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# Testing Students' Knowledge Gain in Active Learning ”Lab-Similar” Environment through Pre and Post Lab Questionnaires

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## Abstract

In a recent paper, five interactive activities were added to Applied Fluid Mechanics course (MET31300) offered at Purdue's University School of Engineering Technology. The previous paper was presented and published in the 126$^{th}$ ASEE Annual conference in Tampa, Florida. The paper presented challenges facing active learning techniques, presented the proposed activities along with a case study where the activities were applied. Students' scores were compared at the end of the semester with other classes when the course was offered with no active learning activities. The proposed activities were applied in three consecutive years and the students' performance was assessed and compared to another group when no active learning activities were used.

To further investigate the direct effect of each activity on students' knowledge, the proposed activities presented in the previous paper were repeated in the same course (Applied Fluid Mechanics) but checking students' knowledge of certain topics before and after conducting or completing the activity. Pre-lab and post-lab questionnaires were handed to students during the lab session and they were asked to answer the questions in the questionnaire without using the textbook, notes or other online sources. Ten questionnaires were designed, five to test students' knowledge prior and five after each lab. The questions given in the post lab questionnaires were relatively at a higher level of difficulty than those given in the pre-lab questionnaires. The percent increase in the average scores for all labs range between 22-75%. The percent increase or improvement was seen to increase through the labs from lab 1 to 5; a trend that would require further investigation to see if it was related to improved performance as the course progressed or due to more familiarity in one topic than the other.

**Keywords:** *active learning, team oriented, interactive learning, student centered, students' survey, pre post questionnaires testing.*

## Introduction

Fluid mechanics is a traditional required course in the engineering and engineering technology programs. Students from different majors including mechanical, electrical and/or civil engineering are required or are interested in taking it due to its wide applications in the industry sectors.

Fluid mechanics is usually taught as a 3-credit hour course with no laboratory embedded to it. Due to rising market demands, employers are seeking more than just the knowledge gained through conventional lecturing in class. There has been raising interests in innovation, logical thinking, complex problem solving in diverse setting environment, team work, and communication skills as well [1]. To meet these new market requirements in the new graduates directly after college, new modernized teaching paradigms and technics are needed [2]. Such techniques could include lab activities, group discussions, small projects throughout the course, flipped teaching techniques or project based course where students select a project to implement or are assigned one and then the topics they cover are selected to meet the objectives of their project.

Courses taught in the form of problem based learning is thought to present a powerful pedagogical tool in learning nowadays, but it has its own benefits and draw backs [3]. Student-centered environments have been known to increase communication skills, ability to work with others in a team, practice logical thinking skills, while being innovative and creative [4]. Evidence is also available that shows this kind of learning environment encourages quantitative reasoning and complex problem solving skills as they are routinely practiced in the work involved in this classroom pedagogy [5].

Students learning and their success in such environments depend on many factors such as the students previous experience in the subject taught, their motivation and interaction within the group or team they are working with.

To help meet the new market needs, the author added five activities to the course where they were conducted similar to a lab testing environment or were demonstrated by the instructor and the students were asked to analyze the results in teams depending on time and testing stations.

Each activity covered certain course learning outcome outlined for the course while engaging the students in a team oriented and active learning environment. The effectiveness of the applied approaches and students' outcomes were previously evaluated using instructor observations, students' scores for submitted reports and test scores, as well. Those were presented during the 2019 ASEE Annual conference in Tampa, Florida and were documented in the proceedings of the conference [2]. All the activities and the lab similar exercises can be found in the reference which is in the proceedings of the 2019 ASEE Annual Conference [2].

In this study, the same activities presented in [2] were repeated for the 3rd consecutive year, but this time, questionnaires were designed and given to students before and after each lab session to test the students' knowledge gain from each activity or lab.

**Research Questions**

The following two questions were the driving questioning behind the questionnaires designed that are presented in this paper:

Q1. What is the effect of each of the added labs/activities on the students' performance?

Q2. How does the overall score look like when using these activities in the course?

