INCORPORATING PROJECT-BASED LEARNING INTO ENGINEERING COURSES
models for two types of non-capstone courses
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

  **Project-based Teaching Strategy**

  - Assign Collaborative Working Groups
  - Present a Real World Problem That Pupils Can Connect
  - Set the Parameters for Completing the Project
  - Teacher Consultation Input/Feedback
  - Final Product Shared with Larger Group

  **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 $\rightarrow$ Biodiesel + Glycerin
- Purification
  - Washing with water vs. adsorption
## Biodiesel Production Concepts

<table>
<thead>
<tr>
<th>Module</th>
<th>New Engineering Concepts</th>
<th>Reinforced Concepts</th>
<th>Course Objectives</th>
</tr>
</thead>
</table>
| 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

<table>
<thead>
<tr>
<th>New Engineering Concepts</th>
<th>Reinforced Concepts</th>
<th>Course Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Viscosity</td>
<td>• Physical properties (chemistry)</td>
<td>• Unit conversions</td>
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<tr>
<td>• Property measurement</td>
<td>• Presence of contaminants (chemistry)</td>
<td>• Data representation and analysis</td>
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<tr>
<td>• ASTM test methods</td>
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<td>• Library research</td>
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<td></td>
<td></td>
<td>• Written and oral communication</td>
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</tbody>
</table>
Biodiesel Performance

- **Calorimetry Experiment**
  - Determine heat of combustion
  - Compare feedstock, product, commercial B20, and petro-diesel

- **Generator Testing**
  - Emissions (NO\textsubscript{x}, CO, CO\textsubscript{2})
  - Fuel Consumption
  - Efficiency
# Energy/Emissions Module Concepts

## New Engineering Concepts
- Energy balance
- Energy content
- Emissions
- Power calculations
- Volumetric efficiency
- Emissions

## Reinforced Concepts
- Heat capacity (chemistry)

## Course Objectives
- 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
- Reverse engineering
- Scale-up and design

### Reinforced Concepts
- Mass balances
- Measurements

### Course Objectives
- 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

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<th>New Engineering Concepts</th>
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<th>Course Objectives</th>
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</thead>
<tbody>
<tr>
<td>• Role of engineer</td>
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<td>• Library research</td>
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<td>• Written and oral</td>
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<td>• Global issues</td>
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<td>• Ethics</td>
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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
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


