Enhancing the Teaching of the Fluid Mechanics Laboratory and Preparation for New and Continuing Teaching Assistants

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Abstract – The main objective of this project was to develop the methodology to enhance the training of the laboratory-teaching assistants for an introductory course in fluid mechanics. We specifically want to establish a graduate training that emphasized the use of mathematical tools such as calculus and statistics, creative writing for presenting the reports, assessment of the experiment conducted and the ability to guide the students to design experiments. The Student Participation Experiments focused on the student's experience in performing a controlled test with a number of variables. In this type of experiment questions of instrumentation, accuracy and reproduction assume a major role. In the Student Project Experiments, the student are required to perform an initial analysis, to design the complete experiment, to calibrate the equipment, to perform the test, and to improve the equipment as needed, and to reach suitable engineering conclusions.

Keywords: Training, Laboratory Teaching, Fluid Mechanics Experiments

SELECTION OF EXPERIMENTS

The current Engineering Fluid Mechanics Laboratory Experiments Manual [1] contains the description and guidelines for the following Demonstration Experiments with a fixed laboratory set-up (can experiments):

1. Properties of Fluids
2. Bernoulli's Equation
3. Sharp-Crested Weir
4. Pelton Wheel
5. Impact Jet
6. Closed Conduit Flow
7. Wind Tunnel
8. Hydraulic Jump
9. Centrifugal Pump Characteristics
10. Mobile Bed Flow Visualization.

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In order to add Student Participation Experiments and Student Project Experiments, the first step is to select from this set of Demonstration Experiments at least two of them. The second step is to transform the selected experiments to satisfy the criteria of participation and project [Bravo, 2004].

The criterion of the Student Participation Experiments needs to focus on the student's experience in performing a controlled test with a number of variables. In this type of experiment questions of instrumentation, accuracy and repeatability assume a major role.

The criteria of the Student Project Experiments will require performing an initial analysis, designing the complete experiment, calibrating the equipment, performing the test, improving the equipment as needed, and reaching suitable engineering conclusions.

EXAMPLES OF STUDENT PARTICIPATION EXPERIMENT IN CE 370

Demonstration of Continuity and Energy Equations

Purpose
The demonstration experiment shows clearly and simply how to use in practice the principles of mass conservation, and energy.

Theory
Consider the parallel circular plates as shown in figure 1 in the next page.

Since the flow is radial outward from the center and the flow area increases linearly with the radius r, the continuity equation shows that the radial flow velocity, V, is decreasing with increasing radius. The equation representing the variation of the velocity is $V = \frac{c}{r}$ where c represents a constant. Neglecting frictional effects, the energy equation shows that the fluid pressure between the plates must be greater at the edge than near the center. Further, since the pressure is the atmospheric pressure at the edges it is less than atmospheric everywhere else between the plates resulting in a downward force on the top of the plate. Application of the energy equation allows the estimation of the downward force. The force necessary to separate the plates is a direct way to measure this force.

Student Participation
- When the plates are, close together how can we determine the constant c? What parameters of the plate and the fluid are necessary for this evaluation? For instance, plate diameter, plate separation, fluid density, and rate of flow.
- When the plates are close together, it is possible to notice that the downward force decreases. Why is that? and how can we evaluate the influence of the friction?.

Transition Flow Rates

Purpose
This experiment allows the student to determine a transition Reynolds number and laminar velocity profile. Several mechanisms at once control these two parameters. The experiment allows the comparison of the results with those in the literature.

Laboratory Equipment Required
- Thirty gallon constant head tank
- 2-inch standard schedule 40 brass pipe entrance section
- 2.0-inch I.D. plastic pipe section
- 2-inch standard schedule 40 steel pipe exit section
- Orifice and manometer
- Glove valve 2”
- Dye injection needle and dye tank

- Scales, stopwatch, thermometer, bucket, measuring tape.

