Vertically Integrating Experiential Learning to Senior Design

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Abstract

Participating in the 2012 National Academy of Engineering Frontiers of Engineering Education symposium will enable me to learn methods for better assessing the outcomes for the vertically integrated senior design program. I anticipate that interactions and feedback from FOEE participants will help me hone my efforts on the vertically integrated modules. Armed with demonstrated working models from other successful engineering educators it will be possible to convey quantitative outcomes to other departments. The goal is to establish a multi-disciplinary capstone design program that leverages many of the common engineering core courses allowing some senior design projects to encompass students from multiple disciplines.

Educational Objective

The Undergraduate Design Project is the major design experience of EAEE students. The subject of the design can be a product, a process, a system, or a component of a system. Projects may be either research oriented (e.g. design of a novel technique or process) or technology oriented (e.g. use of existing technology in solving an Earth/environment problem). However, all projects must involve i)engineering analysis of known facts and ii)their synthesis to arrive to the desirable goal. The students are told to consider themselves to be practicing engineers who are engaged to work on their particular subject by a paying employer or client. The final result, both in terms of the report and the presentations, must be of full professional caliber. Students submit full reports and present their findings in a formal presentation.

A successful implementation of a vertically integrated, NSF funded Departmental Level Reform (DLR) at Columbia University's Earth & Environmental Engineering (EAEE) Department led to an increased enrollment and a more integrated curriculum. The implementation to the Senior Design Course (EAEE 3800) was not as successful. It is not consistently implemented across all design projects. It is currently dependent on the project advisor to suggest to the design team some laboratory techniques that can be utilized during the project. *Another desired outcome of attending the FOEE would be an effective implementation of laboratory module techniques used in design projects.*

Downselect

Table 1 below summarizes the performance of the preliminary concepts based on the key criteria. A Score of zero indicates very poor performance, three indicates acceptable performance, and five indicates excellent performance. The two highlighted concepts will be pursued to the final design stage. Biomass combustion is designed in sufficient detail in to be an alternative design to biomass gasification should the client want to explore this option further. The steam heat recovery was evaluated as having the highest impact, thus being the easiest to implement. These values were determined in consultation with the client, but a more rigorous methodology must be developed to remove client bias.

Table 1: Summary Evaluation of Preliminary Concepts

Criteria/Concept	Environmental Benefits	Space & Operational Constraints	Cost & Payback Time	Total
Biomass Combustion	3	2	5	10
Biomass Gasification	3	4	5	12
Steam Heat Recovery	3	5	5	13
Ammonia Stripping	3	3	0	6
CO_2 Capture & Reuse	5	1	1	7
Anaerobic Digestion	4	1	3	8

Unit Operations & Senior Design

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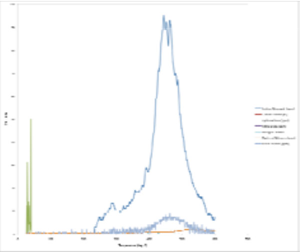
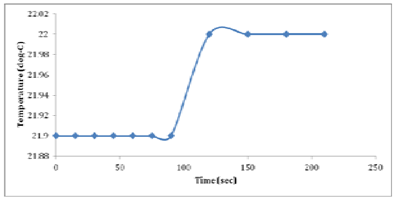
Students utilized an online Enerac 700 field portable emissions analyzer to take measurements of the boiler system used in the Six Points Brewery. This unit is the same unit that is used for the students when testing a Three Way Catalyst module in the unit operations laboratory sequence.

A representative plot of emission data from the ENERAC testing on site is show to the right. Carbon monoxide was the largest source of emissions. Air at a flow rate of 2.1 L/min was used during the experiment. This is a good example of students confirming data that was given to them which allows a better understanding of how the client system works.



