2006-1880: AN ACTIVE LEARNING FLUID MECHANICS COURSE BASED ON OUTCOMES ASSESSMENT

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Abstract

In order to enhance the ongoing preparations of different engineering programs for ABET EC2000 accreditation, several colleges are encouraging transforming basic engineering courses into active/cooperative learning environment. The introductory fluid mechanics course represents a good candidate for such transformation because it is a mandatory course for several engineering programs. The fluid mechanics course under consideration in the present work is a 4-credit, 6-contact hours course and enrolls about 150 students in 5 sections per semester.

The course was redesigned and delivered during the last semester for one section only in order to compare results and evaluate the experience with respect to the other four sections having classical lectures but using data shows and power point presentations. The new course design reflected the 5 pillars of active learning, namely; positive interdependence, individual accountability, face to face interaction, social cooperative skills, and group processing. In order to address ABET EC2000 requirements, the course goal, course outcomes and outcome related course learning objectives were defined. Those learning objectives were based on Bloom's Taxonomy levels of learning and on Krathwohl and Bloom's degree of internalization. The course was intended to address five ABET technical outcomes (3.a, 3.b, 3.c, 3.e, and 3.k) and three non technical or soft outcomes (3.d, 3.g, and 3.i). The course assessment matrix was used to map the course learning objectives into those outcomes and indicate whether each objective addresses the corresponding outcome marginally, moderately, or substantially. It was demonstrated that ABET requirements were satisfied in this course.

Assessment of active learning outcomes in that one section was achieved in two dimensions. The first was the level of confidence the students had in their competency level of an itemized list of thirty three course learning objectives. This was assessed by the students themselves through a common questionnaire. In this regard, the students in the active learning class outscored their counterparts in the classical classes in each item of that list, and averaging by about 12% higher on overall. The second dimension was the students' grades by the end of the semester. Again, the students of the active learning section had higher grades than those of the classical sections by about 34%, even though they had common exams and evaluations in 80% of the course. These two strong results put active learning as a more appropriate strategy of introducing engineering courses than classical lectures.

1. Introduction

Fluid mechanics, as most other university courses, is usually presented in the form of lectures where the students listen to the “professor” as he delivers his lecture. The students in class would probably get a good deal of knowledge and would, hopefully, be convinced with the formulas through their derivation that takes place in the classroom.

1.1 The Quest for Change

Apart from the amount of knowledge that the students grasp, such mechanism of “knowledge delivery” lacks capturing the students’ interest in science. Therefore, graduates from such

programs would be obsolete among the candidates for future jobs, since the main role of future engineers is problem solving and decision making in a competitive market.

1.2 Paradigm Shift

The degrees obtained in engineering programs nowadays should equip graduates with the highest levels of knowledge. According to Bloom's Taxonomy, the higher levels of knowledge are the ability to synthesize and evaluate. Traditional programs of teaching would not be able to prepare the graduates to be able to employ those higher levels of knowledge. . Finally, industry knows that the engineers of the next century must be able to handle a rapidly evolving workplace where lifelong learning is essential to keeping up with the field's evolution¹.

Therefore, accreditation of higher education is no longer obtained through examining course contents in terms of the amount of knowledge presented, nor through checking the qualifications of the instructors. Rather, the new requirement for accreditation is based on the fact that college education should be considered as a product and, therefore, customer satisfaction should be verified and maintained. Industry is the customer, and it has to be satisfied with the product, the engineers, that should be verified to meet the future challenges. This is the whole essence of the process of accreditation of engineering education programs, i.e. outcome based assessment. This requirement in the expectation of higher education is a paradigm shift in the whole process of engineering education.

Sometimes when we teach our courses, we tend to lose sight of the fact that each course is but one element in a learning sequence defined as a curriculum. The closer the relationships are among courses, curriculum, and planned out of class activities, the more effective the learning experience will be for the students². The paradigm shift initiated by the appearance of ABET engineering accreditation criteria EC 2000, see Ref. [3], imposed on course designers to keep in mind this relationship between these three educational aspects. A course has to be designed, taught and assisted to address program objectives and outcomes.

