Paper ID #19349

Films, Foams and Powders: Using Food to Introduce First Year Students to Chemical Engineering

Dr. Polly R. Piergiovanni, Lafayette College

Polly R. Piergiovanni is a Professor of Chemical Engineering at Lafayette College. Besides chemical engineering courses, she teaches an engineering course to nonengineering students. Her current research interests include critical thinking evident in student writing and assessing learning in experiential learning activities.

Films, Foams and Powders:
Using Food to Introduce First Year Students to Chemical Engineering

Introduction

Every few years, Lafayette College updates the introductory engineering course (ES 101), based on changes in the incoming student population. Currently about 200 students enter as engineering majors. Twelve sections of ES 101 are offered so enrollment can be capped at 20 students. Each engineering major (chemical, civil, mechanical and electrical) offers three sections. Four sections are held at the same time – one from each department. Students are enrolled in a particular section for the first seven weeks of the semester ("Module 1") and change to a different section ("Module 2") for the remaining weeks. This allows each student to experience two types of engineering. It is challenging for the Registrar to organize ES 101, but it has been successful for the past three years.

The current version is centered on the engineering design process with two primary learning objectives:

- Students will recognize that engineering at Lafayette College and beyond is innovative and exciting; and
- Students will understand the engineering design process.

In the fall semester, each engineering department in the division offers 7-week modules to introduce the students to the design process within their major. Specific characteristics of the engineering major are not to be highlighted. Engineering design has been defined as "a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" [1]. The definition is complex, and is challenging to teach to first year students. Both traditional engineering design methods and the "design thinking" process promoted by the global design company IDEO have been used in the modules, and each module culminates in a final design project.

For example, students in the Civil Engineering module designed a playground for young children. Mechanical Engineering students designed and built an apparatus to separate golf balls from ping-pong balls. The existing Chemical Engineering module focuses on energy and the environment. To develop a new module for chemical engineering students, Vigeant's "First Year Ranch" course [2], where she introduced first year students to Chemical Engineering using Ranch salad dressing as the vehicle, served as the inspiration. Food production is a natural way to introduce students to the chemical engineering design process. Vigeant's course presented fluid mechanics, colloid chemistry, regulations, economics and scale up challenges and her students were enthusiastic about the course. The idea became clear – develop a module based on food engineering and design.

The design of a new food became the central theme of Films, Foams and Powders, supported by various engineering and scientific concepts. Figure 1 shows the design process used in the module. At the beginning of each section of the course, a "problem" was defined for the students, in terms of a customer desiring a new food. During the next few class periods, the students worked through the process and ended with actually creating the food product they had designed. At the end of the module, the Lafayette students were also enthusiastic about the course and chemical engineering.

