Lessons Learned from being a TA in a Fluid Mechanics Course

Bashear El-Hajj
Department of Civil and Environmental Engineering
University of Pittsburgh
Pittsburgh, PA 15261
bae36@pitt.edu

Dan Budny
Department of Civil and Environmental Engineering
University of Pittsburgh
Pittsburgh, PA 15261
budny@pitt.edu

Abstract

The Fluid Mechanics course is a requirement for graduation and also has a laboratory component. As a new graduate student it was an imposing assignment to have the responsibility to manage the lab for this required course. This paper will describe the contents of the course and the various lab assignments and the responsibilities of the TA. The paper will conclude with the lessons learned and how the TA has to be able to maintain the labs as well as teach the course material.

Keywords – TA, Fluids, Teaching

I. Introduction

Teaching assistantships are a staple of universities worldwide, serving as a valuable resource for students and instructors alike. The teaching assistant alleviates the instructor's work load and provides a theoretically more accessible source of help for students, while gaining experience in classroom and laboratory management. A competent TA, when their skills are properly applied, can greatly improve the students' learning experience and provide feedback to the instructor concerning class and lab effectiveness.

However, a TA most likely will work with several instructors in different courses throughout their term of assistantship. These instructors will all have their own expectations and requirements, to say nothing of different courses that require different approaches. At the same time, courses with higher rates of turnover among TAs require effective training systems to maintain educational standards. Developing such a training system is the responsibility not only of the instructor but the previous TA, who is in the best position to provide advice to their successors based on their own experiences.

This paper will cover the TA's experience with the University of Pittsburgh's fluid mechanics course taught by Dr. Dan Budny in the 2018 fall semester, summarizing the procedure, observations, and lessons learned. The course in question consisted of fifty-five students meeting biweekly for classes and weekly for lab sessions. The instructor managed all classroom sessions and related activities, while the TA's primary responsibility was managing weekly lab sessions and experiments.

II. Assuming Responsibility

The University of Pittsburgh typically hosts workshops for all prospective teaching assistants before fall classes even begin. General expectations and responsibilities are outlined, lessons are taught on dealing with distressed or troublesome students, and the importance of communicating with instructors is stressed.

Each instructor has their preferences and expectations, making it impossible to generalize the instructor-assistant dynamic. Before the first class, the TA should meet with the instructor and establish their responsibilities as soon as possible. In addition to accessing the syllabus and course materials, the TA should confirm exactly how much they will be expected to do and how much leeway they will have in doing it. Some instructors prefer to grade exams and projects themselves but leave assignments to the TA, while others leave all grading work to the TA with either free rein or a detailed grading rubric to be followed to the letter. The TA should learn as soon as possible which type of instructor they have. In the 2018 fluid mechanics course, the instructor preferred to grade exams personally but enlisted the TA and graders to help provided they graded with the same rubric. For grading lab reports and assignments, he provided guidelines but otherwise allowed the TA and graders free rein.

After confirming their role and responsibilities, the TA should sit in on as many classes as their schedule allows. This allows them to keep track of the course's progress and assess the students: whether a class is energetic, apathetic, or troublesome in class inevitably reflects on their behavior in the lab. The same applies for individual students: the more active in class tend to be more active during the lab, students struggling to improve will take on more passive roles (recording results, handling sensors), and students apathetic in class barely participate at all.

However, an equally valuable skill is to assess how the instructors interact with students, as the instructor-student dynamic tends to directly influence the TA-student one. It is documented that students respond better to instructors who are not only visibly qualified in their subject but who make themselves more accessible and approachable [1]. This was certainly demonstrated in the Fall 2018 class, as the instructor has over twenty years of experience in teaching, is well-known around the university, and makes lectures entertaining as well as informative. As a result, students tended to bring questions and issues directly to the instructor, only going to the TA for questions concerning lab work and reports. On the other hand, instructors who are apathetic – or at worst dismissive – towards students tend to drive them to the TA in numbers.

