INCORPORATING PROJECT-BASED LEARNING INTO ENGINEERING COURSES

models for two types of non-capstone courses

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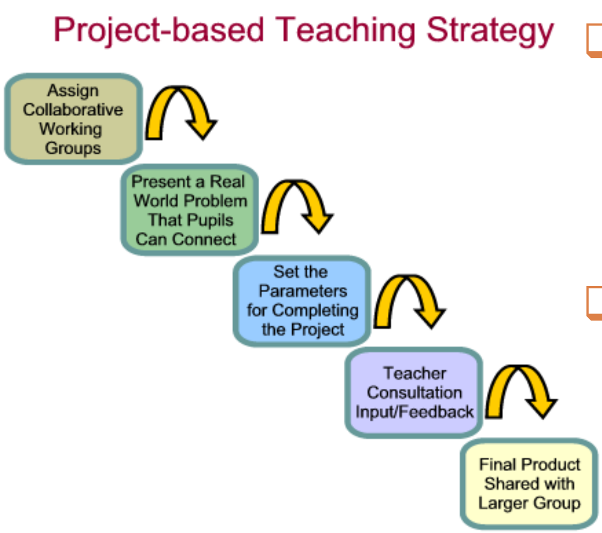
What is Project-based Learning?

- Approach often used for senior design class (Dym et al. 2005)
  - Also a very effective method in lower-level courses
- Assignment leads to the production of a final product (e.g., design, model, device, simulation)
- Culmination is usually a report/presentation
- Real-world problems provide context for learning
  - Complex
  - Ill-structured
  - Open-ended

Problem- and Project-based Learning

(Mills and Treagust, 2003)

- Both involve real-world problems requiring teamwork and *guidance* by instructors



- Problem-based learning
  - Emphasis on acquiring knowledge
  - Solution is often secondary
- Project-based learning
  - Focus on end product
  - Emphasis on applying/integrating knowledge

- Blend of Problem- and Project-based learning is also effective

Advantages

(Prince and Felder, 2006)

- Learner-centered approach
  - Students required to take more responsibility for learning
- Constructivist approach
  - Students construct own version of reality rather than version presented by teacher
- Team-based cooperative learning outside class
  - Active learning, primarily self-directed

Benefits

(Thomas, 2000)

- In comparison with traditional classroom methods, project-based learning results in better:
  - Content knowledge
  - Conceptual knowledge
  - Problem solving ability
  - Metacognitive skills
  - Attitude toward learning

Benefits (con't)

(Mills and Treagust, 2003)

- Problem-based learning also results in better:
  - Communication and teamwork skills
  - Understanding of professional practice
  - How to apply learning to solve problems

Examples of Project-Based Learning at Rowan University

- Freshman Engineering Clinic
  - Introductory, multidisciplinary course
  - Hands-on project provides framework
- Chemical Reaction Engineering
  - Junior-level core chemical engineering course
  - Design project (on paper)
  - 5 assigned memos provide framework
  - Memos synchronized with course content

Freshman Engineering Clinic

- First year introductory course
- 2 credits
- 1 hr lecture + 2.5 hr lab each week
- Multidisciplinary students and content
- ~20 students per section with 1 instructor

"Tell me and I forget
Show me and I may remember
Involve me and I understand"

Course Objectives

- Units conversions
- Data representation
- Data analysis
- Reverse Engineering and Design
- Written communications
- Oral communications
- Teamwork skills
- Ethics, global thinking
- Library research skills

- Taught in a PrBL environment
- Flexibility with regard to order of topics

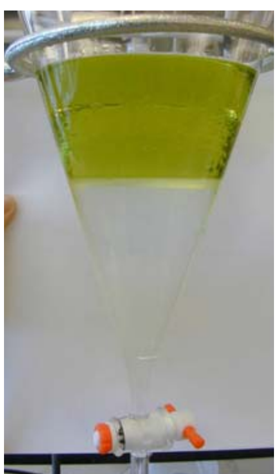
Biodiesel Fuel Production

- Design a process to produce 100% of biodiesel needed to fuel shuttle van to new Tech Center
- Modules investigate engineering aspects of design and production
- Provide framework for learning
  - Introduce new, project-specific engineering concepts
  - Introduce general content related to course objectives
  - Reinforce concepts by application

www.4cleanfuels.com

Reaction, Separation, Purification

- New & Waste Vegetable Oil
- 1-L Batch Reaction
  - Vegetable Oil + Methanol → Biodiesel + Glycerin
- Purification
  - Washing with water vs. adsorption



Biodiesel Production Concepts

Module	New Engineering Concepts	Reinforced Concepts	Course Objectives
Reaction and Separation	• Batch reaction • Mass balances • Phase separation	• Titration, stoichiometry and yield (chemistry) • Derivatives - reaction rates (calculus)	• Unit conversions • Data representation and analysis • Library research • Written communication
Purification	• Phase distribution • Adsorption • Void volume • Flow rate • Quality-quantity trade-off	• Mass balances (engineering) • Gravity flow- derivatives (calculus)	• Unit conversions • Data representation and analysis • Library research • Written communication

Physical Property and Quality Testing

- Physical Property Tests
  - pH, viscosity, specific gravity, cloud point
- Semi-quantitative and threshold tests
  - Aged, oxidized fuel
  - Glycerides
  - Acid accumulation
  - Soap
  - Water

Property Testing Module Concepts

New Engineering Concepts	Reinforced Concepts	Course Objectives
• Viscosity • Property measurement • ASTM test methods	• Physical properties (chemistry) • Presence of contaminants (chemistry)	• Unit conversions • Data representation and analysis • Library research • Written and oral communication