2. Active Learning

The instructor can make the most of a classroom by turning it into active learning. The setup in the classroom would be discussion tables similar to business dinners rather than military seating of rows and columns. The instructor always prompts the students with questions trying to explore their thinking skills in an effort to build new concepts and relate the pieces of knowledge to each other. The questions should include "why", "how" and "what if". The exams may also stem from such groups by letting the team members discuss the exam in their groups, with pens down, for the first five minutes only. Everybody should take the exam separately in the normal fashion.

The idea of considering education as an active, dynamic process has led to extensive research on the benefits of some aspect of active student involvement in the learning process⁴. It had been shown that long term learning occurs when the "learner" integrates the new information with the information they already have to create a new body of knowledge. This process is known as restructuring; the active learning classroom encourages restructuring.

The purpose of the active learning model is to encourage students to be mentally, emotionally, and physically engaged in the process of learning. The number of methods and techniques that can be included in this definition seems infinite; consequently, it is impossible to engage the students in all of the possible active learning experiences. Nevertheless, the use of student teams, continuous improvement of the learning process and constructivist learning exercises in class are among the well established active learning techniques⁵. Students'

participation in classroom discussions presents multi-fold benefits. It increases his knowledge, develops his communication skills and incorporates him as part of the course.

2.1 Concept-Based Formula Development

Faculty members in engineering education are true scientists and, hence, are fond of scientific proofs. This enthusiasm is translated into mathematical exercises in the classroom that the professors enjoy to perform in front of students. During such process, the emphasis on the mathematical aspects establishes the students vision within a narrow window of theoretical borders.

An alternative approach would be to involve the students in realizing the formulas involved in the course. The approach starts with imagining a situation where the particular scientific law is employed. Students are then prompted with a question on the factors, i.e. variables, that would affect the performance of the process. Upon expressing the functional relationship between the variables and the term to be measured, students would determine the role of each of those variables in the equation. In other words, they should be able to decide whether the variable is directly proportional or inversely proportional to the term being considered. This process employs group discussion such that each team realizes the correlation. The instructor may guide the students' thinking by proposing virtual experiments where students think about the situations such that the variables are examined one at a time. In other words the professor acts as a facilitator at most stages of the lecture. His knowledge would be instrumental in the mathematical background of the subject and the correlation with other equations.

2.2 The Reality of Fluid Mechanics

The most important aspect in a university lecture would be the value of "knowledge" being taught to the students attending the lecture. One of the worst dilemmas related to university education among students is the lack of feeling about the importance of the material covered in the classrooms. The most important aspect of engineering knowledge is its applications in real life. Unfortunately, such information is scarce in university textbooks. Therefore, the engineering courses become irrelevant to the students' area of concern and, hence, the students lose interest in the subject.

However, the classroom presents a remedy to this weakness. The professor's experience lies in the wealth of applications he is aware of, and therefore he should relate those applications to the theory being studied. The applications related to the engineering concepts should be well emphasized by the instructors. This element of education is often not well-covered in class.

The nice aspect about fluid mechanics is that there is a vast number of applications that could be cited employing the principles of fluid dynamics and hydrostatics. For instance, viscous effects may be observed in slippery floors especially if oil drops are found on the floor of a garage. The soap bubble is a good indication of surface tension. Stirring a cup of coffee with milk just poured in reveals the streamlines of the flow. Increasing the flow rate in tap water changes the flow regime from laminar to turbulent.

Principles of manometry are employed by homebuilders in determining the elevations of sockets on the walls being built. But there is a more obvious situation where the fluid level stays the same when exposed to the same pressure, such as the atmosphere. It is the scene observed every morning when milk is poured onto corn flakes. Effect of hydrostatic forces is manifested in dams built where the wall gets thinner as we go up. Buoyancy is found in every cup of cold drink or water with a piece of ice in it.

Applications of fluid motion are no less in our lives, whether our bodies or surroundings. The force exerted on firemen as they try to hold the pipe when the fire extinguishing fluid is turned on demonstrates the force due to conservation of momentum. Conservation of mass is exemplified in the blood circulatory system of our bodies. The water piping system in our houses covers the energy equation along with the friction losses.

When TV adds show sports cars, flow visualization of the streamlines is utilized to determine the efficiency of the vehicle configuration in motion. The list goes on and on emphasizing the presence of fluid mechanics in the students' everyday lives. This way, the students are expected to feel the relevance of fluid mechanics to their world, and henceforth an interest in the subject is created.