When students come to the TA, the TA must be readily accessible and establish that they consider the students a priority. Office hours should be assigned during students' free time if possible. Before the first class the TA should check lessons and assignments beforehand to anticipate questions the students may ask. Noticeable trends such as difficulties with a concept or a particular homework problem should be reported to the instructor. Any difficulties the TA has with a subject or question should also be reported, to establish when a question should be referred directly to the instructor. On the subject of grading, the TA should allow questions about grades given – and be ready to explain which mistakes cost a student points. Above all else, the TA must grade consistently, to leave no question of negligence or favoritism. Changing a grade should only be done if the student can prove the TA graded unfairly or violated grading policy.

III. Lab Sessions and Experiments

Despite the number of topics covered in a fluid mechanics course, time restraints restrict the number of laboratory sessions. Over a standard fifteen-week semester, after accounting for the add-and-drop period, exams, and holidays, there are eventually nine lab experiment sessions throughout the semester. Review sessions are hosted in lieu of experiments during exam weeks, to avoid diverting students' effort and attention from their studies. At least one topic is covered in a week, with the number of sections ranging from two to four depending on the number of students. All weekly lab sessions must cover the same experiments if possible, to keep pace with the content covered in class.

Lab reports are written by groups of three to four students. Due to the students being juniors or seniors, the report grading is structured to prepare students for co-op, senior design projects, and professional report writing. As such, some points are given for organization, clarity, and professional appearance. The rest of the grade is based on achieving experiment objectives, attention to detail, and critical thinking skills. This last criterion is evaluated by how well students can explain their results – successfully explaining discrepancies between theoretical results and experimental ones still receives points, while failure to understand the base concept being tested results in a penalty [2].

Multiple experiments on the same or similar topics may be covered in a lab session, but after all listed constraints only nine experiment sessions are possible. These experiments' topics were chosen not only to demonstrate the most important principles covered in class, but to demonstrate principles with real-world applications and simulate situations the students will encounter in the industry [3][4].

- **Specific Weight and Density:** As the first experiment, it is important to begin by utilizing and demonstrating base concepts that will be used throughout the rest of the course and other water- and fluid-related courses. Students are provided with graduated cylinders and digital scales to weigh volumes of liquid and calculate the average specific weight. The increments measured to obtain the average are chosen by the students themselves. Fresh water, salt water, and cooking oils are used. The saltwater is mixed by students themselves and thus gives an unknown quantity to determine, as the properties of saltwater vary with salinity.

- **Pressure with Depth and Distance:** The custom-built apparatus in figure 1 is used for both experiments. The column features a vertical row of pressure taps, while the base features a horizontal row of three taps on the top and one each alongside the vertical and inclined gates. Pressure as a linear function of specific weight and depth is established by attached pressure sensors to the column taps and recording the pressure readings. Pressure readings are also taken at the horizontal taps, as well as those on the vertical and inclined surfaces, to demonstrate that pressure is constant at the same depth.

- **Force on a Gate:** This experiment uses the same apparatus but using the vertical and inclined gates instead of the pressure taps. The apparatus is filled with either fresh or salt water, and students unlatch the gates and hold them closed with a force sensor. By easing off, they can record the minimum force required to prevent water from leaking. However, a downside of the apparatus is its construction of multiple parts. The gates require a seal (spongy neoprene is used) to prevent leakage, while an O-ring is situated between the column and base for the same purpose. These must be periodically inspected and maintained to prevent leakage, as measuring both pressure and force with the apparatus requires a constant water height.