**Methodology and Questionnaires**

Before presenting the methodology for this paper, the five introduced activities are summarized below in Table 1. The table also shows the related course learning outcomes (CLOs) for each activity, and the related ETAC ABET outcomes (old outcomes). Each activity, as will be discussed below, was preceded and followed by questionnaires testing the students' knowledge in topics related to the activity title as indicated in Table 1.

**Table 1**. Introduced activities and their relations to CLOs and ABET outcomes

| Activity | **Course Learning Outcomes** | | | | | | | | | ABET Outcomes |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | |
| 1) Buoyancy | ■ | | ■ | | | | | | | a, b, c, d, e, f, g |
| 2) Mass Flow Determination | | | | ■ | | ■ | | | ■ | |
| 3) Pressure Drop | | | | ■ | ■ | ■ | | | ■ | |
| 4) Time to Empty Tank | ■ | | | ■ | | | | | ■ | |
| 5) Friction Loss vs. Reynold's # | | | | ■ | ■ | ■ | ■ | ■ | | |

Activity #1 (Assignment presented in [2]): The activity investigates the buoyancy effects by tap and salty water on an object immersed in water. A balance, weight scale, beakers and other needed equipment were provided to students. The students had the freedom to use the volume of water and quantity of salt. There were some directing questions to lead the students testing decisions and analysis. A schematic of the assembly for this activity is shown in Figure 1. The pre- and post-activity questionnaires for this activity are shown in Figures 2 and 3, respectively.

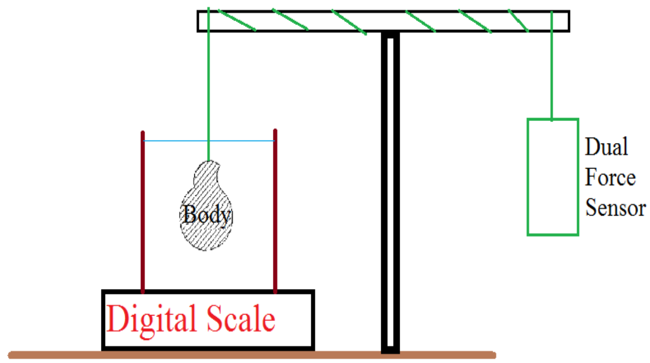
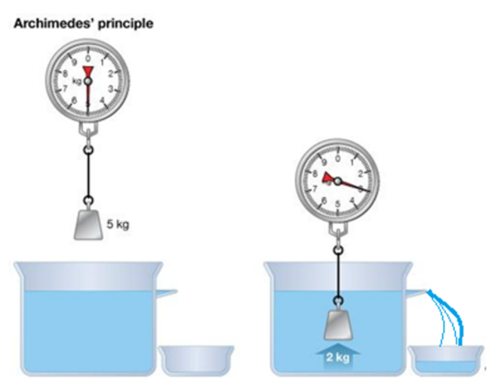



**Figure 1**. Buoyancy testing station

Activity 1: Pre-Lab Activity Questionnaire

1) In few words, define Archimedes' principle.
2) Why the weight of the object as seen on the scale starts to decrease as the object starts getting immersed in water?




3) How much water is displaced in the new bucket?

**Figure 2**. Activity 1 (buoyancy effects) pre-activity questionnaire

Activity 1: Post-Lab Activity Example or Questionnaire

A brass cube, 15 cm on a side weights 300 N.

a) Would it float or sink in water?

b) A cube of foam (Υf = 0.7 kN/m3) is to be attached to the brass cube to keep it in equilibrium and prevent it from sinking. What mass and volume of foam should be used?

**Figure 3**. Activity 1 (buoyancy effects) post-activity questionnaire

Activity #2 (Assignment presented in [2]): Using the venture duct shown in Figure 4, a fan supplied air into the duct where the pressure could be measured using the attached air nozzles. The velocity could be measured using a pitot-static tube and a hot wire anemometer. Pre- and post-activity questionnaires are shown in Figures 5 and 6, respectively.