To better design a gasifier system for the Brewery the students took samples of beer residual biomass (hops, yeast, etc) and determined the heat of combustion and heat of gasification using a Parr Bomb Calorimeter. Again, this is the same unit that is used in the unit operations laboratory when students are determining heating values of different fuels (coal, oil, biomass, waste, etc) and have to determine an unknown fuel from its heating value. Representative data is shown below and matches well with literature.

Initial Mass of Fuel (g)	0.08847
Initial Mass of Wire (g)	0.0183
Final Mass of Wire (g)	0.0109
t_i Initial Time (min)	0
t_f Final Time (min)	4
Ti, Initial Temperature (deg-C)	21.9
Tf, Final Temperature (deg-C)	22
t_a, Time at which temp rises to 60% of its difference	1.8
Td, Characteristic 60% Temp Difference	21.96
r1, Temp Change/Time change before ignition (deg-C/min)	0.004
r2, Temp Change/Time Change after ignition	0.008
Measured Change in T (deg-C)	0.1
Change in T, corrected (deg-C)	0.08
$C_{calorimeter}$ (cal/degC)	2565.872506
Heat given off from combustion (cal)	182.59
Calorific Value (cal/g)	**2063.90**
Calorific Value (J/g)	**8635.38**
Calorific Value (MJ/kg)	**8.635375547**



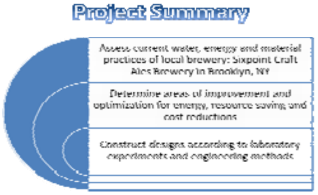
How can more traditional Chemical Engineering unit operations be utilized more regularly in Senior Design course? How can earlier course material be more directly connected to Senior Design projects?

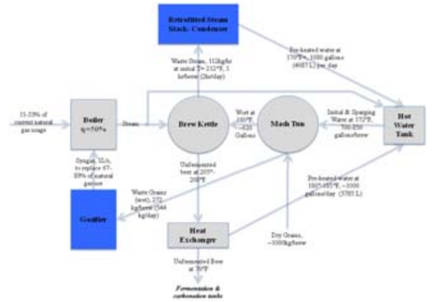
Learning Activity and Materials

The learning activities encompass utilization of equipment used in one course (unit operations laboratory) in another capacity. This allows the student to see the application of previously learned principles and engineering tools in very different settings. In addition, the collection of data results in the students becoming more invested in the design process and makes the project more realistic. The materials were selected testing equipment, spreadsheets and simple drawing packages.

Are there more uniform, consistent packages for design students to use (such as ASPEN)? Should students be left to their own devices to determine the best method of design sizing and communication?

Example Outcome





The biomass gasification replaces the need for 67-89% of the current natural gas consumption, depending on the assumed efficiency of the gasifier. The steam retrofits triple the flow of pre-heated water from the steam stack and avoid an increase in 17.7 GJ of energy requirement a month, 30-49% of the current use (depending on boiler efficiency assumption). They save an additional 14-23% by increasing the minimum temperature of pre-heated water. Together, they offer substantial economic savings of $5358 annually and very reasonable payback times under one year. In addition, approximately 16,200 kg of CO2 are prevented from reaching the atmosphere due to the onsite use of the biomass and an additional $2080 is saved annually by no longer paying a farmer for the waste grain pickup. Figure 9 below, illustrates the primary brewery processes after the recommended improvements.

Migration of Initial Work

NSF Departmental Level Reform (DLR) Program funded work done at Columbia University's Earth & Environmental Engineering (EAEE) Department. The project was successful in revamping the EAEE department increasing enrollment from 7 to ~60 students over the course of about 6 years. The integration of vertical learning including studio based learning was very successful. The incorporation of experiences during coursework into Senior Design was not as successful as hoped. The goal at City College (CCNY) of The City University of New York (CUNY) is to incorporate some aspects of work done at EAEE to the Chemical Engineering Senior Design Course at CCNY

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NAE Theme: Innovation in Curriculum

Combustion &
Catalysis
Laboratory

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