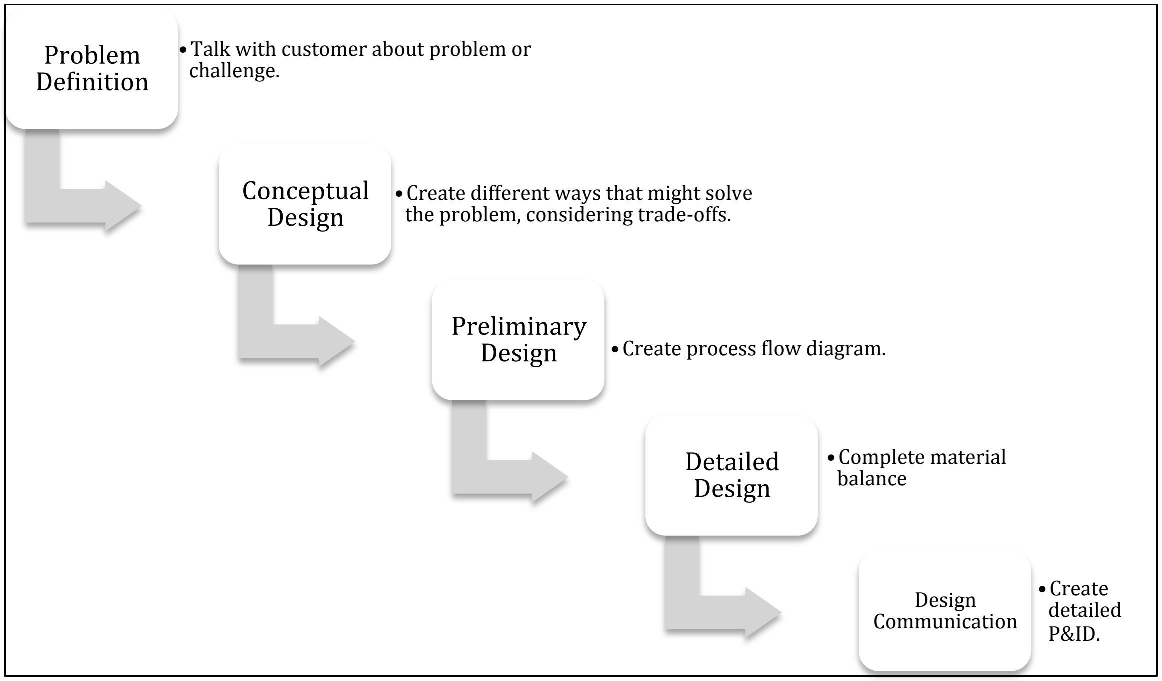

Figure 1. Diagram of the design process used in the module "Films, Foams and Powders". The bullets to the right indicate how the step was applied for a specific topic.

Course Organization

The class met for 75 minutes three times a week in a standard classroom. Enrollment was capped at 20 students, which, along with multiple hands-on activities has been shown to improve retention [3]. The course content was developed based on reading food engineering textbooks, current literature in the field, and recently published cookbooks. The modernist cooking techniques were especially interesting.

For example, the process of spherification – using a liquid food along with sodium alginate and calcium ions to create "faux caviar" – was not really a new technique. It uses the same scientific and engineering principles as cell immobilization or drug delivery processes. After purchasing some ingredients – chemicals – and trying the techniques at home, the faux caviar was served to non-engineering friends and family while they listened to the scientific and engineering explanation. They were fascinated and enjoyed the caviar. So modernist cuisine became the theme for the chemical engineering module.

Eventually, eight topics were chosen to introduce chemical engineering design to the 20 students in the class (see Table 1). Slightly less than one week was spent on each topic – the entire module was completed in seven weeks. The module began with some background material and moved toward modernist cuisine techniques. Each topic in the class began with a hands-on activity, followed by theory and calculations. Four of the topics (shown in bold) concluded with a design experience, and the module culminated with a final design project combining several of the topics. Thus each student participated in five design projects.

Table 1. Topics taught in the Films, Foams and Powders module. The topics listed in bold included a **design project**.

Topic	Activity	Science	Engineering
Food Components	Milk coagulation	Fats, proteins, carbohydrates	Process flow diagrams
Drying	Banana chips	Water activity	Wet and dry composition
Starch Chemistry	Racing starches!	Starch composition	Material balances
Fluid Flow	Pumping starches	Viscosity	Hagen-Poiseuille equation
Edible Films	Starch films		Mechanical properties
Foams	Milk foam formation	Foam chemistry	Frother design
Powders	Deconstructed peanut butter cup	Lipophilic index	Size distribution relationships
Spherification	Faux caviar	Gelification through ions	Fick's law of diffusion

Details of One Topic

The third topic, Starches, began with an introduction to starch chemistry. Students learned the structures of amylose and amylopectin and the differences in their shapes, molecular weights and densities. Starches from different plants have different ratios of amylose and amylopectin, which influences appearance and behavior during heating and hydration. When cold water is added to starch granules, they absorb minimal water.

However, when hot water is added to starch (or a starch solution is heated), the starch granules swell, then break down and release some contents – primarily amylose – into the water. This process is known as gelatinization. Gelatinized starch solutions are clearer and more viscous. Starches with a higher amylose content form a firmer gel or hydrocolloid.

Potato, corn, arrowroot and tapioca starches are available at grocery stores. As the first hands on activity, students were given small samples of the starch powders and the gelatinized starches. (Because it would be difficult for the students to gelatinize the solutions in the classroom, they were prepared in advance.) First, they added cold or nearly boiling water to the powders to observe if gelatinization occurred. Next, using the starch gels, they compared their appearance (dull or shiny, opaque or translucent) and flow from a spoon (heavy or thin, long, short or clumps). Finally, they compared viscosity by placing a spoonful of each starch at the top of a tray and tilted the tray for a "race" to the bottom. They compared these results with the information on amylose/amylopectin ratios to identify the starch sources.