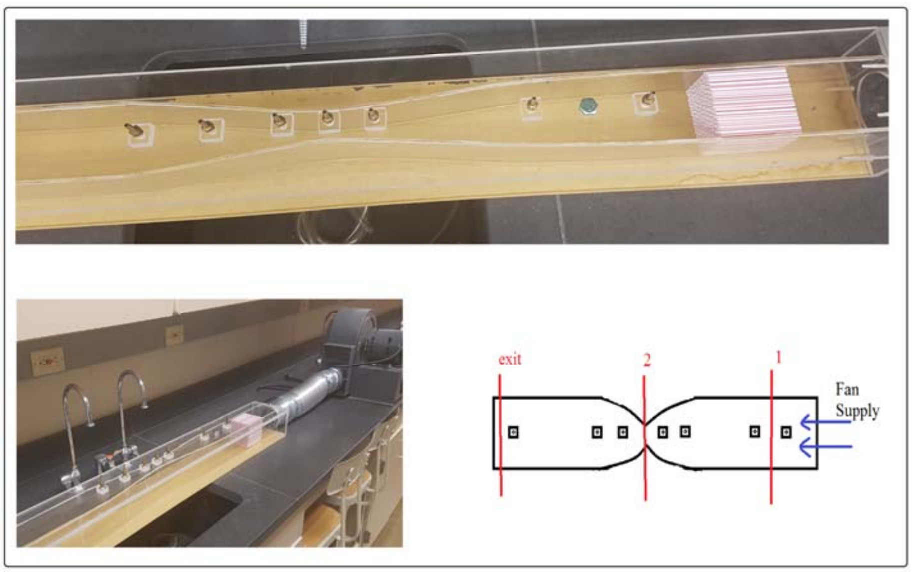


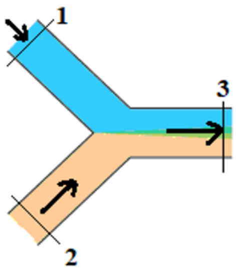

**Figure 4**. Venture duct used to allow mass flow measures and pressure drop inside a duct

MET 31300 – App. Fluid Mechanics

Activity 2: Pre-Activity Questionnaire

1) In your own words, define mass conservation.

2) For the below figure, what is the exit mass flow rate at section 3 if there is 3 kg/s and 2 kg/s entering at sections 1 and 2, respectively.




3) For the above figure, if A1=1 $in^2$, V1=0.7 in/s, A2=0.9 $in^2$, V2=3 in/s, what the required area at section 3 to allow a speed of 2 in/s?

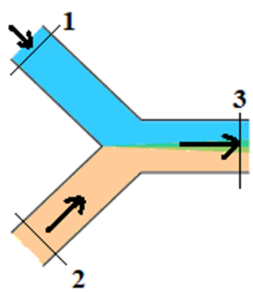
**Figure 5**. Activity 2 pre-activity questionnaire

MET 31300 – App. Fluid Mechanics

Activity 2: Post-Activity Questionnaire

1) If the system is steady state, fill in the blank:

$$\dot{m}_1 + \dot{m}_2 - \dot{m}_3 = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$




2) In Lab # 2, what are some causes for not having the mass flow rate the section 1 and at exit equal (name at least two)

3) Which method used in today's lab is the most accurate for measuring the mass flow rate? (anemometer, pitot-static tube or U-tube manometer?)

**Figure 6**. Activity 2 post-activity questionnaire

Activity #3 (Assignment presented in [2]): The same apparatus used for activity 2 in Figure 4 was used to investigate pressure drops inside the duct. The pressure drop inside the duct was investigated while the duct was laid horizontally and inclined at an angle. The pre- and post-activity questionnaires are shown in Figures 7 and 8, respectively.

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Activity 3: Pre-Activity Questionnaire

1) Why does the pressure drops as a fluid pass through a duct or pipe?

2) A Fluid passes through a duct; if P1 – P2 is negative, which section is upstream and which one is downstream (section 1 and 2)

3) Is the pressure drop measured using a U-tube manometer gage or absolute pressure? Explain.

**Figure 7**. Activity 3 pre-activity questionnaire

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Activity 3: Post-Activity Questionnaire

1) What are the factor that affect the pressure drop?

2) What is the effect of the fluid velocity on static pressure drop?