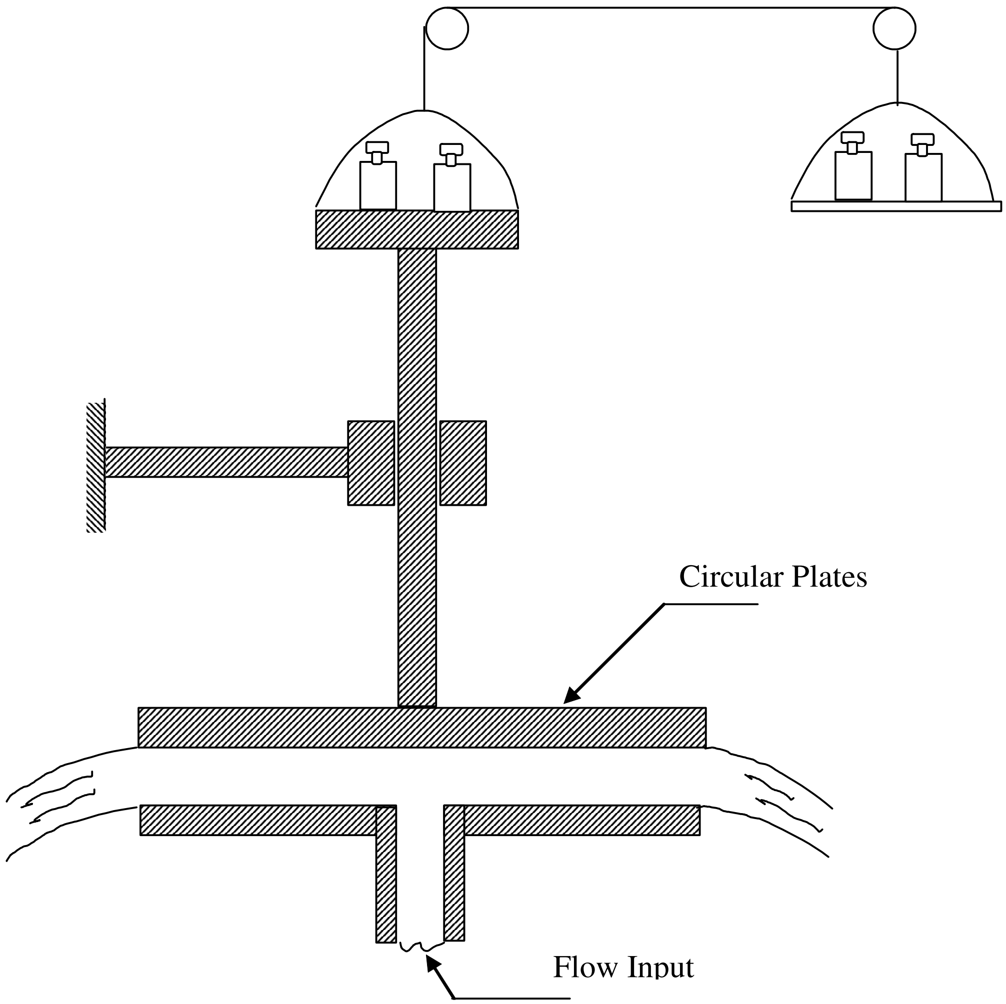

Figure 1. Schematic of the apparatus for the experiment to demonstrate the continuity and energy principles

Student Participation

1. How can we determine the onset of turbulent flow?
2. With a constant bulk flow rate (less than that at which turbulence first occurred at the center of the pipe), how can we obtain a velocity profile for laminar flow?
3. The laminar velocity profile is given by the equation: $\frac{U}{U_{\max}} = a\left(\frac{r}{r_o}\right)^2 + b\left(\frac{r}{r_o}\right) + c$

   Where

   U is the point velocity

   Umax velocity at the center

   r distance from the center

   r_o pipe radius

   Determine the constants a, b, and c of the equation above.

4. Evaluate the average or mean velocity theoretically and experimentally. Compare the results and discuss possible sources of errors.

EXAMPLE OF STUDENT PROJECTS EXPERIMENTS

Transient Emptying of a Cylindrical Tank

When a cylindrical tank empties through a small nozzle on the bottom, it is sufficient to assume that in the absence of friction the application of the Bernoulli's equation gives the instantaneous efflux velocity as:

$$V = \sqrt{2gh}$$

Where h is the height of the water level.

The development of this experiment aims to the examination of the assumption of no friction, especially when the nozzle diameter is a sizable portion of the tank diameter.

The experimental equipment available is as follows:

- 4-in diameter glass or Plexiglas tubing,
- various diameters of nozzles,
- quick release valve,
- time recording devise.

Extension of this experiment illustrates a different point. This is the emptying of a cylindrical tank through a long drainpipe. In this case, the unsteady effect is negligible compare with the friction factor.

DEVELOPING OF THE METHODOLOGY FOR THE TRAINING

The aim of the project is:

- To develop a methodology to demonstrate the basic principles of applied engineering to the trainee.

  The examples presented for the participation and project experiments make a clear attempt to demonstrate to the trainee that all type of experiments start with an understanding of the phenomena because of the observation and measuring. For example for the flow between circular plates, the mass conservation law (continuity equation) is the basic principle that explains why the velocity decreases when the radius increases. Also contrary to the quick conclusion that because a jet of fluid is impacting the plates, the application of the energy equation lead us to the conclusion that the pressure inside the plates is negative and produces a force that is downward.

  The next request for the trainee is to study in detail the Impact Jet experiment and determine if there is a possibility in transforming the current set up experiment to a student participation experiment.

  The basic guideline for the future training of Graduate Assistants is applying first the basic laws of Fluid Mechanics. Following this methodology will avoid the first judgment based upon our senses.

- Provide training in the technique of measurement and use of equipment,

  The examples presented for the participation and project experiments shows that sometimes-simple tools are required for measuring some parameters required to perform the experiment. However, the simple the instrument use for measuring, the greater the risk of making a wrong measure. In this case, the technique of measurement should focus in the calibration of the instrument and the care of using it. If possible, use a standard instrument. For instance, the use of a bucket and a stopwatch for measuring the flow rate requires first the calibration of the bucket and the test of the stopwatch. The calibration refers to the determination of the volume of the bucket by calculation and by using other way of physical measure of the volume capacity. Before accepting a final value, perform at least three or more trials. May be, a simple average of the values obtained by direct measurement is not the best choice. Consider always the possibility of reading errors and the weight of these errors in the final determination.

