Novel Experimental Component of Chemical Engineering Course

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Abstract

To enhance practical understanding in the introductory chemical engineering course at the University of Florida, an experimental component has been incorporated into the course curriculum that provides a hands-on approach to fundamental concepts. Students analyze and predict transient processes in two separate experiments. Each begin with a pre-lab assignment in which students are introduced to the problem and make theoretical predictions. Groups of three test their predictions while an instructor asks questions to test their conceptual understanding. After the laboratory activities, an evaluation was performed to determine effectiveness. We discuss how this experimental component and its evaluation 1) reinforced understanding of fundamental course concepts, 2) allowed students to make and test predictions, and 3) elucidated issues that need improvement in the future. Through this and future efforts, students will be able to enhance problem-solving skills over and above conventional coursework.

Keywords

chemical engineering, teaching methods, scale-up, unsteady state, mechanics

Background and Motivation

Chemical engineering is a profession centered around pragmatic solutions to difficult and often complicated process problems. It is thus imperative for an engineer to be both theoretically competent in his/her area of expertise and capable of adequately visualizing and carrying out experimental validation of predictions. While theory is covered by rigorous coursework students must complete at University of Florida and many other ABET-accredited institutions, physical hands-on activities are not provided in the scope of engineering until late in the curriculum, usually in the third or fourth year of study. This work-in-progress was developed for University of Florida's introductory chemical engineering course, Material and Energy Balances (MEB), to spur conceptual extension of problems in the textbook to the real world.

A difficult subject for many students in MEB is the modeling of unsteady state processes. This is due to the presence of an accumulation term that is difficult to conceptualize from a differential perspective. The presence of the time derivative often confuses students and the practical utility of a calculation is often lost. To help understand the use of the differential balance, experiments were specifically designed to be time-dependent.

Experiments and Implementation

The experimental component of the course took place in two separate assignments. Each assignment consisted of a pre-lab to establish understanding and make preliminary calculations, an in-lab practice that would be used to test the predictions, and a post-lab where discrepancies between data and predictions are analyzed and explained.

Determination of Steady State Height in a Water Tank

A simple demonstration of an unsteady state process is the filling of a water tank at a constant flowrate with an outlet flowrate that depends on the height of the water. The experimental setup, shown in Figure 1, consists of a pump that circulates water from a reservoir below to a water tank, where the water can leave through exit piping at the bottom of this tank.

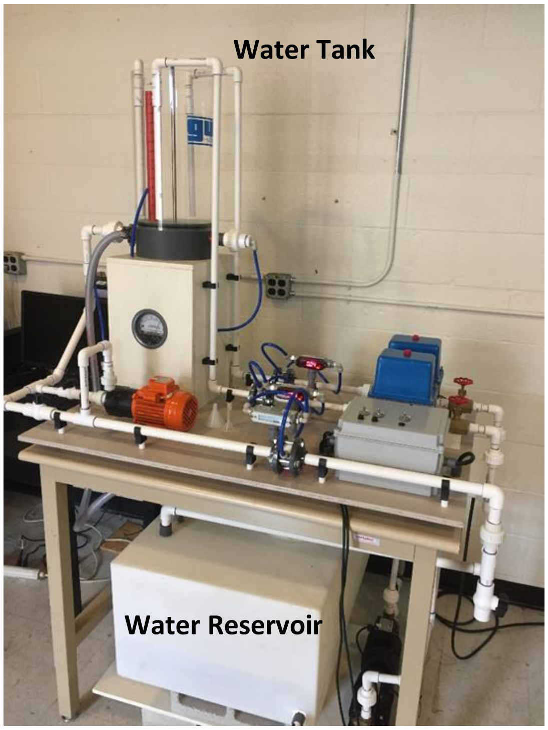


Figure 1. Water tank experiment. Pumps circulate water from bottom reservoir (below table) to tank above.

The objectives of this experiment are to 1) predict a steady state water height for the tank given an input flowrate, 2) predict the transient behavior for a system slightly away from steady state, and 3) explain any discrepancies between the theory and the and the experimental results. Students are given a theoretical background in the pre-lab assignment explaining the relationship between the outlet velocity and the height of the water in the tank (this course is taken prior to fluid mechanics) to understand, at the very least, that the outlet velocity varies with height. Students are also taught to use an exponential fit to predict transient behavior near the steady state conditions so as to get the system time constant.