3) Name two instruments used in this lab to measure the pressure drop and name one challenge (kinds of cons and pros) for each unit selected

**Figure 8**. Activity 3 post-activity questionnaire

Activity #4 (Assignment presented in [2]): This activity was one of the activities used to meet the CLOs 1, 4 and 9. The objective of the activity was for the students to investigate the transient effect of Bernoulli's equation. Two tanks were used on top of each other with the upper tank having three similar nozzles. The nozzles were used to allow water to exit the upper tank to the lower one. Stop-watches and measuring devices were used to complete this activity.

Figure9 shows the apparatus used for this activity. Figure 10 and 11 show the pre- and post-activity questionnaires.

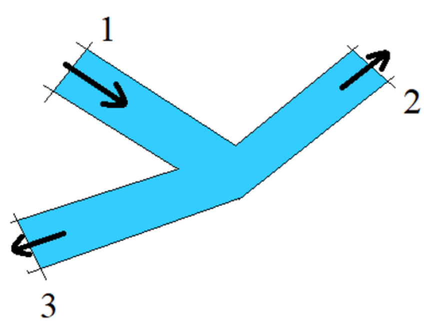
**Figure 9**. Tank emptying measurement apparatus

MET 31300 – App. Fluid Mechanics Name:

Activity 4: Pre-Activity Questionnaire

1) Name two restrictions when you can't apply Bernoulli's equation.

2) A fluid enters port 1 and is split into two ports as shown. Write down the mass conservation or continuity equation for the system if it is under steady state.




3) How would the continuity equation in question 2 look like if the system is unsteady?

**Figure 10**. Activity 4 pre-activity questionnaire

MET 31300 – App. Fluid Mechanics                                                    Name:

Lab 4: Post-Activity Example or Questionnaire

1) Write the mass conservation for a system under unsteady state conditions.

2) If a tank is draining water from its lower end, then the drop in height (or change in volume) is linear with time.

   True ____________

   False ____________

3) After completing Lab # 4, do you expect the drop in height as a function of time to follow the same trend despite the number of nozzle being opened ?? (i.e. is it the same curve and divided or multiplied by a certain factor which is a function of the number of nozzles?). Explain.

**Figure 11**. Activity 4 post-activity questionnaire

Activity #5 (Assignment presented in [2]): This apparatus has multiple pipes with different pipe sizes and material. It also has multiple types of elbows and valves. With the aid of 3D printed pressure vents, the students were able to measure pressure drops across multiple pipe, valves and elbows and were able to deduce the friction loss coefficients for the various pipe materials and compare it to text book values. The activity also asked the students to develop relation between the head loss and the flow rate. The apparatus is shown in Figure 12 whereas the pre- and post-activity questionnaires are shown in Figures 13 and 14, respectively.

**Figure 12**. Pipes, valves and fittings friction loss activity apparatus

MET 31300 – App. Fluid Mechanics Name:

Activity 5: Pre-Activity Questionnaire

1) Sketch the head loss for a pipe versus flow rate where head loss is on the y-axis and the flow rate is on the x-axis.

