AC 2011-781: THE IMPACT OF ACTIVITY BASED LEARNING, A NEW INSTRUCTIONAL METHOD, IN AN EXISTING MECHANICAL ENGINEERING CURRICULUM FOR FLUID MECHANICS

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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, Lynn 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.

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Laura Bottomley 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.

Dr. 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., Dr. 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.

Dr. Bottomley has authored or co-authored 37 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 web site. She is a member of Sigma Xi, past chair of the K-12 and Precollege Division of the American Society of Engineering Educators and a Senior Member of the IEEE.

The Impact of Activity Based Learning, a New Instructional Method, in an Existing Mechanical Engineering Curriculum for Fluid Mechanics

Abstract

Replacing lecture time with activity based learning positively affects university students in undergraduate fluid mechanics 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. We will show the impact of activity based learning through surveys and observations.

Activity based learning is a new instructional method applied to an existing mechanical engineering curriculum for fluid mechanics. The new instructional method involves students in hands-on activities that are originally designed or modified from existing activities by the graduate instructor, student presentations, instructor demonstrations and projects. Fluid mechanics is one of the more disliked courses in the engineering curriculum due to the difficulty of the material. The goal of the activities, that address the same objectives of the course, is to help the student grasp the concepts and improve the overall learning experience.

Introduction

"Conventions afford us economy of existence, ways of dealing with the day to day rigors of living without re-encountering or reinventing the world every day. So conventions are the source of great comfort, even if this is at the expense of thought." [1] This has never been more evident than when observing university students. They are so used to routine and feeling that if they complete a checklist and receive a good grade that they have learned. Perhaps they have learned the material but they haven't learned how to think. From observation, students treat classes as something on a to-do list with the reward being a degree when they have checked off all items on the list. Within the scope of a class, students find great comfort in their to-do list of 10-12 weekly homeworks, 3 tests, maybe a project and then a final exam. All items are treated as part of a to-do list. When homeworks are only worth 10% then they either copy problems from the solution manual or turn in poor work only to wait until the solutions are posted to learn the material. Thus, there is no effort or incentive to read the book, try to solve the problem on their own (which is the point at which great learning occurs) and truly understand concepts. They once again take comfort in conventions, thinking that by understanding how to solve a few types of situations that this is all the knowledge they need. However, this is not sufficient. It is essential to understand concepts and math skills that can be applied to any situation to find a solution. This is particularly true with the study of undergraduate Fluid Mechanics. This course is often taken upon completion of Statics and Dynamics and in tandem with Introductory Thermodynamics. It is a student's first experience with solving problems where you cannot just look up an equation, use it and get the right answer. They must apply the conservation laws to develop equations to solve for the flow of the fluid. There is no one, pre-existing equation for each type of problem. In this case, one must reinvent and cannot fall back upon pre-existing conventions.

So this begs the question, "How do we break convention?"
The short answer is, "Active learning through hands-on activities."

Dr. Richard Felder has long been a proponent of active learning, which he defines as, "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." He does not propose to entirely eliminate the act of lecturing, however highly encourages that active learning be incorporated into the classroom experience. He proposes that teachers engage students in relevant activities involving problem solving that last 30 seconds to a minute. One of the things he suggests that the instructor do is have the students explain a complex concept in terms a high school student could understand. [2] This lends itself well to support the objective of the Lesson Plan project whose underlying goal is to teach the concept by forcing the student to teach the material to someone much younger. Dr. Ron Campbell is a huge proponent of learning by teaching and always encourages students to teach through 5-minute presentations.

This paper describes activity based learning as a new instructional method applied to an existing mechanical engineering curriculum for fluid mechanics. The new instructional method involves students in hands-on activities that are originally designed or modified from existing activities by the graduate instructor, student presentations, instructor demonstrations and projects. Fluid mechanics is one of the more disliked courses in the engineering curriculum due to the difficulty of the material. The goal of the activities, that address the same objectives of the course, is to help the student grasp the concepts and improve the overall learning experience.

There were many aspects of this experiment. This paper will focus on the students' perceptions of how effective the activities were in their learning. The students were given a survey at the end of the course asking: "How helpful were the activities in learning fluid mechanics?", How helpful were the activities in learning math?", "How challenging were the activities?" and "How well did you enjoy the activities? Two classes of students were surveyed; one in the fall 2009 (N=33) semester and the other in the spring 2010 (N=23) semester.

Experiment

The inspiration for the experiment came from two sources. The first was from the desire to make Fluid Mechanics a course that students would enjoy. The challenge was how to accomplish this. The solution came from working with North Carolina State University's GE Foundation and National Science Foundation funded GK-12 Outreach Program, RAMP-UP, where hands-on activities were used to teach math and engineering to children in grades 3-5. Upon observing the students' success in grasping concepts, it was decided to try a similar approach with university students. Thus was born the idea of using activity-based learning in a fluid mechanics course. However, the activity-based learning would take a slightly different form than that proposed by Dr. Felder. Instead of problems to solve, the students would build three-dimensional objects that would demonstrate the concept being taught and then they would learn the math corresponding to it. In addition to in class activities, there were out of class projects designed to help visualize the concepts. These projects were titled Flow Visualization and Lesson Plan.