The experimental process begins by the students turning the pump on, closing the outlet valve, and calculating the flowrate by timing how long the water level rises in the water tank. Upon calculating flowrate, the outlet valve is opened, and the system can reach steady state while its predicted value is calculated by the students with assistance of the instructor. Finally, the outlet valve is closed to raise the water level and subsequently opened to time how long the water level takes to reach 50% of the initial deviation.

The post lab activity consists of data analysis where students commented on the accuracy of predictions, calculated a time constant for the system, and elaborated on how the predictions could be improved.

Determination of scale-up factor in a batch filter process

The second experiment students performed concerned the batch vacuum filtration of a diatomaceous earth slurry (see figure 2). Darcy's law for flow through a porous medium was used by the students to make predictions for 1) volume of water captured over time and 2) determination of the permeability, K, upon experimental data collection.

The experimental procedure is as follows. The group is asked to weigh out enough diatomaceous earth to make a predetermined mass percent solution with 4L of water. Once this slurry is mixed, the filter is set up and the slurry is poured in. The vacuum is turned on, the valve is opened, and the group begins timing. There are three jobs for the students: 1) operate the vacuum at a constant vacuum pressure throughout data collection; 2) continuously mix the column such that no settling occurs during filtration; 3) record the time at which the collected water volume reaches predetermined increments. After the completion of this activity, students clean up by shutting off the vacuum and cleaning the filter cake from the equipment.

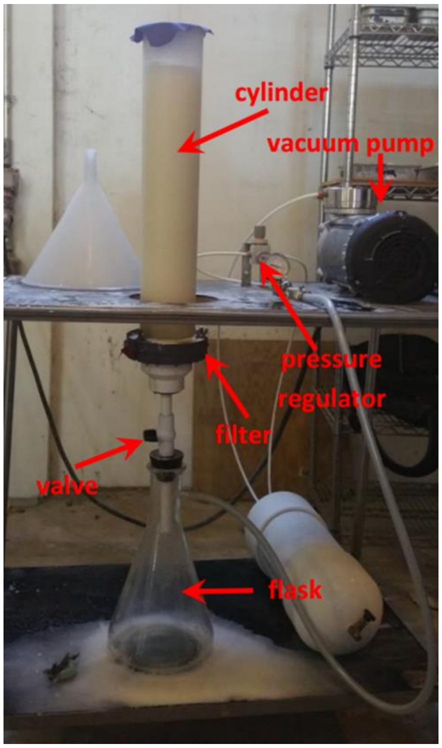


Figure 2. Batch filtration experiment.

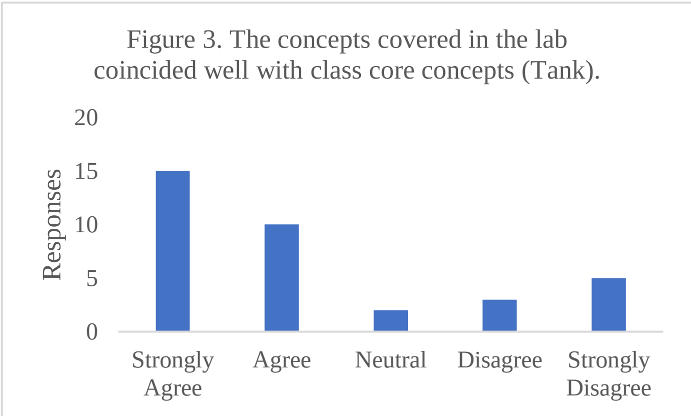
During the post lab, the volume-time data is analyzed to determine a scale-up factor, the permeability of the diatomaceous earth, to make predictions for a continuous industrial process involving rotary filtration.

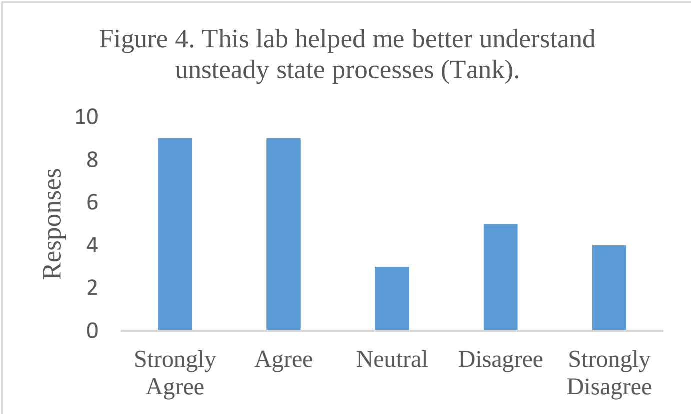
Evaluation

Voluntary evaluation was given for both laboratory assignments, in the form of numerical evaluation (1-5) and short answer, and was very insightful to clarify known issues and ascertain unknown issues. Since this was the first time this program has been carried out, it was expected that students would have mixed reactions to this effort.