Biodiesel Performance

- Calorimetry Experiment
  - Determine heat of combustion
  - Compare feedstock, product, commercial B20, and petro-diesel
- Generator Testing
  - Emissions (NO_x, CO, CO_2)
  - Fuel Consumption
  - Efficiency

Energy/Emissions Module Concepts

New Engineering Concepts	Reinforced Concepts	Course Objectives
• Energy balance • Energy content • Emissions • Power calculations • Volumetric efficiency • Emissions	• Heat capacity (chemistry)	• Unit conversions • Data representation and analysis • Library research • Written and oral communication

Reverse Engineering and Design

- Construct and test 150 L biodiesel processor
- Test and improve biodiesel processor

Design Module Concepts

New Engineering Concepts	Reinforced Concepts	Course Objectives
• Reverse engineering • Scale-up and design	• Mass balances • Measurements	• Unit conversions • Library research • Written communication

Ethics and Global Issues

- Oral and written assignments
  - Corporate average fuel economy standards
    - Should SUVs count as Cars or Light Trucks?
  - A critical analysis of global warming data
  - Ethanol and biodiesel – a solution to GGE or just another farm subsidy?
  - Carbon emissions trading

Ethics / Issues Module Concepts

New Engineering Concepts	Reinforced Concepts	Course Objectives
• Role of engineer		• Library research • Written and oral communication • Global issues • Ethics

Summary

Biodiesel Production Project

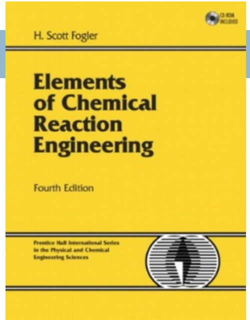
- Students gained technical knowledge of biodiesel process through hands-on investigations
  - Reaction
  - Separation
  - Quality Testing
  - Performance Testing
  - Pilot plant
  - Ethics

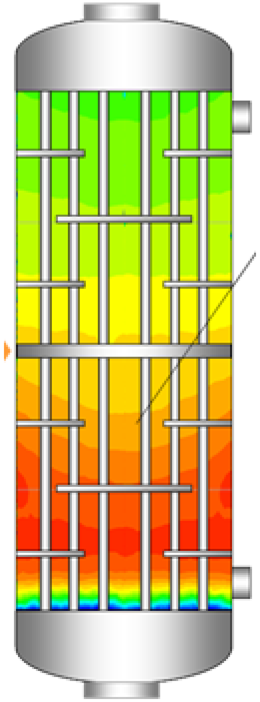
Educational Outcomes

- Students demonstrated the following abilities:
  - Teamwork
  - Analysis of data
  - Library research skills
  - Written and oral communications
  - Understanding of ethical and global issues

Chemical Reactor Design

- 4-credit junior level ChE core course
- 2 x 1.25 h and 1 x 2.5 h meeting weekly
- 3 exams (65%) and HW (10%)
- Project (outside of class time)
  - Teams of 3-4 students
  - 5 memos at 2-3 week intervals
  - Final presentations
  - Final report
  - 25% of course grade





Reactor Design Project Overview

- Design a reactor for the production of a (specified) commodity chemical
  - Literature review
    - Background on product and production technologies
    - Reaction kinetics for specified system
  - Initial design
    - Isothermal, isobaric, simple kinetics
  - Gradually remove simplifying assumptions
  - Reactor analysis using hand calculations, POLYMATH®, and Aspen Plus® process simulator

Project-Course Synchronization

- Memo 1: Background & overall mass and energy balances
- Memo 2: Isothermal, isobaric reactor sizing with simple kinetics
- Memo 3: Pressure drop and reactor size optimization
- Memo 4: Multiple reactions
- Memo 5: Energy balances with multiple reactions

Making things go smoothly

- Memos were synchronized with lecture topics
- Teams were assigned one of two products
  - Chose kinetics from literature; steered away from unreasonable choices
- Resources (online, library reserve, library reference)
  - Detailed guide to references avoids confusion
- Teamwork and problem solving skills are essential
- Graduate assistant helped teams troubleshoot models

Summary

- PBL in Engineering Curricula
  - PBL in courses at Rose-Hulman, Carnegie Mellon, and WPI (Rosenbaum, 2006)
  - PB curricula at Aalborg Denmark, Monash and Central Queensland University (Mills & Treagust, 2003)
- Benefits of PBL
  - Content knowledge
  - Conceptual knowledge
  - Problem solving ability
  - How to apply learning
  - Metacognitive skills
  - Attitude & Motivation
  - Communication and teamwork skills
  - Understanding of professional practice

References

- Dym, C., Agogino, A., Eris, O., Frey, D., and Leifer, L., "Engineering Design Thinking, Teaching, and Learning," *Journal of Engineering Education,* Vol. 94, No. 1, 2005, pp. 103–120.
- Mills, J.E., and Treagust, D.F., "Engineering Education—Is Problem-Based or Project-Based Learning the Answer?" *Austraaslian Journal of Engineering Education,* *http://www.aaee.com.au/journal/2003/mills_treagust03.pdf*.
- Prince, M.J. and Felder, R.M., "Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases," Journal of Engineering Education, Vol. 95, No. 2, 2006, pp. 123-138.
- Rosenbaum, D.B., Schools erase chalk-and-talk. Engineering News-Record, Sept 2. 1996, pp. 24-30.
- Thomas, J.W., "A review of research on Project-based Learning," San Rafael, CA: Autodesk Foundation, 2000.