Project sponsored through the *Transforming Learning for a Third Century (TLTC)* grant program at the University of Michigan
Revitalizing the Chemical Engineering Senior Design Experience: Empowerment, Entrepreneurship, and a Flipped Classroom Experience

Andrew Tadd, Department of Chemical Engineering
Elaine Wisniewski, Program in Technical Communication
Leena Lalwani, Art, Architecture, and Engineering Library

June 15, 2015
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Presentation Structure

1. Why do this project?
2. How did we do it?
3. Did it work?
Why do this project?

Course context

STUDENTS
N=51

INDUSTRY MENTORS

INSTRUCTORS
Technical
Communication
Library
Why do this project?

**Typical projects**

- Instructor-generated problems
- Focuses on details of technical design
- Typically projects with commodity products/large-scale plants
Why do this project?

Typical projects

- Instructor-generated
- Focuses on details of technical design
- Typically projects with commodity products/large-scale plants

Students miss out on identifying their own project opportunities
Why do this project?

Our Goals

- Introduce elements of entrepreneurial thinking
- Maintain strong focus on technical design of processes
- Focus on:
  - more student ownership of design projects
  - emphasizing creativity, defining final product and requirements

http://abc.go.com/shows/shark-tank
How did we do it?

1. Students were formed into pitch teams focused on sectors

2. Students were tasked to identify
   - a potential product
   - its associated market, and
   - the potential economic benefit

3. Present their ideas in a pitch session, with department alumni and their peers evaluating the proposed projects
Request for Proposals

MichiChem, Fall 2014 Funding Cycle

1. General

MichiChem, a wholly owned fictional subsidiary of UM ChE, seeks proposals for new chemical processes to be constructed at either its U.S. Gulf Shore or Southeast Michigan plant complexes. MichiChem is comprised of multiple business lines, and many of these will be seeking proposals for allocation of capital resources. Our existing facilities have extensive infrastructure (rail access, power, plant utilities, etc.) that can be utilized, subject to potential expansion requirements.

Proposals will be due in written form (see requirements below) on Wednesday September 17, and presented orally on Friday September 19 to the decision making body. It is anticipated that winning proposals will be announced on Friday September 19, with teams formed and work to begin on September 22.
Proposals requested for new products or alternative methods

Five broad interest areas in chemical engineering sectors

2. Background/Areas of interest

MichiChem currently produces agricultural and commodity chemicals, consumer products, plastics, and some pharmaceuticals. We seek proposals for processes to produce new products, or conventional products using alternative methods. Successful proposals will fit within these broad areas of interest:

- Off-patent pharmaceuticals (generics), including those of interest in under-industrialized markets
- ‘Green’ or ‘sustainable’ consumer cleaning products (these adjectives may be taken to describe the production process, i.e. substitution of renewable for non-renewable feedstock, or the product itself in use, i.e. a non-toxic or biodegradable product)
- Any commodity chemical (<$2500 per metric ton) or bulk polymer currently in the market but sourced using a non-petroleum primary feedstock
- Renewable fuels (preferably liquid transportation fuels, but open to more exotic proposals)
- Processes using natural gas as a chemical feedstock (i.e. non-fuel application of domestic US fracking gas)
‘Green’ or ‘sustainable’ consumer products

Processes with natural gas as chemical feedstock

Commodity chemicals from non-petroleum feedstock

Renewable fuels

Off-patent pharma
| 'Green' or 'sustainable' consumer products | Processes with natural gas as chemical feedstock | Commodity chemicals from non-petroleum feedstock | Renewable fuels | Off-patent pharma |

Students ranked their preferences and were placed in teams of 3 students.
How did we do it?

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<tr>
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<tbody>
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<td>11 Ethanol from switch grass</td>
<td>16 Aripiprazole</td>
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<td></td>
<td></td>
<td></td>
<td>12 Landfill gas to gasoline</td>
<td>17 Aripiprazole</td>
</tr>
</tbody>
</table>
Penta Chart Examples

**Penta Chart Examples**

**Title of your Proposal**

**Problem Statement**
- Describe the technology problem being addressed and its importance to the organization's technology needs.
- Describe how the requested flight supports your technology development efforts.
- List potential uses of the mature technology.