2.3 Methodology of Teaching

In what follows is a deliberation of an interactive process for the basic chapter in the first course of fluid mechanics.

Syllabus: To start with, students are asked to think about what could be of importance in this subject. The students would bring up examples of pipe flow, rivers, dams, airplane motion (aerodynamics). Then the instructor is advised to bring their attention to more interesting and applied problems. One of the prompts would be to inquire about the possibility of fluid mechanics problems in their bodies. Eventually, they would come up with the flow of blood in our bodies.

Then, another prompt could be about things that they might had before coming to class that morning, e.g. drinking a cup of coffee. The shape that they observe on the coffee with milk when they stir to dissolve the sugar resembles vortex motion displaying streamlines. The other interesting situation could be bringing up a picture of the American female sprinter who used to be the Olympic champion in 100 and 200 m distances. She used to cover herself up with a black suit stretching from her head up to her toes. This is to show the students that aerodynamics is not the science for supersonic fighters only, but it belongs to our motion, and our life in a more panoramic view.

Consequently, students would start recalling more and more fluid mechanics examples, e.g. ship motion, the soap bubble, and the power required to pump water from the ground reservoir to the one at the top of the building they are residing in. This would draw the students' attention to the wide variety of applications of fluid mechanics in our lives, and henceforth the importance of learning the material with a spirit of enthusiasm.

Upon collecting all ideas, the topics are classified into categories of fluid mechanics fields. Thereby, one of the first things introduced would be the difference between hydrostatics and fluid mechanics. This way the students build a mind map of the course creating an interest in their subconscious memory because all the material covered in the course would be from the menu of their proposed topics.

The mind map would take the student from manometry to hydrostatic forces on surfaces, ending the fluid statics part at buoyancy and floating bodies. The student can imagine the fluid dynamics section by considering the conservation laws, i.e. mass, momentum and energy. The map would lead the students to cover more and more of specialized topics including modeling and similitude, pipe flow, and flow patterns. Table 1 presents the course outline with the syllabus distributed along the semester.

Fluid Properties: Students are able of recalling many properties of fluids, but may miss some of them such as viscosity. The instructor should not, in this case, teach them the new term by throwing the knowledge to them. Rather, he should seed it by raising their concern

about practical situations where viscous effects are relevant. An example could be the story of a student coming late to class in a hurry without noticing the sign of “wet floor” which the janitor had put! The question should be about the experience that the student might undergo. Obviously, the student would slide. Then, the important question should be: WHY? This is the word that the instructor should pose tens of times each session. The students would eventually realize the viscous effect.

Viscous Forces: Emanating from the last example, the instructor may extend the scenario of the late student “skating” on the wet floor by comparing that case with the virtual situation where the floor was wetted with oil rather than water! Interestingly, the author told his students about a situation where he was coming out of a successful meeting with the university rector. The author was walking fast in great joy towards his car which was in the basement of the administration building. The parking lot is made of solid clean smooth concrete. The author did not realize that there were some oil drops on the floor from one of the cars which left the parking lot. The scene was worth filming to demonstrate the effect of viscosity as the instructor had a “free ride” for some meters before having an unpleasant “touch down”.

This story was utilized by the author to let his students develop the equation for the viscous force by asking them about the factors that led to his slide. But the instructor should push it only that far. The rest should be up to the students’ innovation in relating what factors affect calculation of the shear stress, i.e. $\tau = f(\mu, V, \Delta y)$.

The students came up with these parameters: V (velocity), Δy (quantity of oil indicating its height), μ (viscosity) and ρ (density). The problem was that at least half of the class included the density in their answers. Then came the role of the instructor to guide them to realize the independence of the shear force on the density. He prompted their thinking by asking the following question: What difference would have been if the oil drops on the floor were replaced by water drops? The viscous force would almost vanish, of course. Still, the students believed that oil is more dense than water and, therefore, the viscous effect was less. So the instructor asked them about the food that their mother cooked for them; was the oil on top of the water in the pot? Then students realized that oil is less dense than water. Thereby, ρ was excluded from the relationship and the confusion was cleared.