The amylose/amylopectin ratio affects the gelation temperature of the starches – each of the four starches behaves differently when it is heated with water. Demonstrating this in a classroom setting is difficult, so the process of preparing the gelatinized starches for the hands-on activity was filmed, uploaded to YouTube, and then shown during class. We also discussed and observed retrogradation – after a starch gel has been refrigerated, some of the water holding capacity is lost and the amylose molecules reassociate into an ordered structure. They could relate this to pudding that has been refrigerated for a day or two and has liquid surrounding the soft solid.

The engineering portion combined the two engineering skills they had learned previously: drawing a simple process flow diagram and wet and dry composition calculations. They solved simple material balance problems to determine the amount of water to add to a mass of starch to obtain a particular composition, and calculated how much water must be evaporated from a gel to obtain a certain composition on a wet basis.

They practiced the calculations in class and completed a homework assignment with similar problems.

The Starches topic did not contain one of the four design projects. However, the second design project, creating an edible starch film, required students to understand how the amylose/amylopectin ratio affected the strength of the film.

Each design project asked students to use information from the lectures, the hands-on activities and the homework and apply it to design a new food. For example, after learning about edible thin films (a modernist cuisine technique often using starches), the students were asked to use their knowledge of the effect of the amylose/amylopectin on the mechanical strength of films and the effect of additives (which they had tested in an activity) to design an edible thin film product. Design projects included starch film packets made with balsamic vinegar that contained olive oil to place on top of a salad, to starch films made of chocolate syrup to wrap around a scoop of ice cream. Not every project worked the first time – the ratio of starch, water and flavoring was important – but students were given two chances to improve their product to emphasize the iterative portion of the design process. Along with creating their project, they completed a worksheet showing how they applied the first four steps of the design process.

The Films, Foams and Powders module culminated in a final design project where students used their experiences from the four previous projects to combine into a new food. The students were creative, and more successful because they applied what they had learned from earlier problems. "Pinie Bites" – dehydrated pineapple with powdered caramel syrup and "Tri-Apple D'Lite" – dehydrated apple halves filled with spherified apple cider and wrapped with caramel starch films were two of the most popular treats.

Preparing for the hands on activities was a lot of work for the professor, but in future offerings a student could be hired. Other ways to streamline the process will be investigated. For example, Ingredion [http://www.ingredion.com/] generously donated samples of several modified starches that will gelatinize without heating. This could simplify the preparation process. One topic offered in the first module – Creating Fizzy Fruit as a way to demonstrate diffusion – was expensive and only slightly successful and so was not offered in the second module. Scale up of the course to offer to hundreds of students would be challenging without dividing them into smaller laboratory sections.

Conclusions

The course was offered twice in the fall semester to approximately 80 first year students. The final design reports and exam indicated that the students had understood the design process and engineering concepts. An informal survey showed that students rated "spherification of liquid foods" and "creating powdered Nutella" as their favorite activities. According to Behrens, the hands-on, practical element of practicing design also provides insight into the practice of engineering [4]. Having students think as actual engineers think in solving real problems faced with limited resources improves some skills and enhances motivation. This was attempted in the course.

This is a work in progress. The lecture notes, homework assignments and details for the hands-on activities are being edited and will be available to faculty at the AIChE Chemical Engineering Summer School. A final version of the entire course will be submitted for publication in Chemical Engineering Education or a similar journal.

References

1. Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, *94*(1), 103-120.

2. Vigeant, M., and Jablonski, E., (2015). First Year Ranch: Introducing Chemical Engineering through Salad Dressing Design. AIChE 2015 Annual Meeting. (ISBN:9978-0-8169-1094-6).

3. Hoit, M. and Ohland, M. (1998), The Impact of a Discipline-Based Introduction to Engineering Course on Improving Retention. Journal of Engineering Education, 87: 79–85. doi:10.1002/j.2168-9830.1998.tb00325.x

4. Behrens, A., Atorf, L., Schwann, R., Neumann, B., Schnitzler, R., Balle, J., & Aach, T. (2010). MATLAB meets LEGO Mindstorms—A freshman introduction course into practical engineering. *IEEE Transactions on Education*, *53*(2), 306-317.