**Proposed Flight Experiment**

- **Experiment Readiness:** State when the experiment will be ready for flight.
- **Test Vehicles:** State your proposed platform (fixed-wing, small rocket, etc.) and the high-altitude balloon system.
- **Test Environment:** Describe the relevant environments in which the experiment has previously flown and those requested through flight opportunities.
- **Test Apparatus Description:** Provide test and photo(s) to depict the test apparatus and operator interface.

**Technology Development Team**
- Provide name, organization, and email address of principal investigator.
- Provide contact information of the organization providing funding support to this effort.
- Provide name of organizations that may or may become partners in this technology development.

**Objective of Proposed Experiment**
- Define the specific objective(s) of the proposed flight campaign(s).
- Describe the expected flight and how it will be used to advance your technology development effort.

**Technology Maturation**
- Describe the criteria that must be met to achieve each TRL between the current TRL and TRL 6 or higher.
- Describe the steps to mature the technology to TRL 6 or higher.
- State the deadline, if any, to mature the technology to TRL 6 or higher.

**DARPA**

**Main Achievement**
- Placeholder explanatory text. Replace with text and diagrams as necessary.

**How It Works**
- Placeholder explanatory text paragraph. Replace with text and diagrams as necessary.
- Technical capability showing improvements over state of the art.
- Address how strategy may reduce or eliminate pathogen's ability to acquire resistance.

**Assumptions and Limitations**
- Assumptions.
- Limitation(s).
- Comment on how FDA may evaluate approach.

**What is the state of the art and what are its limitations?**
- (INSERT DIAGRAM(S))

**What are the key new insights?**
- (INSERT DIAGRAM(S))

**A Sentence Why It Is Important/ Useful**

**Proposed Concept Goals**

**Characterize the Quantitative Impact**
- (INSERT TABLE, GRAPH, OR OTHER SUITABLE VISUALIZATION)

**As compared to start of the art technologies and/or prior evolution**

**What is potential capability of this technology?**
- (REPLACE WITH DIAGRAM/ TEXT/ THRESHOLD CRITERIA)

**NEW INSIGHTS**

**Primary answer here. Add more text as necessary.**
- First bullet point.
- Additional as necessary.

**STATUS UPDATE**

**Primary answer here. Add more text as necessary.**
- Second key insight.
- Additional as necessary.

**What are the key new insights?**
- (INSERT DIAGRAM(S))

**First key insight. Add more text as necessary.**
- Second key insight. Add more text as necessary.

**Describe novelty as compared to state of the art.**
Duckweed as a Renewable Fuel Source
MichiChem at the University of Michigan

Proposal:
Harvest duckweed in order to produce ethanol for a renewable fuel source.

HOW IT WORKS:
Growing duckweed

Harvesting and drying

Ethanol

Ethanol production

ASSUMPTIONS AND LIMITATIONS:
• Surface grower
• Rapid growth, may cause crowding
• Large competitive refineries must sell this ethanol for $72/ barrel
• Year-round growth with sufficient nutrients
• Moderate sized ethanol plant produces approximately 50-100 million gallons of ethanol per year
• Ethanol price: $2.36/gallon, unleaded gasoline: $2.79/gallon, so ethanol is in demand

Duckweed is an alternative for ethanol production
• Photosynthesis removes CO$_2$
• Produces 5 to 6 times more starch than corn per unit footage
• Requires 20% of growing space compared to corn
• Functions as a bio-remediator for water
• Similar processing as corn for ethanol

Integrate higher percentages of ethanol into biodiesel
Use waste products for animal feed
Wastewater treatment
Increase ethanol production and uses
Explore cellulosic ethanol production

Duckweed will provide an alternative in order to reduce our dependence on non-renewable fuels.
Converting Pure Methane into Ammonia

Producing fertilizer to help feed the world

**BACKGROUND & MOTIVATION**

- With the discovery of shale gas, the US has become the leading natural gas producing country in 2014
- Because of increased production, the price of natural gas has dropped significantly
- Our goal is to utilize recent natural gas abundance for cheaper fertilizer manufacturing

**INNOVATION**

- Uses a cheap feedstock and process to minimize cost of production of fertilizer grade ammonia
- Recycle water from exothermic reaction cooling jacket into boiler to reduce energy cost to produce steam for endothermic reaction
- Explore catalyst synthesis inclusion in process

**DESCRIPTION**

This process will convert Methane into Ammonia

- Form catalyst from aluminum oxide and magnetite
- A steam reformer will remove the hydrogen from the methanol, using above catalyst
  \[ \text{CH}_4 + 2\text{H}_2\text{O} \rightarrow 4\text{H}_2 + \text{CO}_2 \]
- The residual carbon dioxide will be recombined with water into methane and reprocessed
- The hydrogen will be reacted over a catalyst with nitrogen from air, undergoing the Haber process:
  \[ \text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3 \]