The next task was to build the relationship. The instructor asked each group to think of virtual experiments to test the effect of each of the four parameters. For instance, if the instructor was coming out from the rector office in a dismal manner such that he was walking slowly, what implications this would have? The comparison of such situations gave the students clues to the effect of each one of the parameters and the equation was built by the students themselves. This elaborates on the methodology stated earlier (section 2.1 Concept-Based Formula Development).

Surface Tension: The instructor may blow a soap bubble, obtained from children toys markets, in front of students to see that it moves like a balloon in the classroom. The first goal was to let students relate the natural observations they had been watching in the past to the scientific basis of fluid mechanics or engineering, in general. The second goal was to enable students to deal with fluid mechanics problems as an important aspect of our everyday life, including children toys.

The process goes on and on to cover the rest of the course contents from fluid statics to fluid dynamics and dimensional analysis. The point made here is that this process of mental involvement with the subject establishes students’ awareness with the scientific knowledge the instructor tries to deliver.

Table 1: Course Structure of the (ME 290) Fluid Mechanics Course.

Week	Session	Designation	Description	Pages
1	1	M1_1	Introduction, First day materials, Forming teams	
	2	M1_2	Introduction to fluid mechanics, Fluid viscosity	3-28
	3	M1_3	Team work exercises on fluid viscosity	
2	4	M2_1	Surface tension, Vapor pressure, Speed of sound	29-37
	5	M2_2	Streamlines, Flow visualization	38-43
	6	M2_3	Introduction to FM Lab, Error analysis, Lab 1	
3	7	M3_1	Individual exam1	
	8	M3_2	Fluid statics & manometers	63-77
	9	M3_3	Team work exercises on manometers	
4	10	M4_1	Hydrostatic forces (plane surfaces)	78-83
	11	M4_2	Team work exercises on plane surfaces	
	12	M4_3	Hydrostatic forces (curved surfaces)	84-88
5	13	M5_1	Team work exercises on curved surfaces	
	14	M5_2	Buoyancy, stability, rigid body motion	69-102
	15	M5_3	Lab 2	
MID TERM COMMON EXAM 1				
6	16	M6_1	Reynolds transport theory, Conservation of mass	135-152
	17	M6_2	Team work exercises on the continuity equation	
	18	M6_3	Momentum equation	153-171
7	19	M7_1	Team work exercises on the momentum equation	
	20	M7_2	Individual exam 2	
	21	M7_3	Lab 3	
8	22	M8_1	Conservation of energy	172-192
	23	M8_2	Team work exercises on the energy equation	
	24	M8_3	Lab 4	
9	25	M9_1	Individual exam 3	
	26	M9_2	Dimensional analysis (homogeneity)	293-302
	27	M9_3	PI theorem	303-308
MID TERM COMMON EXAM 2				
10	28	M10_1	Design Project Lab1	
	29	M10_2	Design Project Lab2	
	30	M10_3	Design Project Lab3	
11	31	M11_1	Team work exercises on PI Theorem	
	32	M11_2	Similitude	
	33	M11_3	Team work exercises on similitude	
12	34	M12_1	Individual exam 4	
	35	M12_3	Viscous flow in pipes (fully developed flow)	343-360
	36	M12_3	Turbulent pipe flow	361-375
13	37	M13_1	Team work exercises on pipe flow	
	38	M13_2	Flow in non-circular ducts	376-384
	39	M13_3	Lab 5	
14	40	M14_1	Minor losses	385-399
	41	M14_2	Team work exercises on flow losses	
	42	M14_3	Lab 6 / Project oral and written presentations	
FINAL COMMON EXAM				

2.4 Tools

In addition to the audio-visual aids, the instructor can utilize some of the new books involving real life projects/problems. Schaum's Outline Series has joined forces with MathCad to create the next generation in learning tools: "Schaum's Interactive Mechanics and Hydraulics"⁶. Each of its 100 problems features a built-in calculation that lets the student change variables, test ideas, and instantly get the effect in an accompanied diagram or graph. Besides textbooks, some lecture notes are available on the net. The downloadable and printable pages from Leeds University in the UK⁷, Sri Venkateswara College of Engineering in India⁸, Massachusetts Institute of Technology in the US⁹ are some of the examples instructors may find useful when designing their courses.