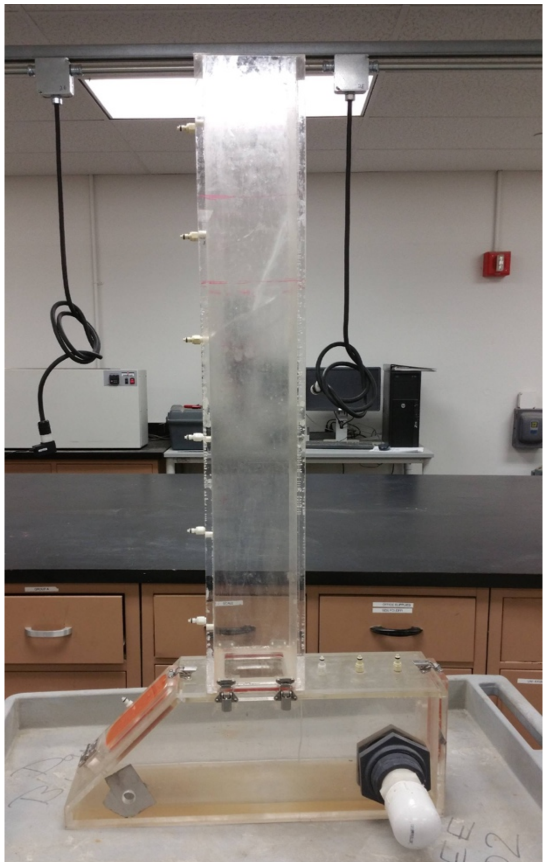

Figure 1: Apparatus for Pressure-depth and Gate Force Experiments.

- **Archimedes' Principle:** Tanks with overflow tubes are used to float or sink various objects in fresh or salt water. The tanks are previously filled almost to overflow so any displaced water will exit. Graduated cylinders are used to capture the displaced water and measure its volume. Objects provided include soda cans of various brands (similar volumes but different compositions cause certain brands to sink but others to float) as well as plastic and aluminum boxes designated as 'barges'. These allow the students to not only calculate the buoyancy forces from the displaced volume, but also to calculate draft and freeboard on a ship by loading the 'barges'.

- **Bernoulli's Equation:** A Venturi nozzle with attached manometer tubes is used to demonstrate the inverse relationship between static pressure and dynamic pressure of water flowing through a pipe. Students use an insertable probe to measure the total pressure at the different cross sections. Students can then calculate the dynamic pressure, the velocity of the water, and finally the flow rate. This experiment not only demonstrates Bernoulli's equation and the effects of varying pipe diameter; it also gives students their first glimpse at head losses. At this point of the course students will have only used the simplest form of Bernoulli's equation, not accounting for losses, so this experiment gives them their first glimpse at the inevitable loss of pressure in any pipe system.

- **Flow Patterns:** Using a flow-visualization channel, students may emulate the old practice of building scale models of bridges and dams to predict their reactions to current. Models and blocks of different geometric shapes are given to the students, are tasked with producing and identifying streaklines, eddies, vortices, stagnation points, and other flow patterns. This experiment also provides an opportunity for students to exercise their creativity, to create new setups and test their effects, as well as finding configurations to produce specific patterns and effects. Students are typically challenged to create whirlpools and dams, among other setups. Water coloring and the additive Pearl Swirl are added to the water to improve the visibility of the flow patterns, similar to the use of smoke in wind tunnels.

- **Conservation of Mass and Energy:** A cylindrical plastic column is used to simulate controlling the water level in a reservoir. Pipes with fitted valves are located at the bottom to control the flow rate for water entering and exiting the system, also controlling the water level in the cylinder. To demonstrate conservation of energy, the same setup is used, but with the addition of a miniature turbine to the outflow tube. The turbine is plugged into a voltmeter or convertible sensor to determine voltage and current produced by the flowing water. Students can then calculate the power produced and compare it to the theoretical power output to obtain the turbine's efficiency. To verify the results, both input and output must be carefully measured.

- **Conservation of Momentum:** This experiment consists of a 180º pipe fitted with a force sensor to restrain the pipes against the momentum of flowing water. Water is pumped through the setup and the sensor records the reaction force needed to restrain the resulting pressure. A disadvantage of the setup, however, is the sensitivity of the force sensor to high pressure. Instead of using the mains for this experiment, a weaker submersible pump in a tank of water is used to provide the inflow at more tolerable pressures.

- **Head Loss in Pipe Systems:** Flow rate and losses of a pipe system are crucial factors in the selection of pumps. A multi-level and multi-branched pipe system with pressure taps, depicted below in figure 2, is used to simulate the piping system in a multi-story building. Manometers on the sides can be attached to pressure taps to measure the head loss across several valves, elbows, and different lengths and cross-sections of pipe. Students can then use the obtained data and Moody diagram to calculate loss coefficients and Reynolds Number.