- Provide training and experience in collecting and interpreting experimental data,

  Collection of data during the performance of an experiment should follow a protocol. The protocol refers to the steps that the collection of data should follow. For instance, there is a need of executing just the simple measurement of the volume capacity in the examples presented every time under the same conditions. One big concern should be the waiting period to be certain that the flow has reached a steady condition, i.e. no influence of the fluid regime will affect the measurement.

  The collection of data also requires its interpretation. Just a simple collection without analysis is not the right procedure to achieve a successful experiment. Many times is necessary to determine the feasibility of the data before hand. For instance, analysis of a maximum flow rate in the examples presented will be very useful to make the right interpretation of the data collected.

- Provide training to design and conduct experiments, as well as to analyze and interpret data,

  The student participation experiment is the first step to provide an initial training for the design and conduct an experiment. Just the follow up of a fully described experiment does not offer any hint about the considerations required for designing a new experiment. It must be recalled that a successfully experiment requires the full knowledge of the phenomena that is analyzed. In addition, the conduction of any experiment needs the understanding of the phenomena. The student participation experiment aims to both of these important factors. The student will realize the necessity to understand the phenomena before attempting to answer questions about instrumentation, accuracy, and repeatability.

  Moreover, the fact of questioning the instrumentation, accuracy and repeatability, is the starting point to make the student aware of the need to analyze and interpret the data collected.

  The student project experiments will reinforce these concepts. Once the student gets the training in analyzing and interpreting the data collected, new ideas will flourish for designing new experiments.

- Provide training to design a process to perform an experiment,

  The introduction of a protocol for the data collection, continuing with the analysis of the data collected, and ending with the right interpretation of the data collected as a result of the implementation of the student participation and student project experiment, will only enhance the students' ability to design a process to perform an experiment. The three basic steps for both of these two new types of experiments becomes the basic training required to design a process to perform an experiment.

- Provide training to lead the students to function in a team.

  There is no doubt that the introduction of the two new types of experiments will train the students to work as a team. First, during the student participation experiment, the questioning about instrumentation, accuracy and repeatability will require the group participating to discuss and share their knowledge before reaching any conclusions. Moreover, just the generation of a protocol to collect data is the starting point to set up a team that will need to work in one accord. The difference with the traditional set up experiment is that for the student participation and student project experiments there are no written guidelines. For the generation of the guidelines of the experiment the students need to concur in the methodology to perform the experiment. The success is then tight to the team participation.

ELABORATION OF THE GUIDELINES FOR THE TRAINING

The training of the Teaching Assistants will focus in the following guidelines:

1. Training in Developing Student participation Experiments
    a. Student's experience in performing a controlled test with a number of variables
    b. Instrumentation, accuracy and repeatability
2. Training in developing Student Project Experiments
    a. Performing an initial analysis
    b. Designing the complete experiment
    c. Calibrating the equipment
    d. Performing the test
    e. Improving the equipment as needed
    f. Reaching suitable engineering conclusions

It is advisable to explain in detail each of the items outlined above during the training session. The aim is to let each participant understand the actual meaning of the topics and remark the fact that normal set up experiments do not take in consideration these factors.

Ask the participants to analyze the examples provided, that are different that the current set up experiments in use.

As part of the training session, request the participants to provide at least an initial selection of the possible experiment that could be transformed into student participation or student project experiment. The instructor and the participants should discuss together the pros and cons of the selection.

ELABORATION OF THE ASSESSMENT TOOLS

One form to get a feed back from the students is to generate a series of Classroom Assessment Techniques (CAT's). The generation of CAT's is the best low-threat technique to get a feed back about the level of learning that the students achieved.

The two types of simple CAT's that are suitable for the type of teaching imparted in the Laboratory Instructional Area are:

Minute Paper

The idea is to stop two or three minutes early the end of the laboratory experiment and ask the students to respond briefly to some variation on the following two questions: "What was the most important thing you learned during this class?" and "What was the most important question remains unanswered?. The questions must be prepared and typed in a sheet of paper and be collected for their evaluation.

Muddiest Point

This CAT is a variation of the one before. It consists of asking students to jot down a quick response to one question: "What was the muddiest point in today's experiment? This type of CAT is applicable when the experiment contains a significant amount of new information. In the laboratory experiment environment, the project experiments and the participation experiments qualify for this type of CAT.

Example of a Minute Paper

What was the most important thing you learned during the execution of this experiment?

What important question remains unanswered?

CONCLUSIONS

Implementation of the new type of experiments was not possible yet mainly because the contracts with the TA's occur only few days before the school starts. The authors continue looking for the opportunity to have the TA's available at least a couple of weeks before the starting of the classes. However, the administration supports enthusiastically the idea.

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