2.5 Team Exercises

The course was designed to give the students a chance to work, in groups, on ten exercises. These exercises are obtained from Ref. 6. The following are suggested problems to be used by instructors as team exercises:

SUBJECT	SUGGESTED PROBLEMS
Fluid viscosity	1.11, 1.28
Manometers	2.18, 2.73
Submerged plane surfaces	3.6, 3.34
Submerged curved surfaces	3.13, 3.47
Continuity equation	7.6, 7.54, 12.4 and 12.41
Momentum equation	13.8, 13.76
Energy equation	7.24, 7.35
PI theorem	6.9, 6.61
Pipe flow	8.8, 8.10
Flow losses	8.15, 8.22, 8.26

2.6 Exam Problems

The exams should be as relevant as possible to themselves, at least one of the problems, such that the taste of active learning stays active in the exams, too. Here are a few examples:

1. You were asked to find your density, so you entered in a cylinder full of water. The cylinder was 2 m high while its diameter was 1.4 m. As you entered the tank an amount of 0.5 m^3 spill over the floor. As you stood straight up in the tank, your body floated such that half of your head was above the water level. Make necessary assumptions to calculate your density?
2. The city municipality installed several artificial falls to the attractions the city already has. Water flows down one of those mountains at a flow rate of $0.186 \text{ m}^3/\text{s}$, through a 5 cm diameter pipe. Find the pump power required to pump the water to the top of the mountain which is 16m high.

3. Assessment

In addition to the pleasure both the instructor and the students find, the course structure and its outcomes have to be assessed both academically and actually by assessing the levels of learning achieved.

3.1 Levels of Learning and ABET Requirements

The academic measure for the success of interactive learning lies in the assessment of the course with regard to achieving the six knowledge levels of Bloom's Taxonomy. First of all, the learning objectives of the course are listed in Table 2. They are comprised of 33 items. Since the contents of fluid mechanics at the introductory level have not changed for several generations^{10 & 11}, the outcomes addressed by the proposed course must include at least those addressed by classical fluid mechanics courses as found in the table. However, the list includes other items and, therefore, could be classified into four categories as follows:

- a. Technical Knowledge
- b. Experimentation
- c. Team Work
- d. Creativity and Life Skills.

The outcomes presented in Table 2 typically include the well known ABET a-k criteria (see for example Ref. [12]). The extent of achieving those objectives in this course of fluid mechanics (ME 290) is demonstrated in Table 3, where the ABET 2000 outcomes are listed in the header row. The extent of achieving those levels according to Bloom's Taxonomy, see Refs. [13] and [14], is represented in terms of the letters A, B, or C in the following manner:

- A: skill levels 1 or 2 (knowledge or comprehension),
- B: skill levels 3 or 4 (application or analysis), and
- C: skill levels 5 or 6 (synthesis or evaluation).

It is evident from the matrix that the course learning objectives satisfy ABET requirements.

3.2 Comparative Assessment of the Course Outcomes

Finally, the extent of achieving those objectives and the grades of the students in the course were assessed. The circumstances were just right for conducting a comparative assessment on the effect of active learning on the students' comprehension of the subject and their performance in the exams. There were five sections of Fluid Mechanics offered last semester (Fall 2005), but only one of them was conducted using active learning, as outlined earlier. There was a total of 92 students in the sections using classical teaching, while 27 students were in the section employing active learning. This prompted an excellent situation for a scientific comparison based on a good sample of students.

To start with, the performance of students in the exams is assessed. The major exams, the final exam and the lab work were common to all sections, leaving only 20% of the grade to the instructor for class work including quizzes. The students in the active learning section outscored their colleagues in the other four sections by 34%. On the other hand, a questionnaire was conducted after the students submitted their final exam, and obviously was filled by all students. Each student expressed his level of competency in each of the 33 elements in the list on a scale from 1 to 5 (1 being the lowest and 5 being the highest) as shown in Table 4. The results were demonstrated in Fig. 1. The outcome was remarkable, since the assessment in each item was in favor of active learning. The average competency level of the students in the active learning class was 3.77 while that for students in the rest of the sections was only 3.18, both results being out of 5. On the average this could be translated to a 12 % leverage of active learning strategy in conducting engineering courses.

Table 2: Course Learning Objectives.