Positive Feedback

Most students surveyed seemed to believe the concepts in the tank lab coincided well with Material and Energy Balances and helped understand, broadly, unsteady state balances (see figures 3&4). The short

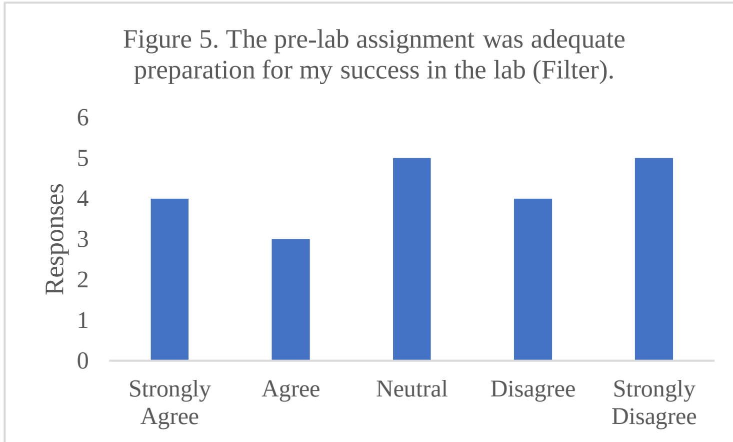




answer component of the surveys determined that both in-lab activities were straightforward, although being helped by the instructor facilitated the process tremendously.

Negative Feedback

The negative feedback was very helpful in establishing areas of improvement. For example, the prelab and post-lab assignments, by many accounts, were not clear in the directions. This point of view was seen specifically for the filter lab reviews (figure 5).



A central key response to "Do you have any recommendations on how we could improve this program for future classes?" was the lack of coverage of the material in lecture. Unsteady state balances were covered, but the specific topics of tank draining and filter balance were not. Since these do incorporate non-MEB topics (i.e. fluid mechanics), it would be reasonable to accommodate this issue by covering both subjects briefly in lecture in the context of unsteady state balances.

The instructors could determine weaknesses in the lab operation as well. Some topics that were introduced in pre-lab (time constants, understanding an exponential fit) were almost universally misunderstood. Lab times were only thirty minutes which was, for an unprepared lab group uncertain of the new lab environment, challenging to accommodate. There was also insufficient time for groups to adequately complete and understand the prelab.

Summary/Plans for Improvement

Both lab assignments demonstrated the capability for students at this level to complete and understand practical interpretation of theoretical engineering knowledge. While many engineers may learn practical skills at internships, incorporating early hands-on activities ensures that all chemical engineering students are prepared for key concepts in unit operations and industry.

Since this was the first year of the program's incorporation, several issues were identified and concrete goals have been established to improve this program in coming years. The pre-lab and post-lab assignments will be much more thoroughly edited and worked out. Time for the labs will be appropriate for laboratory groups to independently understand the lab and complete it with little or no instructor assistance. Much more time will be given to complete the pre-lab such that relevant material can be covered in lecture (without hindering concepts exclusive to MEB) and students can reach out with any conceptual issues to the teaching assistant or instructor.

Nevin Brosius

Nevin Brosius is a second year PhD student in chemical engineering and teaching assistant for MEB at University of Florida. Since working as a math tutor at Penn State, he has held a heavy interest in STEM teaching. He has participated in Habitat for Humanity, Hugh O'Brien Youth (HOBY) and Alachua County Engineering & Science Fair. Since entering graduate school, he has led an outreach effort for Graduate Association of Chemical Engineers (GRACE) and has established an educational component as an integral part of his dissertation. In research, he has submitted work in the measurement of surface tension. He acknowledges funding from Florida Space Grant Consortium and UF Alumni Fellowship Program.

Evan Wilson

Evan Wilson is an undergraduate student in chemical engineering at University of Florida. He has acted as an auxiliary undergraduate instructor in Material and Energy Balances to assist in experimental activities and occasionally lead review sessions for the course. He independently adapted a design for the filter experiment portion of this work and helped create pre- and post-lab documents for students. An avid researcher, Mr. Wilson has shadowed two graduate students in completing aerospace-related surface tension research projects. He acknowledges funding from UF Undergraduate Scholars Program.