Team-based projects for teaching chemical engineering separations

Noah Malmstadt
University of Southern California

Introduction and Objectives

The students

Second-year Chemical Engineering majors in *Introduction to Separation Processes*—their first class that integrates a major element of engineering design.

The projects

- Solve a specified isothermal flash problem by writing a computer program that implements elementary root-finding.
- Design a distillation column by writing a computer program than simulates the process of distillation.

Intended outcomes

- An ability to apply fundamental knowledge obtained earlier in the curriculum.
- An ability to design an engineered system.
- Comfort in working on a multidisciplinary team.
- Familiarity with modern programming tools (e.g. MATLAB) for solving engineering problems.

Developmental History of Innovation

The status quo

In addition to regular homework and exams, the course currently incorporates two multi-week design project assignments. Both assignments involve programming to simulate separation unit operations: a vapor-liquid flash separation and a distillation column. Students are expected to execute their projects using MATLAB, and to produce a report describing their approach and the results of their simulation.

What we've learned so far

In the first year that a project element was included in the course, students struggled due to their generally weak programming background. However, in the past three years, our department has introduced a course for first-year undergraduates on computational numerical methods (I designed and currently teach this course). While this has improved the overall reception to the project element in *Introduction to Separation Processes*, students still spend the majority of their project work time struggling with the mechanics of programming rather than grappling with the engineering concepts that represent the core learning objectives for the course. This is the major obstacle that must be overcome.

A potential additional benefit

Students want to work collaboratively on these projects, and that they benefit from collaboration. In response, I plan to restructure the projects such that they are team-based tasks.

Learning Activities and Materials

Team-based projects

Projects will be based on procedural programming, with 4-5 procedures required to complete the full project and each student assigned to a procedure. Projects will be completed by 4-5 person teams, and each student will be graded based on their performance on their assigned procedure. Collaborative teamwork will be encouraged.

Video tutorials

I will create a set of 5-10 "screencast"-style videos to guide the students through some common issues in programming implementation and to focus them on addressing the underlying engineering concepts. Each video will be about 5 minutes long, and they will be downloadable on demand from the course website.

Co-writing modular functional code

As in-class exercises, students will develop code modules that can be applied to the final project. I will begin the class by outlining potential approaches. After 15 minutes, students will discuss and comment on their progress. This will be iterated for two periods, resulting in a completed module that can be shared by all teams. An example of the modules that would be developed for the distillation project is shown below.

Co-written modules to aid distillation design

- Initialize column given specifications and assumptions.
- Find thermodynamic constants given temperature, pressure, and composition
- Find the bubble-point temperature of a stream given pressure and composition
- Find the enthalpy of a stream given pressure, temperature, and composition

Execution

Team deliverables

Each team will produce a report consisting of a technical description of the theory underlying the simulation, a description of how the team chose to implement that theory in practice, a response to a series of questions that the simulation is designed to answer, and an evaluation of the performance of the simulation. These first two elements will be expected from each team member while the final two will be submitted on a per-team basis.

Sharing my results

The materials I will develop, including project assignments, videos, and module designs, will be shared with other chemical engineering educators via the online American Institute of Chemical Engineers Concept Warehouse.

Major Issues to Resolve

Issues that I have a route to approaching

- Collaborative projects risk free-rider issues, in which less engaged or able students will rely on their peers to get the work done. These issues can be alleviated to some extent by making the project modular, and having each member of a collaborative team assigned to a clearly defined subsection of the project.
- It is difficult or impossible to define a good grading rubric for a project before you have seen what typical student work on that project will be. Students will often produce unexpected approaches and encounter unexpected problems. It is best to develop rigorous grading rubrics over several years of executing similar projects.

Open issues that need a solution

- How can large (>70 students) classes be operated in an interactive mode such that all students have an opportunity to participate?
- What are best approaches to encourage introverted students, some of whom are not fluent in English, to contribute during in-class discussions?
- What are the best practices for evaluating team-based projects when the contributions of individual students are sometimes unclear?
- What are the best practices for motivating students to prepare for classes while avoiding sacrificing class time to quizzes and reviews?

Discussion

Goals for the project

I designed these projects hoping that I could train students to:

- Translate the mathematical description of an engineering system to a practical demonstration.
- Work with simulated systems that allow them to interactively understand the performance and limits of separation unit operations.
- Communicate the results of their work in technical but clear language.
- Cooperate with peers in a team-oriented task.

Lesson 1: Dealing with student procrastination

Students will procrastinate on large projects. TA-led discussion and tutorial sessions on a strict schedule during the course of the project can force students to work on a schedule. Milestones due at early points in a multi-week project are also helpful. An open-door office hours policy, on the part of either the instructors or the TAs, can actually encourage procrastination.

Lesson 2: Teams are engaged and aggressive

Empowered as collaborative teams, students are more likely to approach the instructor and TAs than they are as individuals. Discussions are richer, more free, and more productive. Intra-team competition can be fuel for learning.

Lesson 3: Fear is the mind-killer

There are few things that students find more intimidating than being forced to use unfamiliar and uncomfortable tools. Far too many engineering students regard programming as a terrifying and insurmountable obstacle. Even very talented students may need to be treated gingerly when they're pushed out of their comfort zone.

Acknowledgments

Curriculum development efforts supported in part by NSF awards CMMI-1068212 and CBET-1067021

2013 Frontiers of Engineering Education
Irvine, California
October 27-30

Sponsored by:
The National Academy of Engineering and
John McDonnell and the McDonnell Family Foundation

USC University of Southern California

NATIONAL ACADEMY OF ENGINEERING
OF THE NATIONAL ACADEMIES