Six, in-class activities were performed throughout the semester coinciding with the relevant lecture material in class. Two out-of-class projects were assigned with due dates corresponding to relevant lecture material. The six in-class activities were titled, *Rainbow Layer Cake* ©, *Foil Boat, Float, Float* [3], *Sink or Swim* (Bowling Balls and Soda Cans in Water), *Marshmallow Madness* (Control Volume Analysis) ©, *Twist and Turn* (Fluid Flow) ©, and *Construction Function* (Pipe Flow) ©. Students were given approximately 30-40 minutes to perform each activity. They were encouraged to work in groups of 2 or 3.

Foil Boat, Float, Float which is an original RAMP-UP activity designed for middle school students. However, it can 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 are given an equal size piece of aluminum foil and are given the freedom to design the shape of the boat and test it in a tub of water. Glass beads are used as weight and the goal is to design a boat that will 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. She designed a boat that held 175 beads.

Survey Data

The students were given a survey on the last day of class to determine their perception of the activities. They were asked to rank how helpful they thought the activities were in learning Fluid Mechanics and Math using a Likert scale of 1 = very unhelpful, 2 = unhelpful, 3 = neutral, 4 = helpful, 5 = very helpful. The number of responses per level of the Likert scale are shown in Figures 1 and 2 for the Fall 2009 class and Figures 3 and 4 for the Spring 2010 class. Note that the activity, Rainbow Layer Cake ©, an original idea, wasn't created until January of 2010 and therefore there is no survey data to record from the Fall 2009 class.