- **Pumps:** An apparatus consisting of a pair of pumps in a piping system is used to demonstrate the effect of different pump configurations on a pump curve. The pipe system is fitted with strategically placed valves to cut off flow from pipes between the pumps, allowing the pumps to work in series or parallel depending on which pipes are open or sealed-off. Closing valves also allows for drastic changes in pressure, even to the point of causing visible cavitation. After the experiments, students may construct the hydraulic and energy grade lines of the system to see the pumps' effects.

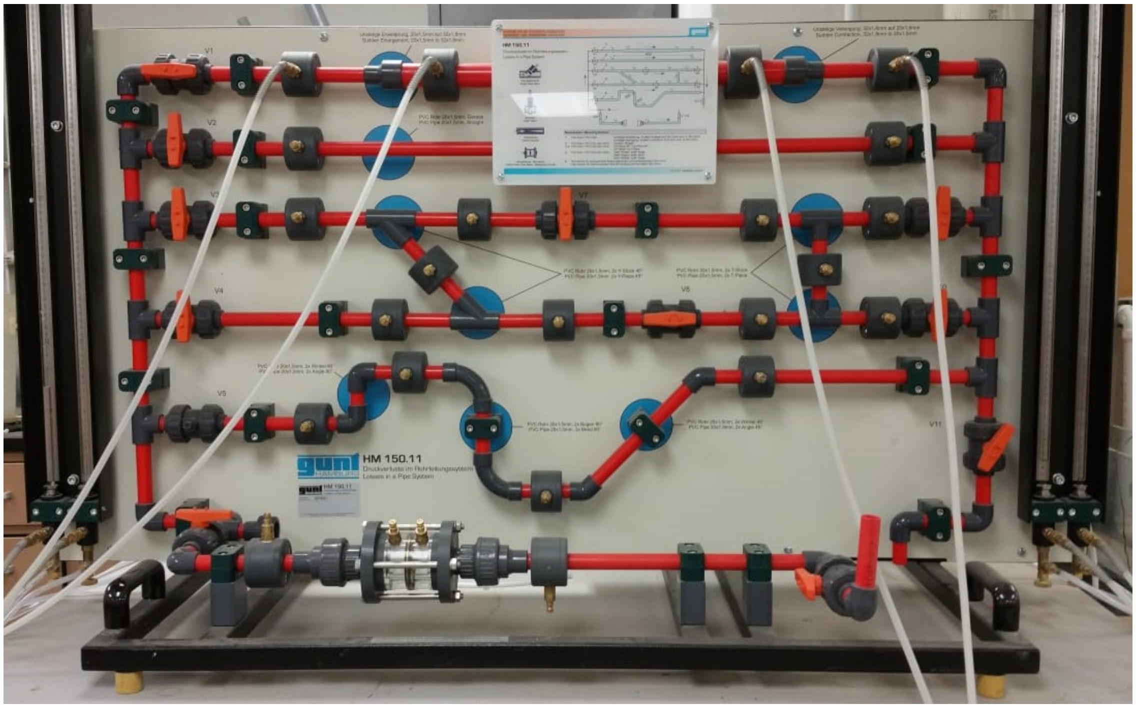

Figure 2: Head Loss Pipe System Panel

IV. Student Groups

Students work the lab sessions in groups of three or four, choosing members of their groups by the first lab session. All homework assignments, lab work, and reports are done by the entire group. As with the reports, the purpose is to prepare students for senior design projects and the industry, where they will be working in teams of engineers. No roles or responsibilities were officially assigned to group members by the TA or instructor, but inevitably students began to move into specific roles. Some members took on more active roles in experiments while others routinely printed the report. In several groups a specific student would routinely be the one to submit work to the TA and ask all questions concerning the reports. This dynamic was encouraged, as it allowed group members to play to their own strengths rather than force them into unsuitable roles.