1	Recognize the meaning and the definitions of different fluid properties such as pressure, density, temperature, viscosity and velocity fields.
2	Calculate shear stresses and viscous forces under various circumstances.
3	Understand the laws related to fluid properties including ideal gas law, surface tension and speed of sound.
4	Classify flow conditions (Steady vs. Unsteady, Inviscid vs. Viscous, and Incompressible vs. Compressible).
5	Identify flow situations using streamlines, pathlines and streaklines.
6	Apply manometry for measurements of pressure.
7	Evaluate pressure distribution in a hydrostatic fluid.
8	Calculate pressure forces on submerged bodies of different geometries including flat and curved surfaces.
9	Predict Buoyancy forces on floating bodies.
10	Understand the stability concept of floating bodies.
11	Apply Reynolds transport theorem to obtain conservation laws of fluid mechanics.
12	Solve problems of conservation of mass using steady as well as unsteady continuity equation.
13	Evaluate dynamic fluid forces using the linear momentum equation (Newton's second law of motion).
14	Calculate energy requirements (i.e. shaft work) of fluid flow in light of potential and kinetic energies using the energy equation.
15	Formulate non-dimensional equations using π -Theorem.
16	Analyze flow simulate and model-prototype similarity using dimensional analysis.
17	Analyze fully developed laminar and turbulent pipe flows.
18	Calculate pipe losses using Moody chart.
19	Evaluate pressure losses in fittings, valves and sudden enlargements/contractions.
20	Use simple measuring devices and understand their physical principles.
21	Prepare written reports relative to lab experiments.
22	Understand the different roles / responsibilities of being an effective member in a team.
23	Resolve conflict and reach agreement in a group.
24	Accept and value the importance of fluid mechanics for engineering practice.
25	Relate fundamentals of fluid mechanics to the wide spectrum of real life problems
26	Simplify complicated fluid problems using suitable assumptions.
27	Divide complex fluid problems into manageable tasks and assemble solutions together.
28	Learn with self esteem.
29	Generate ideas creatively.
30	Tackle real life problems with confidence
31	Think about engineering solutions even if you are not responsible for them.
32	Accept and value the importance of team working for engineering practice.
33	Accept and value the efficiency of active learning in engineering disciplines.

Table 3: Mapping the Learning Objectives onto ABET 2000 Outcomes Matrix.

Learning Objectives	3a	3b	3c	3d	3e	3f	3g	3h	3i	3j	3k
1									B		
2	B										
3	B										
4	B										
5	B										
6	B		A								
7	B		A								
8	B		A								
9	B										
10	B										
11	A										
12	B		A								
13	B										
14	B										
15	B										
16	B		A								
17	B										
18	B		B								
19	B		C								
20	B		A								
21		B					A				
22				B			A				
23				B			B				
24					B						A
25	B				B						A
26	B				B						A
27	B				A						A
28									B		
29	B				C		A		B		A
30					A		A				A
31							A		B		A
32				B						A	
33									B		

A: Skill level 1 or 2 in Bloom's Taxonomy

B: Skill level 3 or 4 in Bloom's Taxonomy

C: Skill level 5 or 6 in Bloom's Taxonomy

Table 4: Students' Questionnaire on Course Outcomes

Upon completing this course indicate your level of confidence in your ability to perform each of the following tasks. For example, if you have little or no confidence in your ability to recognize the meaning of different fluid properties, then mark Poor. If you are extremely confident of your ability, mark Excellent.