Figure 1

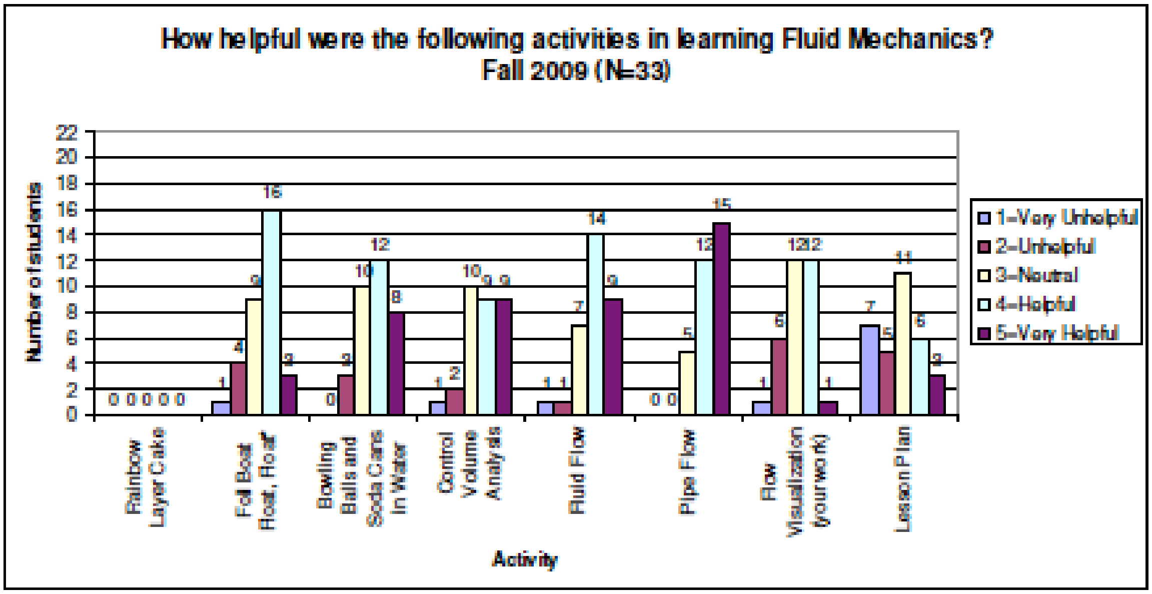


Figure 2

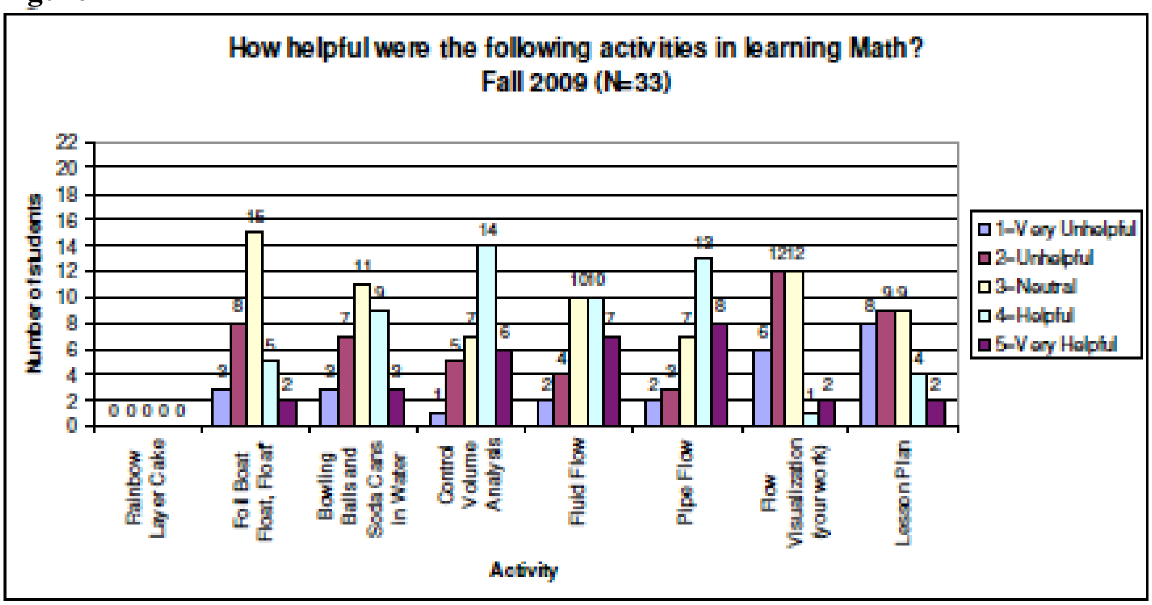


Figure 3

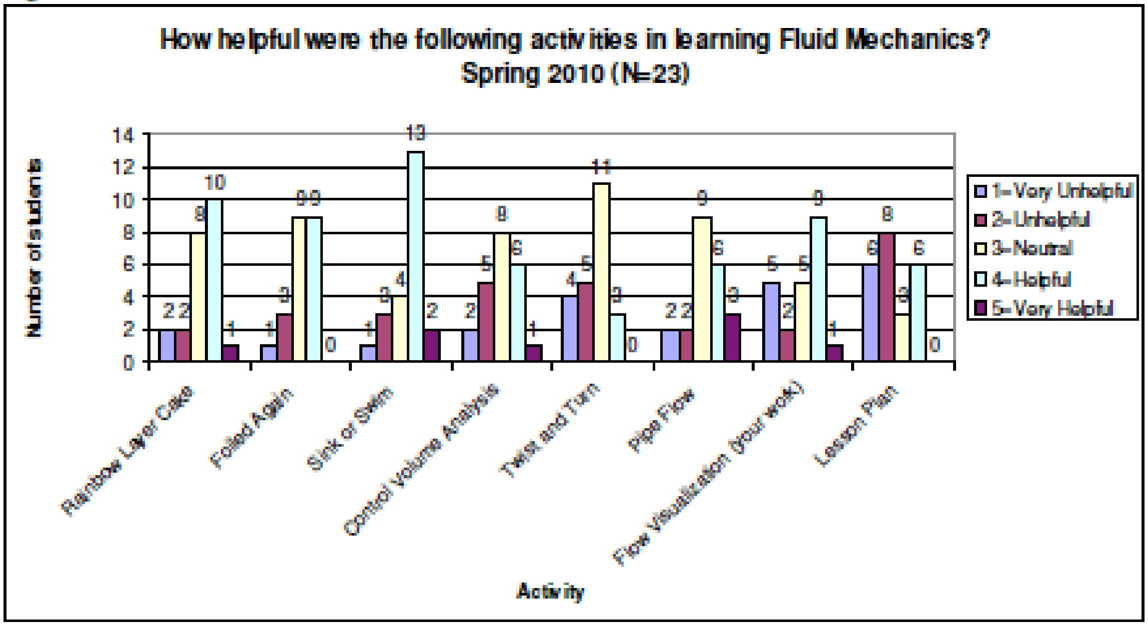
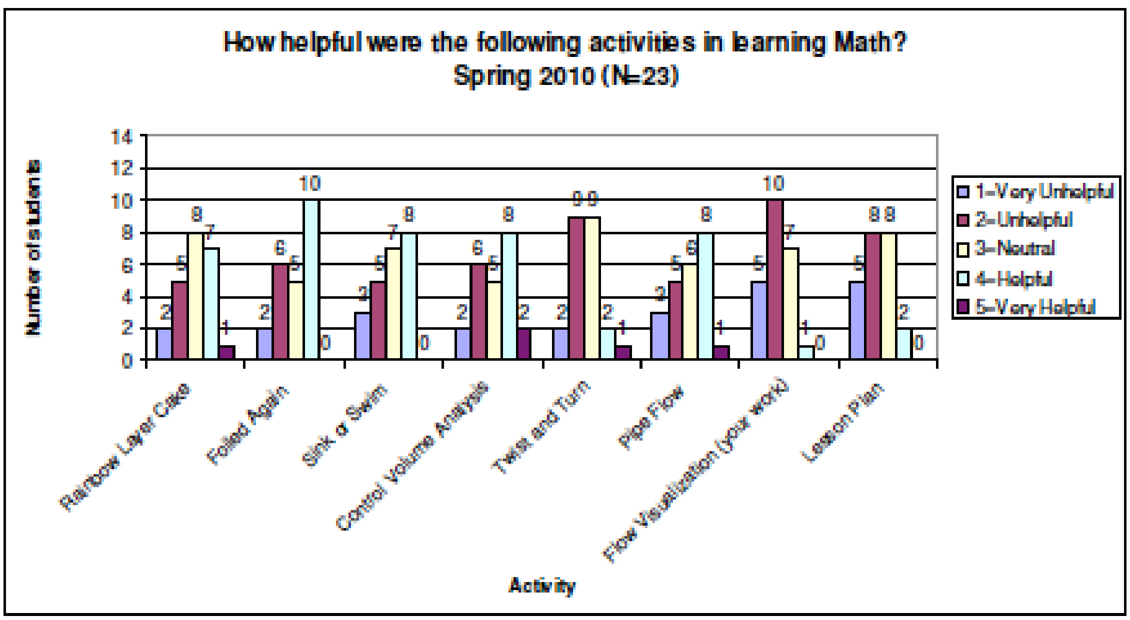


Figure 4



The students were also asked to rank the perceived level of difficulty of each activity using a Likert scale of 1 = very difficult, 2 = difficult, 3 = neutral, 4 = easy, 5 = very easy. The student responses are depicted in Figure 5 and Figure 6 for the Fall 2009 and Spring 2010 classes respectively.