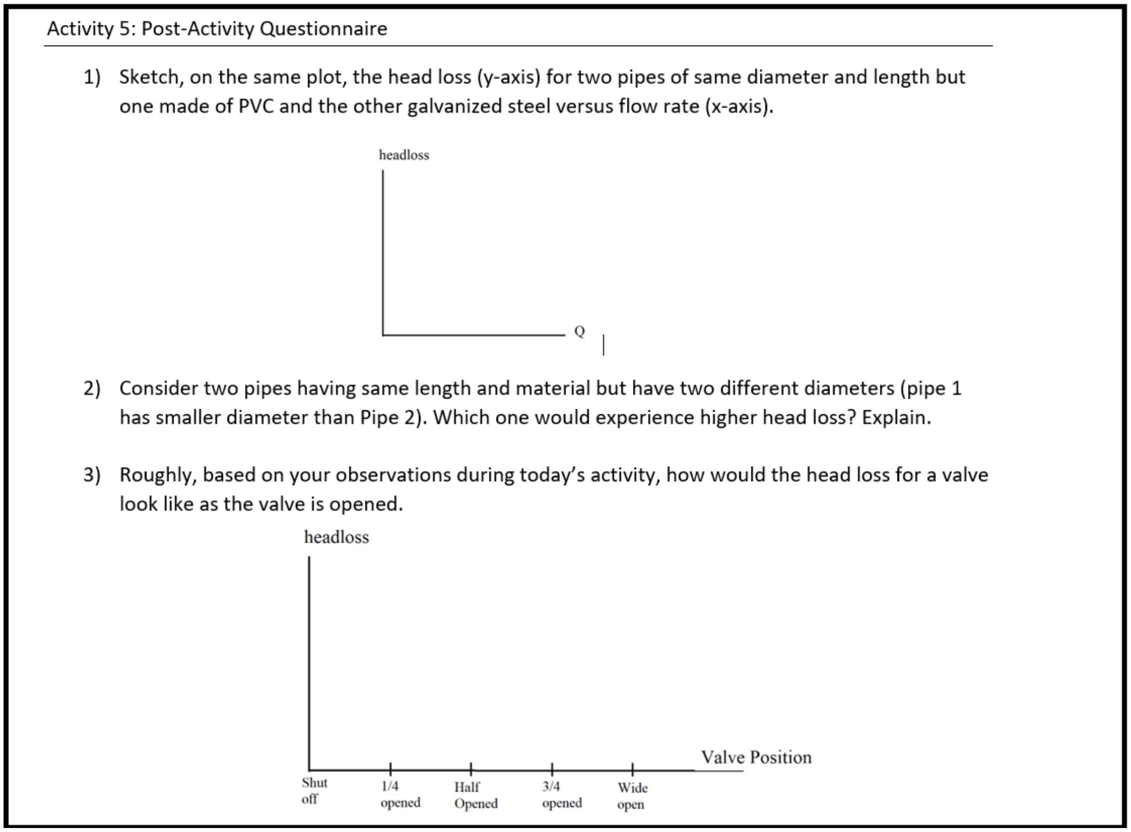
2) Choose the right answer to fill in the blanks:

   For Laminar flow, the friction loss coefficient _________, whereas for turbulent flows it ______.

   a. decreases linearly, decreases linearly
   b. decreases linearly, increases linearly
   c. decreases linearly, decreases exponentially
   d. decrease linearly, increases exponentially

3) What are the variable(s) needed to calculate the friction loss coefficient from Moody's chart?

**Figure 13**. Activity 5 pre-activity questionnaire



Activity 5: Post-Activity Questionnaire

1) Sketch, on the same plot, the head loss (y-axis) for two pipes of same diameter and length but one made of PVC and the other galvanized steel versus flow rate (x-axis).



2) Consider two pipes having same length and material but have two different diameters (pipe 1 has smaller diameter than Pipe 2). Which one would experience higher head loss? Explain.

3) Roughly, based on your observations during today's activity, how would the head loss for a valve look like as the valve is opened.



**Figure 14**. Activity 5 post-activity questionnaire

## Results and Discussion

The pre- and post-activity questionnaires were collected and graded for each activity/exercise and the average of all scores from each questionnaire are shown in Table 2 along with improvement in each activity when looking into the post- versus pre-activity questionnaires. As can be seen the students were able to improve their skills after conducting each activity and this improvement reached as high as 75%. It is worth mentioning that Activity 3 had the highest improvement because it had the lowest assessment scores in the pre-activity questionnaire. This was mainly due to the fact that the questions were new to the students and a bit challenging specially when asked them to determine the upstream and downstream sections. However, the post-questionnaire for this activity showed that the students picked up the concepts and scored 70 out of 100 resulting in 75% improvement.

**Table 2**. Questionnaires average scores and the percent improvement between pre- and post-questionnaire

| | Activity 1 | Activity 2 | Activity 3 | Activity 4 | Activity 5 |
|---|---|---|---|---|---|
| Pre-activity average scores (100 possible points max.) | 60 | 67 | 40 | 67 | 52 |
| Post-activity average scores (100 possible points max.) | 73 | 85 | 70 | 70 | 87 |
| **%increase in score** | **22%** | **27%** | **75%** | **4%** | **67%** |