<i>Upon completing my fluid mechanics course, I can:</i>		<i>Poor</i>	<i>Fair</i>	<i>Good</i>	<i>Very good</i>	<i>Excellent</i>
1	Recognize the meaning and the definitions of different fluid properties such as pressure, density, temperature, viscosity and velocity fields.	1	2	3	4	5
2	Calculate shear stresses and viscous forces under various circumstances.	1	2	3	4	5
3	Understand the laws related to fluid properties including ideal gas law, surface tension and speed of sound.	1	2	3	4	5
4	Classify flow conditions (Steady vs. Unsteady, Inviscid vs. Viscous, and Incompressible vs. Compressible).	1	2	3	4	5
5	Identify flow situations using streamlines, pathlines and streaklines.	1	2	3	4	5
6	Apply manometry for measurements of pressure.	1	2	3	4	5
7	Evaluate pressure distribution in a hydrostatic fluid.	1	2	3	4	5
8	Calculate pressure forces on submerged bodies of different geometries including flat and curved surfaces.	1	2	3	4	5
9	Predict Buoyancy forces on floating bodies.	1	2	3	4	5
10	Understand the stability concept of floating bodies.	1	2	3	4	5
11	Apply Reynolds transport theorem to obtain conservation laws of fluid mechanics.	1	2	3	4	5
12	Solve problems of conservation of mass using steady as well as unsteady continuity equation.	1	2	3	4	5
13	Evaluate dynamic fluid forces using the linear momentum equation (Newton's second law of motion).	1	2	3	4	5
14	Calculate energy requirements (i.e. shaft work) of fluid flow in light of potential and kinetic energies using the energy equation.	1	2	3	4	5
15	Formulate non-dimensional equations using π -Theorem.	1	2	3	4	5
16	Analyze flow simulate and model-prototype similarity using dimensional analysis.	1	2	3	4	5
17	Analyze fully developed laminar and turbulent pipe flows.	1	2	3	4	5
18	Calculate pipe losses using Moody chart.	1	2	3	4	5
19	Evaluate pressure losses in fittings, valves and sudden enlargements/contractions.	1	2	3	4	5
20	Use simple measuring devices and understand their physical principles.	1	2	3	4	5
21	Prepare written reports relative to lab experiments.	1	2	3	4	5
22	Understand the different roles / responsibilities of being an effective member in a team.	1	2	3	4	5
23	Resolve conflict and reach agreement in a group.	1	2	3	4	5
24	Accept and value the importance of fluid mechanics for engineering practice.	1	2	3	4	5
25	Relate fundamentals of fluid mechanics to the wide spectrum of real life problems	1	2	3	4	5
26	Simplify complicated fluid problems using suitable assumptions.	1	2	3	4	5
27	Divide complex fluid problems into manageable tasks and assemble solutions together.	1	2	3	4	5
28	Learn with self esteem.	1	2	3	4	5
29	Generate ideas creatively.	1	2	3	4	5
30	Tackle real life problems with confidence	1	2	3	4	5
31	Think about engineering solutions even if you are not responsible for them.	1	2	3	4	5
32	Accept and value the importance of team working for engineering practice.	1	2	3	4	5
33	Accept and value the efficiency of active learning in engineering disciplines.	1	2	3	4	5

Students' Evaluation of Course Outcomes

Figure 1: Results of students' evaluation of their level of confidence.

3.3 Students' Works

Working in groups, students are expected to formulate the expressions for various relationships. But what is more interesting is the creative thinking of developing experiments to correlate the variable with each other. For instance, in the quest to correlate viscous forces, one group of students proposed throwing a book on a wetted table in a sliding manner. The book would slide for some distance. Then the fluid wetting the table surface is changed, and the book is thrown at the same force. The distance traveled by the book gives a relative measure of the viscosity of the fluid acting as a lubricant. Another group proposed an experiment where the viscous force is measured by a rope-pulley system. On one side a plate is immersed in a cup of coffee. The plate is attached to the rope such that weights are placed at the other side of the pulley. The force is measured by the weight required to make the sheet just start moving up out of the coffee in the cup. The same experiment is to be repeated using honey in the cup instead of coffee. The difference in weights is indicative of the viscous forces experienced in both cases. Many more experiments/projects could be illustrated in the fields of dams, fluid levels in tubes, fluid motion and the associated forces, pump and turbine utilization in real life situations.

4. Conclusion

The knowledge sought in engineering education nowadays should equip graduates with the highest levels of tools required to tackle tough challenges. Unless students enjoy building the knowledge in class room, graduates will be handicapped when faced with such challenges. Active learning is an essential ingredient in making students absorb the scientific knowledge deemed and in building an interest in the formulas they would otherwise memorize. The role of the instructor lies in emphasizing the important aspects of the subject especially in learning the logic behind modeling and problem simplification. Ultimately, active learning was found to be quite instrumental in motivating students to gain knowledge. One of the students wrote in the assessment sheet that they have to fill at the end of each class: This class is our class and not yours. Dealing with students, their performance both academically and learning-skills wise was assessed thoroughly in comparison with the students taking the same material and the same exams at four other sections but not subject to active learning. All of the results were very encouraging, i.e. in favor of adopting active learning as the strategy for preparing future engineers.

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