Figure 5

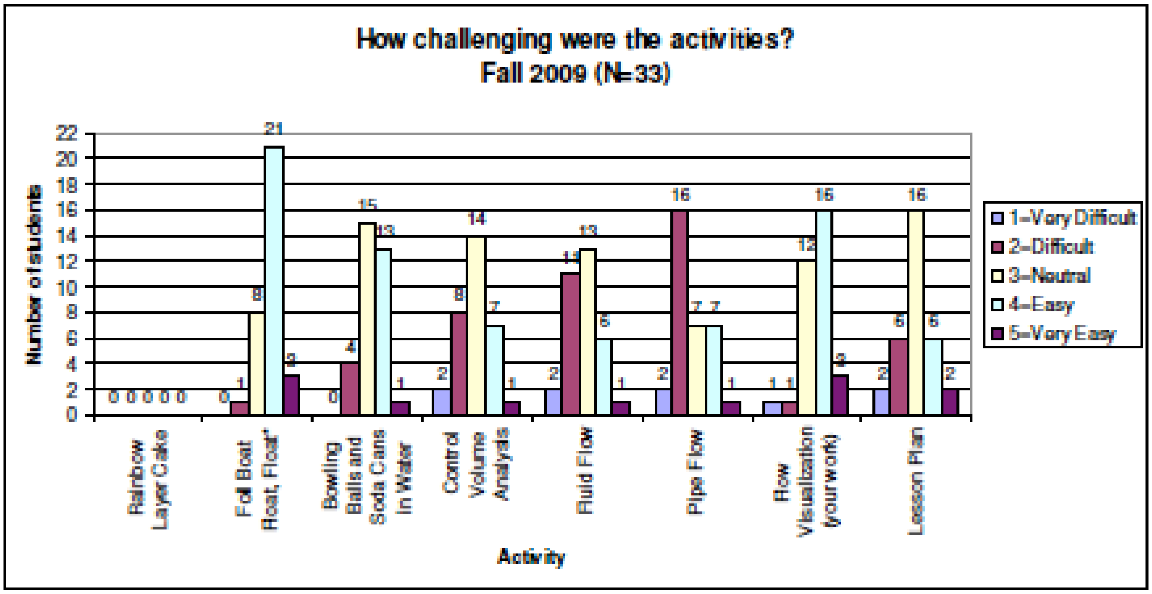
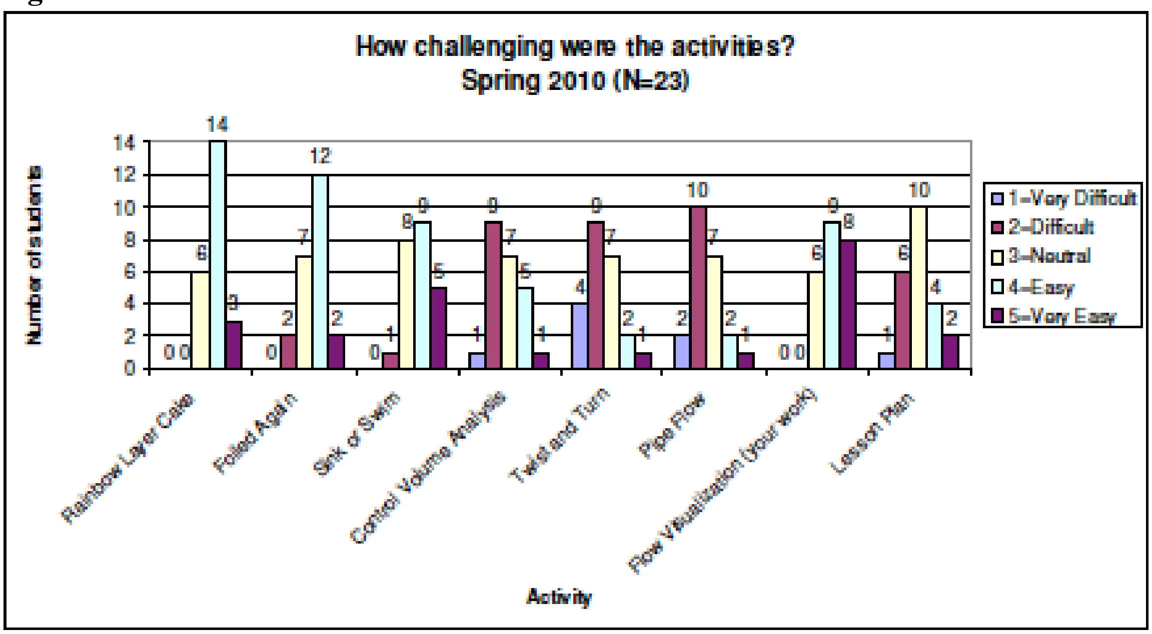


Figure 6



The students were also asked to rank how well they enjoyed each activity using a Likert scale of 1 = greatly dislike, 2 = dislike, 3 = neutral, 4 = like, 5 = greatly like. The student responses are depicted in Figure 7 and Figure 8 for the Fall 2009 and Spring 2010 classes respectively.

