A Problem Based Approach to Facilitate Linking Theory and Practice

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Abstract

The paper describes the early results of an innovative approach to help students connect theory and practice. The approach leverages a redesigned two-semester unit-operations course. In the first semester, the students conduct several structured experiments that cover a range of unit operations. In the second semester, the students are required to solve realistic chemical-engineering problems by identifying appropriate physical models and applying suitable analytical and experimental procedures. The students have the opportunity to review and refine procedures during the span of four laboratory sessions allotted to each experiment. The use of software tools, including ASPEN and JMP, are encouraged. The students preferred the problem based learning process that provided context over the traditional, structured learning process however; they did not test their results against existing theories and refine their work. Corrective actions that includes requiring students to perform an interim review of their work are planned.

Keywords

Unit operations, Reflection, Theory and Practice, Problem based approach.

Introduction

A colloquium, led by the American Institute of Chemical Engineers in an NSF[1] sponsored study made several key findings and recommendations. While many of the findings echoed longtime issues, two recommendations are worthy of paraphrasing in the context of this current endeavor: The colloquium recommended emphasizing process safety, applied statistics, process dynamics and applied process control through new teaching materials and effective integration into the curriculum. The study also noted that industry-bound engineering students generally failed to make the connection between the fundamentals and practical problems encountered in industry. The surveys conducted by the colloquium indicated differences of opinion about whether a co-op is a necessity. However, there was a broad consensus that new graduates should have a firm grasp of the fundamental concepts and acquire a realistic sense of context that enables them to apply the concepts judiciously and effectively. Further, the study states “many of the suggested changes to the academic curriculum focused on ways to apply the engineering fundamentals to real-life engineering situations and problems.”

The “Frontiers in Chemical Engineering Education” project, led by Bob Armstrong[2] of MIT recommended major curriculum changes in 2005. The key recommendations were to shift to a curriculum focusing on molecular transformation, multiscale analysis and the engineering systems approach. The approach suffered from a lack of textbooks and the driver and the resources to execute such wholescale changes. Nevertheless, the goals of the project are still valid. The paper describes how the second unit operations laboratory course aims to meet many of the objectives outlined in the two aforementioned initiatives and some early results.

Background

Until recently, the CBE students at UTK enrolled in one unit operations laboratory course, UO-1. The UO-1 course at the University of Tennessee, Knoxville has the following objectives:

1. To develop technical communication abilities through formal written reports and oral reports.
2. To cultivate interpersonal working skills as team members.
3. To provide practical experience in operating equipment, analyzing data and understanding experimental error.
4. For the selected experiments, develop an in-depth understanding of the describing operation.

As part of the UO-1 experiments, the students performed and analyzed experiments in heat transfer, fermentation, distillation, reaction, pump flow etc. The students completed each experiment in one lab session. The experiments did not require the students to use the experimental results in any practical way. Most students, in this scenario did not relate their experiments to any practical situation. To close this gap, a second unit operations course, UO-2, was added to the chemical engineering curriculum starting in fall 2019. The second laboratory course, unlike the first course is open-ended and focuses on solving problems. The students, in this course solve practical problems such as sizing a commercial scale equipment, using the scaled-down lab models made available to them. Very little information besides the operating manuals for the equipment is provided. The students are required to develop the experimental procedures. Students have four weeks to work on each problem and are encouraged to consult with their TAs and the instructor, thus, they have the opportunity to reflect and improve on their methods. It was anticipated that providing context, multiple weeks to complete each experiment and time to reflect on their work would help the students connect theory and practice (Gitterman[3]).

Implementation

The first cohort of students enrolled in the course in fall 2019. There were a total of eight problems. The students were divided into groups of three to four students. Due to time constraints, each group was required to address four of the eight problems. The students used the lab scale models for estimating the unknown parameters in their equipment model. A sample process is described next:

The students calculated the minimum size of a reactor for the hydrolysis of sucrose using a cationic resin, given a target rate for production and conversion. Since the reaction rates were not provided, the students obtained the rate data from a lab scale reactor. The students had to ensure that their experimental conditions met the assumptions in their model. The results were used to size a commercial scale reactor. The students were given four weeks to complete the experiment. It was anticipated that this was adequate time for them to generate initial data, analyze their procedures and results, generate any additional data if required, and arrive at a solution.

Student Response

Since the course was offered for the first time in fall 2019, the first round of student feedback was received in December 2019. Several students indicated the need for better organization of the lab and more help with executing the experiments. These issues will be addressed during future offerings of the course. Many students favorably commented on the design of the course.