The anhydrous ammonia product will be separated and cooled to a liquid to prepare for shipping

**Assumptions**

- Feed comes from pure liquefied methane that has gone through regasification
- Cost of methane feedstock must remain low
- Assume Haber process reaction completes as stated
- High pressure and temperature requirements
- Expensive catalyst

**ANTICIPATED IMPACT**

- Lower energy cost of production
- Planned production 1000 tons/day
- Methane consumption ~353 tons/day
- Expected revenue between $222,168 and $546,797 per day

**PATH FORWARD**

- Monitor natural gas and ammonia on-going pricing trends
- Analyze heat exchange of reactors with cooling jacket during process reactions
- Expect theoretical development to be done by the end of FY1, and construction of plant done by end of FY3 providing there are no delays
- **MSs:**
  - **MS mid FY1:** define operation conditions for plant process
  - **MS end FY1:** develop theoretical prototype for more efficient plant process
- Increased efficiency of current process

**Point of Contact:** Jay Antonishen, Michael Carpenter, Daniel Cohen
How did we do it?

1. Students were formed into pitch teams focused on sectors

2. Students were tasked to identify
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3. Present their ideas in a pitch session, with department alumni and their peers evaluating the proposed projects
How did we do it?

Voting and Scoring System

• Pitches presented in one 3-hr class session
• Scoring of pitches by total points
• Students and mentors awarded points to any number of pitches

350 (26%)
980 (74%)

Students
Mentors
## How did we do it?

### Pitch Presentation Results

<table>
<thead>
<tr>
<th></th>
<th>Student</th>
<th>Mentor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aripiprazole</td>
<td>105</td>
<td>60</td>
<td>165</td>
</tr>
<tr>
<td>Ethyl Vanillin</td>
<td>68</td>
<td>60</td>
<td>128</td>
</tr>
<tr>
<td>Bioethanol</td>
<td>96</td>
<td>20</td>
<td>116</td>
</tr>
<tr>
<td>Herbal Bite-Blocker</td>
<td>80</td>
<td>30</td>
<td>110</td>
</tr>
<tr>
<td>Methotrexate</td>
<td>76</td>
<td>25</td>
<td>101</td>
</tr>
<tr>
<td>Ammonia</td>
<td>83</td>
<td>20</td>
<td>103</td>
</tr>
</tbody>
</table>

![Pie chart showing the distribution of total scores across different products and participant types.](chart.png)
‘Green’ or ‘sustainable’ consumer products

1 Ethyl vanillin

2 Herbal bite-blocker

3 Alkyl polyglycosides (APG)

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Students ranked their preferences and were placed in teams of 4-5 students.
‘Green’ or ‘sustainable’ consumer products

- Ethyl vanillin
  Teams 5,6

- Herbal bite-blocker
  Teams 3,4

Commodity chemicals from non-petroleum feedstock

- Ammonia from landfill gas
  Teams 9,10

Renewable fuels

- Bioethanol from corn stover
  Teams 11,12

Off-patent pharma

- Methotrexate
  Teams 1,2

- Aripiprazole
  Teams 7,12
Did it work?

• Assessment based on
  – Student course evaluations
  – Targeted survey conducted several months after course
  – Instructor impressions
Did it work?

Student Course Evaluations

- “I really liked getting to pick our own topics we were interested in.”
- “Having to think through many different problems and figuring out how to tackle new problems as you go.”
- “Getting to opportunity to work with a great team, exchange ideas, and present our ideas/designs in various different ways. I also really liked how open the projects were (i.e. we were able to pretty much do whatever we wanted in the design process).”
- “I loved this course. Getting to design something was a lot of fun. I wish we had more design work throughout our ChemE classes.”
Did it work?

Instructor Takeaways from Experience

• Although students appreciate structured projects, they seemed excited to define and select their own project.

• Instructors should automate more logistics with project voting and provide specific criteria during voting.

• Pitch process increased student buy-in and allowed for creativity all while meeting needs of process-focused design course.
Would you invest in this approach?

Andrew Tadd  atadd@umich.edu
Elaine Wisniewski  ewis@umich.edu
Leena Lalwani  llalwani@umich.edu

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