Figure 7

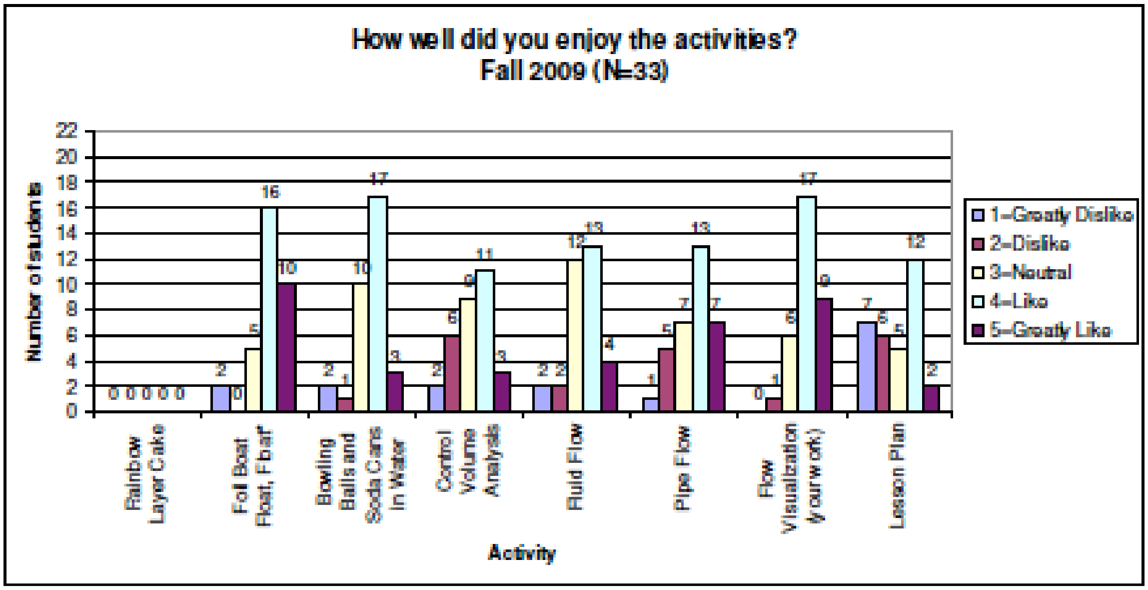
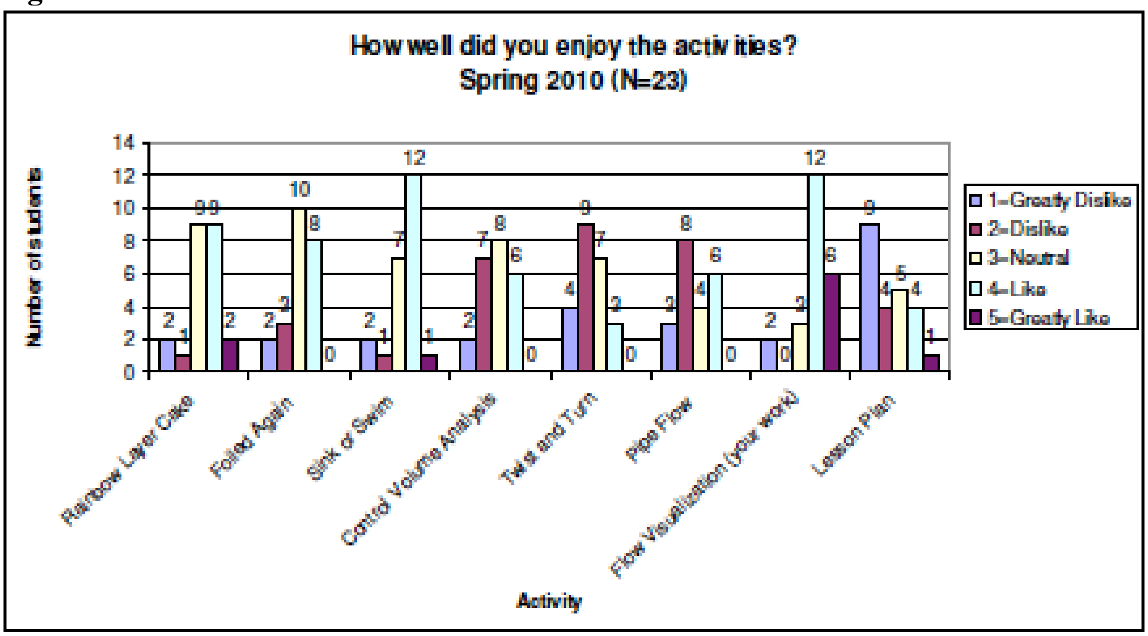


