and exciting topic for students. In fact, several students approached the instructor about possible graduate programs in energy/renewable energy. (At this time, FGCU only offers degrees in Civil, Environmental, and Bio Engineering.)

The rubric (Table 1) designed to evaluate the lifelong learning assignments was directed at self-learning, a major component of lifelong learning. A statistical analysis of the 2009 and 2010 Fluid Mechanics classes performance on test problems related to specific fundamentals addressed on the lifelong learning assignments was performed. Results are presented in Table 2 along with 2009/2010 student grade point averages. Paired t-tests showed a high probability that the lifelong learning assignments impacted learning of specific Fluid Mechanics fundamentals. The average GPA scores from 2009 to 2010 increased only slightly and were not considered as a variable in analysis. Comparing the two lifelong learning assignment grades (based on the rubric of Table 1), the t-test $P = 0.208$ indicates no significant difference between the two assignments; most students received high grades with averages of 88 and 89. However, a review of the survey comments appears to indicate a greater interest in the second assignment. This could be simply due to the less ambiguous nature of this assignment and strong student interest in renewable energy

Table 2a. Comparison of 2009 (pre LLL assignment) and 2010 Test Scores

Lifelong Learning Assessment				Questions: LLL#1 Fundamentals					
	Avg. GPA	Lifelong Learning Assignments (LLL)	number of students	Hydrostatic Pressure		#1 Buoyancy		#1 Surface Tension	
				Mean	Std D	Mean	Std D	Mean	Std D
2009	C+	N.A.	46	72	11.3	70	12	69	15.2
2010	B-	2 assignments	62	86	9.8	80	8.2	85	9.8
Paired t-test of means ***p = statistically significant** **N.A. = not applicable** **Std D = standard deviation**				t-test, 1 tail *p<0.01		t-test, 1 tail *p<0.01		t-test, 1 tail *p<0.01	

Table 2b. Comparison of 2010 (pre LLL assignment) and 2010 Test Scores

Lifelong Learning Assessment				Questions: LLL#2 Fundamentals			
	Avg GPA	Lifelong Learning Assignments (LLL)	number of students	#2 Turbine/Energy		#2 Energy losses	
				Mean	Std D	Mean	Std D
2009	C+	N.A.	46	74	10.1	72	10.4
2010	B-	2 assignments	62	84	8.5	78	5.2
Paired t-test of means ***p = statistically significant** **N.A. = not applicable** **Std D = standard deviation**				t-test, 1 tail *p<0.01		t-test, 1 tail *p<0.05	

Summary and Conclusions

Inspiring students to learn a more abstract subject like Fluid Mechanics is challenging. The inclusion of the lifelong learning assignments provided students the opportunity to investigate the fundamentals of fluid mechanics that apply to real world engineering challenges. Assessment of learning showed that indeed students had a higher level of understanding of certain fundamentals in the 2010 class with the inclusion for the first time of the lifelong learning projects (class offered once a year since 2007). Student survey results confirmed an increased interest in Fluid Mechanics which then encouraged students to consider, research, and analyze independently the applications of Fluid Mechanics principles to their chosen topic focus. The Lifelong Learning approach to this course in particular appears especially effective. Future Fluid Mechanics classes will incorporate even more "real-world" problems in class assignments. Since there are many other factors beyond the scope of this paper that could impact the level of learning, more data will be collected and future analysis performed. This analysis will include a more detailed assessment of student acknowledgement of the need for lifelong learning [10,11]. Also, because of the success of these lifelong learning projects, more self-learning exercises will be incorporated in other classes in order to encourage investigative, critical thinking and an improved learning outcome.

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