Per course policy, exams and quizzes are conducted individually for the first half of the semester. After the midterm, the test policy changes to 'group quizzes' and a 'group exam'. These tests and quizzes are usually open-book, and in each group the only member allowed to write the answers is the member with the lowest average on the previous two exams. The other members provide help by looking up figures and performing calculations. This acts as a more functional method to encourage teamwork, especially when some group members take less active roles in experiments and writing reports. The group quiz forces all members to do their part, while also teaching them to solve problems long-distance. Engineers are routinely called to consult on problems in areas they cannot immediately access and must not only find a solution based on secondhand materials and information but explain the solution to personnel on-site. Simulating such a situation is of course intentional.

Students are always encouraged to bring any issues with their groupmates to the TA or instructor. On the first and second exam, survey questions are provided to rate the participation of other group members in reports and homework. This is intended to let the TA identify problem students and speak with them privately, but this method failed in the Fall 2018 semester. Out of 14 groups, only two groups used the survey to report problems with a group, and only one of these came to the TA asking to resolve the situation. In contrast, a seemingly well-performing group whose members had rated each other well later came to the TA complaining about members not performing their fair share of the work.

There are multiple explanations for this. Students in the last group admitted to giving the higher ratings to avoid further conflict, and only came forward when problems escalated anyway. Unwillingness to escalate conflict may have caused students to avoid reporting issues – a theory supported by the fact that both groups that came to the TA for resolution only did so when their own efforts failed. On the other hand, the students in the fluid mechanics course were all juniors and seniors, and most had taken courses with each other before. They also had taken or were concurrently taking a soil mechanics course also requiring lab work to be done in groups. As such, they were likely to be working in the same group for both classes and were already aware of their groupmates' performance in previous classes as indicators. Of the three groups reporting issues with members, the underperforming members in two of them had transferred into the class late and were not initially members of the group.

V. Tips and Tools

Another duty of the TA was to inspect the lab and take inventory before each experiment. Trial runs were often necessary to prepare the experiment and equipment ahead of time and identify faulty or missing equipment. The apparatus used for the pressure-with-depth and force on a gate experiments, for example, required periodic inspection of the seals and O-ring to prevent leakage, while the setups for head loss and conservation of mass and energy required to be assembled ahead of time. Lab inspections were usually carried out on Fridays to prepare for the coming week's experiment and to give time for replacement equipment to arrive over the weekend if necessary. For experiments with specialized equipment, such as the pumps and head loss setups, trial runs were held even earlier to identify and resolve potential issues. Any broken or missing equipment had to be immediately reported. In the event a missing or faulty component could not be replaced in time, it was necessary to improvise a replacement using other lab materials.

All sensors and electronic equipment used in the labs were PASCO equipment, with the labs originally requiring a PASCO Powerlink device to interface sensors with a computer. By the 2018 fall semester, however, the software was outdated and incompatible with students' laptops. Xplorer GLX handheld units were used instead to gain readings from the sensors. These began to show their age by the end of the semester, so starting 2019 PASCO Airlink interface units have been implemented. This units wirelessly interface between the sensors and SPARKvue data organization software on a computer or even a mobile phone, allowing students to receive data from the sensors directly. Their effectiveness in the lab will be evaluated as the semester continues.

VI. Conclusion

The teaching assistantship is a valuable if challenging experience, providing a graduate student with training for future work in laboratories or teaching positions. In summary, the best skills for a TA are situational awareness, preparation, and building a rapport with instructors and students. The lessons learned from managing the lab sessions during the 2018 fall semester have been relayed to the instructor and the feedback has been applied concerning adjustments to the course curriculum and lab policies. Further results and observations will be noted as the current semester progresses.

References:

[1] Ginsberg, S. M. (2010). Effective Strategies for Improving College Teaching and Learning. *The Teaching Professor*, 4

[2] Dick, W., Carey, L., Carey, J. (2009). Systematic Design of Instruction (7th Ed.). Prentice Hall.

[3] Kresta, M.S. (1998). "Hands-on Demonstrations: An Alternative to Full Scale Lab Experiments." Journal of Engineering Education 87:7-9.

[4] Schwartz, T.L. and Dunkin B.M. (2000). "Facilitating Interdisciplinary Hands-on Learning using LabVIEW." International Journal of Engineering Education 16(3):218-227.

.