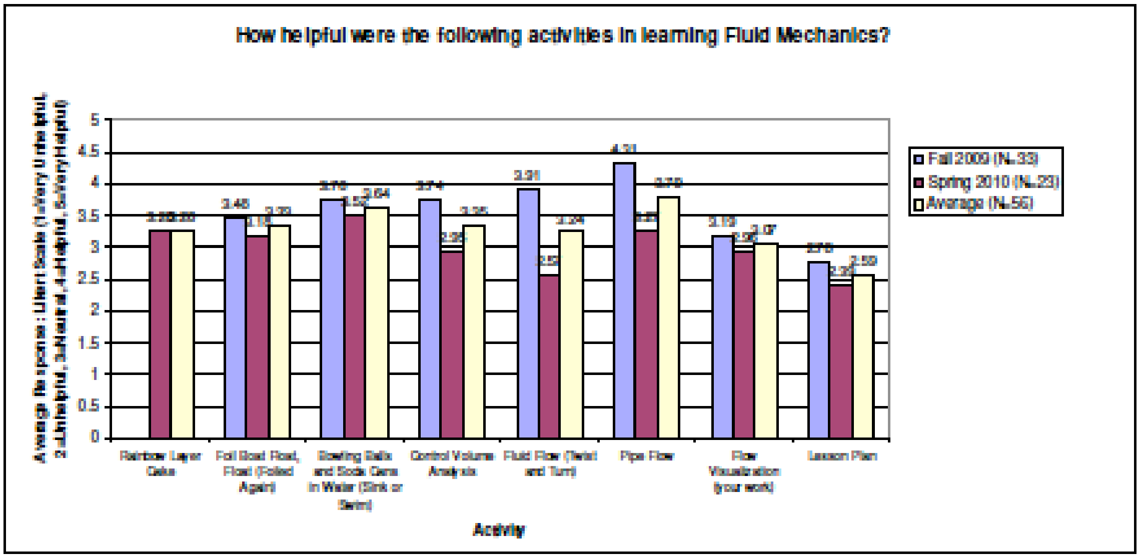
Figure 8



Survey Results

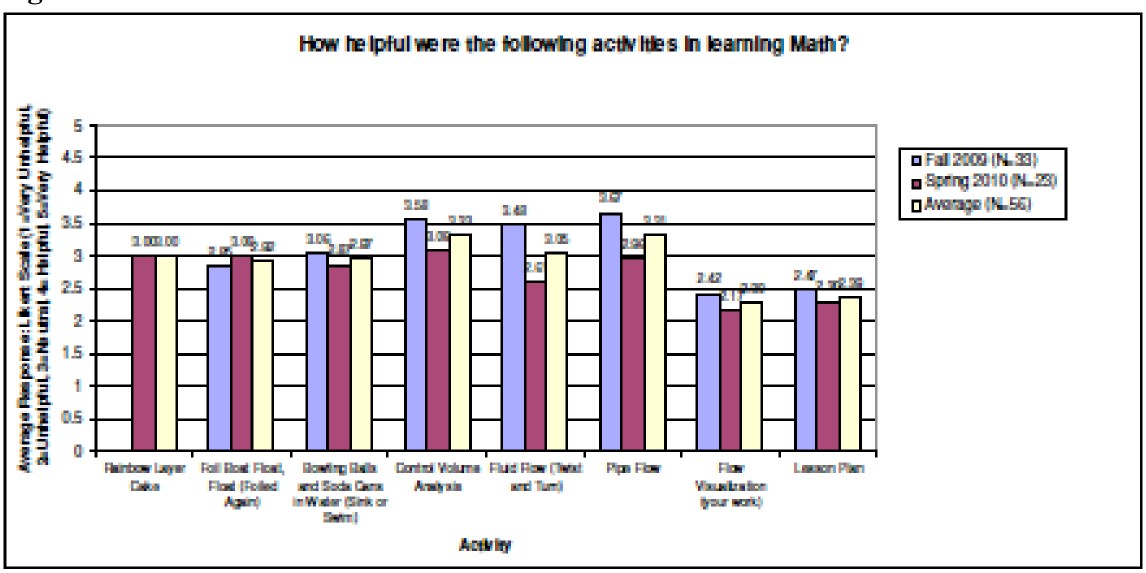
All students surveyed found most of the activities helpful in learning fluid mechanics. The most helpful one was *Construction Function* (Pipe Flow) © with an overall average of 3.79 (N=56). The least helpful was the out of class project, Lesson Plan. This project is either hated or loved but mostly hated. The most frequent feedback is in the form of, "If I wanted to be a teacher, I would have majored in education, not engineering."