The author's own perception is the students did well with the initial design. Many groups leveraged the simulation software ASPEN and the experimental design software JMP in planning their experiment. However, the students often did not compare their observations against theoretical predictions and then investigate the potential reasons behind any discrepancies. Instead, they accepted the experimental observations at their face value.

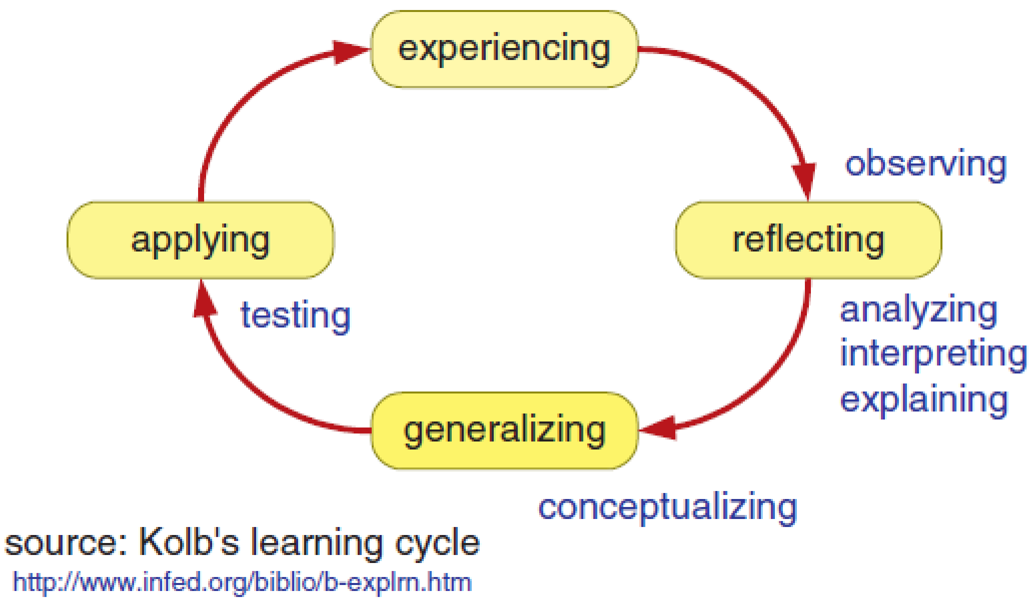

Figure 1: Kolb's learning cycle

Simply stated, the reflection step in Kolb's learning cycle occurred only to a limited extent. The possible reasons for this observation are as follows:

- Students are used to the prevalent learning methods at the university and tend to defer to a process that involves performing each experiment only once. Early in the process, they did not foresee the need to refine and/or repeat their experiments following an interim analysis.
- It cannot be assumed that students will attempt to connect their experimental results to existing theories. A structure, that requires them to perform such evaluations, is necessary.

- Due to equipment issues, there was not sufficient time for the students to perform an experiment multiple times.
- Engineering students are not trained in brain storming problems and providing positive feedback and criticism regarding each other's work.

It appears the course needs to follow a format that requires students' to pursue Kolb's learning cycle. An example of this would be to require students to write an interim report that critics their results and identifies avenues for improvements. Inputs from experts on learning theory would also be very valuable as both social and technical barriers need to be overcome.

Conclusion

The early indications are, a problem based approach to solving problems in a unit operations course, can help students connect theory and practice. The first offering of the course was in fall 2019. The students enjoyed having a frame of reference and were open to using software tools such as ASPEN and JMP in planning and analyzing their experiments. Issues were encountered with the organization of the course; these will be addressed during future offerings of the course.

The major goal of the course, namely to help them connect theory and practice was met only partially. It appears students need more meta-knowledge on how to pursue scientific investigations and to critic each other's work effectively in a team environment. The plans are to revise the course such that students are required to make some predictions based on theory initially and then compare the predictions versus the actual results after the initial round of experiment. The inputs of experts in the field of education theory will also be leveraged in the future redesign of the course.

References

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Dr. Raghavan is an experienced chemical engineer with nearly twenty nine years' experience in chemical industry. He is well versed in process development, technology transfer, manufacturing, trouble shooting and compliance aspects of pharmaceutical and specialty chemical processes. He has a record of implementing innovative solutions that enhance robustness of processes and generate large savings. He has received several technical achievement awards for his contributions. Dr. Raghavan is a certified Merck Sigma Green Belt. Since retiring from Merck & Company in 2013, Dr. Raghavan is currently pursuing a career in academia at the University of Tennessee, Knoxville.