A better picture for the effect of these applied activities would be by looking into the overall student performance and the final scores including exams and homework assignments. Averages of students' scores after each exam and averages of the total course scores were collected and compared to previously records. In Fall 2016, the course was taught with no added activities, and the first time the activities were added was in Fall 2017. The scores for 3-consecutive years has been collected and shown for Fall of 2017, 2018 and 2019 in Figure 15. The figure shows gradual jump in the scores of all categories. In Fall 2017, when the activities were introduced, the improvement was not significant, but then throughout continuous improvement made to the activities, significant rise in the scores was seen in 2018 and 2019. The final exam scores are usually the lowest due to the fact that students have other exams being conducted at the same time, more material to be tested in, having other assignments and commitments. Since the activities introduce a new concept of learning that the students were not familiar with in getting their knowledge, the results in Figure 15 show that the students not only kept the same level of proficiency when following these active learning techniques but in fact they performed better.

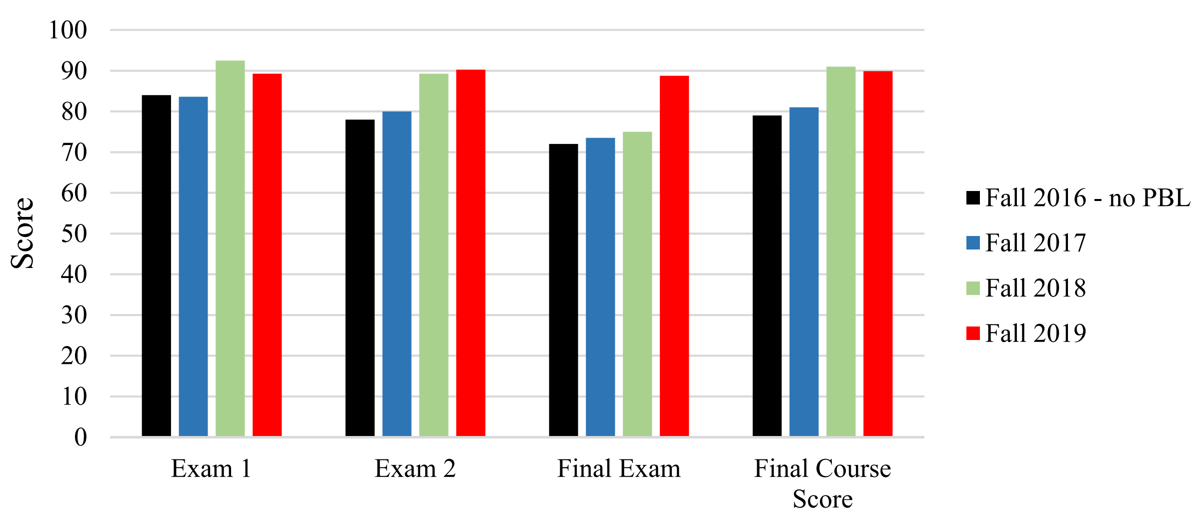



**Figure 15**. Averages for students' scores in different categories considered throughout the course

## Challenges

There are couple challenges worth mentioning where the authors need to put more efforts in the future to have better results. First of all, these type of learning techniques take too much time to be prepared the activity and the material. It also needs some resources and support. The authors are in the process of submitting an NSF proposal to transform fluid mechanics and fluid power classes at XXX department in the XXX University toward more student centered and active learning classes. The second challenge that the authors had when applying such paradigm was proper assessment for all students; since these activities were done in groups, some students may not be involved in the testing or analysis as others do. Lastly, the presented questionnaires which were applied for the first time in this class in Fall 2019 were designed so they could be answered within 5 minutes each or less. This was a major challenge for the authors. From the instructors' perspective, this would double his challenge as they'll need to design the activities and the two questionnaires, preceding and following each activity, to be all completed in 75 minutes or less.

## Conclusions

Five active learning techniques were added to Fluid Mechanics course and their effect on student's performance was evaluated by looking into pre and post questionnaires. The questionnaires were graded and the averages of students' performance during midterm and final exams were presented along with the overall course grade for Fall 2016, 2017, 2018 and 2019. The paper showed that students' performance increased with these active learning techniques. Continuous improvement to the way these activities are designed, presented to students and being conducted showed that it helps students scores even better.

There are many challenges and the authors are working to better design and present the activities to satisfy more of the ABET learning outcomes and course learning outcomes, as well.

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