Figure 9



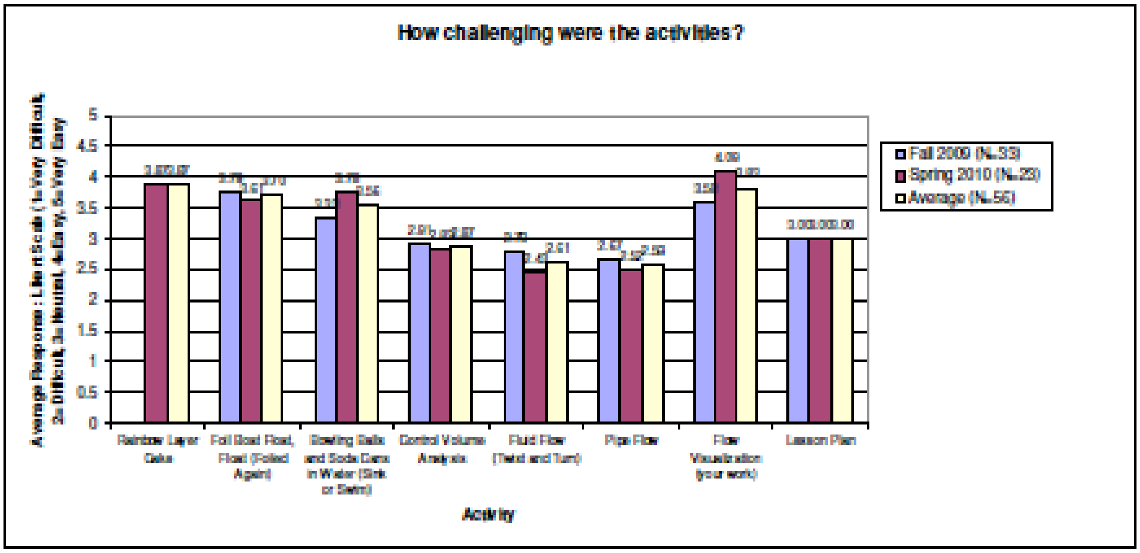
The two activities that proved to be the most helpful in learning math were *Marshmallow Madness* (Control Volume Analysis) © and *Construction Function* (Pipe Flow) © with averages of 3.33 and 3.31 respectively. The out of class project, Flow Visualization, while good for teaching fluid mechanics was not helpful in teaching math with the lowest average of 2.30.

Figure 10



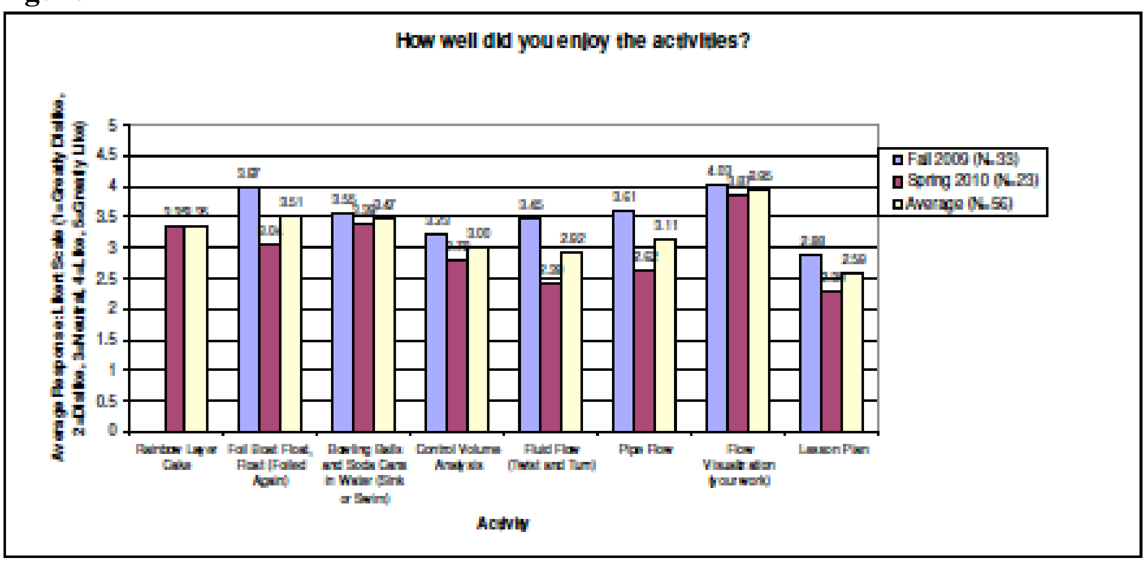
The most challenging activity proved to be *Construction Function* (Pipe Flow) © with a difficulty rating of 2.59.

Figure 11



For the most part, all activities were enjoyable with the most enjoyable one being Flow Visualization with an average of 3.95 and the least enjoyable being Lesson Plan with an average of 2.59.

Figure 12



Conclusion

In general, students perceive the activities to be helpful in teaching the basic concepts of fluid mechanics and math. In addition, the activities are enjoyable and help create a more relaxed learning environment in the classroom (from observation).

References:

[1] Belth, Marc. 1993. Metaphor and Thinking: The College Experience. Lanham, Maryland: University Press of America.

[2] R.M. Felder and R. Brent, "Active Learning: An Introduction." ASQ Higher Education Brief, 2(4), August 2009

[3] An original activity from RAMP-UP, a GK-12 Outreach Program at North Carolina State University

Appendix: Statistical Analysis of Survey Responses

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Foil_FM	Equal variances assumed	.584	.456	1.215	53	.230	.303	.249	-.197	.803
	Equal variances not assumed			1.239	49.075	.221	.303	.245	-.189	.795
Bowling_FM	Equal variances assumed	.018	.895	.904	54	.370	.236	.261	-.287	.759
	Equal variances not assumed			.894	45.530	.376	.236	.264	-.295	.767
CV_FM	Equal variances assumed	.284	.596	2.674	51	.010	.787	.294	.196	1.378
	Equal variances not assumed			2.682	45.858	.010	.787	.294	.196	1.378
FluidFlow_FM	Equal variances assumed	.332	.567	5.135	53	.000	1.341	.261	.817	1.865
	Equal variances not assumed			5.151	49.068	.000	1.341	.260	.818	1.865
Pipe_FM	Equal variances assumed	2.525	.118	4.117	52	.000	1.040	.253	.533	1.547
	Equal variances not assumed			3.820	33.377	.001	1.040	.272	.486	1.593
Visual_FM	Equal variances assumed	3.179	.080	.795	53	.430	.231	.290	-.352	.814
	Equal variances not assumed			.753	37.375	.456	.231	.307	-.391	.853
LessonPlan_FM	Equal variances assumed	.020	.888	1.169	53	.248	.390	.334	-.279	1.059
	Equal variances not assumed			1.186	49.858	.241	.390	.329	-.271	1.050
Foil_Math	Equal variances assumed	.534	.468	-.547	54	.587	-.152	.277	-.707	.404
	Equal variances not assumed			-.543	46.261	.590	-.152	.279	-.713	.410
Bowling_Math	Equal variances assumed	.000	.997	.644	54	.523	.191	.297	-.404	.785
	Equal variances not assumed			.650	49.084	.519	.191	.294	-.400	.782
CV_Math	Equal variances assumed	.313	.578	1.629	54	.109	.489	.300	-.113	1.090
	Equal variances not assumed			1.602	44.586	.116	.489	.305	-.126	1.103
FluidFlow_Math	Equal variances assumed	1.567	.216	3.017	54	.004	.876	.290	.294	1.458
	Equal variances not assumed			3.127	52.562	.003	.876	.280	.314	1.438
Pipe_Math	Equal variances assumed	.009	.924	2.292	54	.026	.710	.310	.089	1.331
	Equal variances not assumed			2.288	47.206	.027	.710	.310	.086	1.335
Visual_Math	Equal variances assumed	1.186	.281	.984	54	.330	.250	.260	-.270	.771
	Equal variances not assumed			1.001	52.721	.321	.250	.250	-.251	.752
LessonPlan_Math	Equal variances assumed	2.004	.163	.552	53	.583	.164	.298	-.433	.761
	Equal variances not assumed			.575	52.821	.567	.164	.285	-.409	.738
Foil_Challenge	Equal variances assumed	2.006	.162	.933	54	.355	.179	.192	-.206	.564
	Equal variances not assumed			.902	41.615	.372	.179	.199	-.222	.580
Bowling_Challenge	Equal variances assumed	.433	.513	-2.108	54	.040	-.449	.213	-.877	-.022
	Equal variances not assumed			-2.054	42.820	.046	-.449	.219	-.891	-.008
CV_Challenge	Equal variances assumed	.516	.476	.308	53	.759	.080	.260	-.442	.602
	Equal variances not assumed			.305	45.538	.762	.080	.263	-.449	.609
FluidFlow_Challenge	Equal variances assumed	.413	.523	1.338	54	.187	.353	.264	-.177	.883
	Equal variances not assumed			1.309	43.870	.197	.353	.270	-.191	.897
Pipe_Challenge	Equal variances assumed	.378	.541	.549	54	.586	.145	.264	-.385	.675
	Equal variances not assumed			.553	48.789	.583	.145	.262	-.382	.672
Visual_Challenge	Equal variances assumed	.077	.783	-2.309	54	.025	-.511	.221	-.955	-.067
	Equal variances not assumed			-2.328	49.863	.024	-.511	.220	-.952	-.070
LessonPlan_Challenge	Equal variances assumed	.134	.716	.000	53	1.000	.000	.266	-.533	.533
	Equal variances not assumed			.000	46.060	1.000	.000	.268	-.539	.539
Foil_Enjoy	Equal variances assumed	.004	.953	3.477	54	.001	.926	.266	.392	1.460
	Equal variances not assumed			3.534	53.050	.001	.926	.262	.400	1.453
Bowling_Enjoy	Equal variances assumed	.072	.789	.592	54	.556	.154	.260	-.368	.676
	Equal variances not assumed			.586	45.889	.561	.154	.263	-.375	.683
CV_Enjoy	Equal variances assumed	.474	.494	1.561	52	.125	.443	.284	-.126	1.013
	Equal variances not assumed			1.593	50.581	.117	.443	.278	-.116	1.002
FluidFlow_Enjoy	Equal variances assumed	.009	.924	4.002	54	.000	1.063	.266	.531	1.596
	Equal variances not assumed			4.049	49.355	.000	1.063	.263	.536	1.591
Pipe_Enjoy	Equal variances assumed	.045	.833	3.269	52	.002	.987	.302	.381	1.593
	Equal variances not assumed			3.281	43.231	.002	.987	.301	.380	1.594
Visual_Enjoy	Equal variances assumed	1.172	.284	.644	54	.522	.161	.250	-.340	.661
	Equal variances not assumed			.606	35.667	.549	.161	.266	-.378	.699
LessonPlan_Enjoy	Equal variances assumed	.018	.895	1.599	53	.116	.571	.357	-.145	1.287
	Equal variances not assumed			1.603	47.989	.116	.571	.356	-.145	1.287