MICHIGAN ENGINEERING
UNIVERSITY OF MICHIGAN

Project sponsored through the *Transforming Learning for a Third Century (TLTC)* grant program at the University of Michigan

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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

CHEMICAL ENGINEERING
UNIVERSITY OF MICHIGAN

June 15, 2015

ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

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Presentation Structure

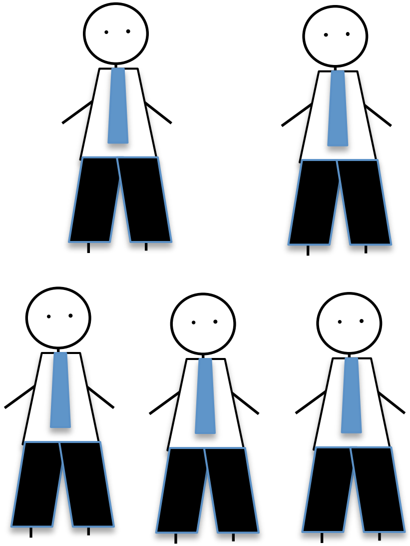
1. Why do this project?
2. How did we do it?
3. Did it work?

Why do this project?

Course context

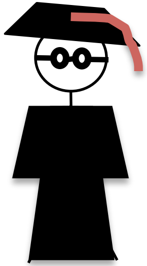
STUDENTS
N=51

INDUSTRY MENTORS

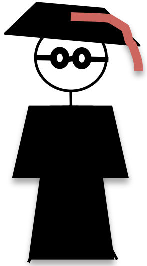


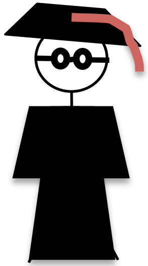
INSTRUCTORS

Technical



Technical Communication



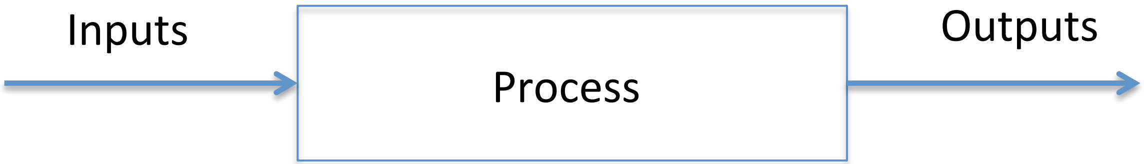


Library

Why do this project?

Typical projects

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

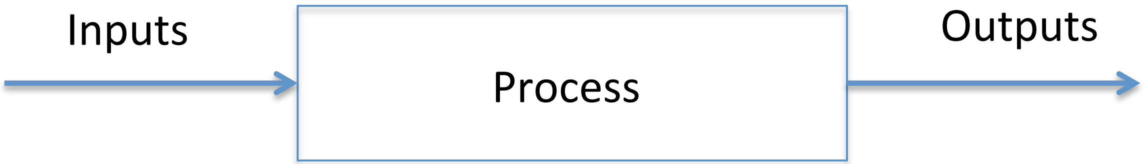


Why do this project?

Typical projects

- Instructor-generate…
-
- …projects with commodity products/large-scale plants

Students miss out on identifying their own project opportunities

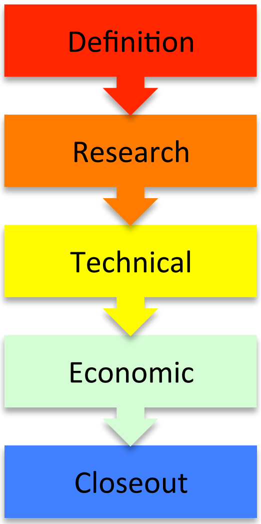


Why do this project?

Our Goals

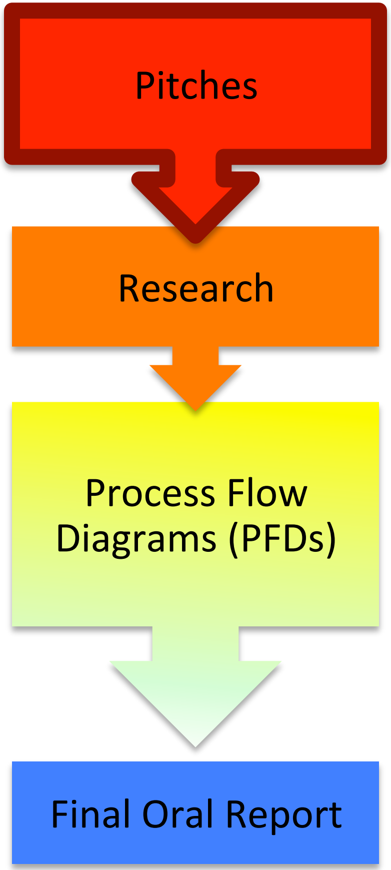
- Introduce elements of entrepreneurial thinking
- Maintain strong focus on technical design of processes
- Focus on:
  - more student ownership of design projects
  - emphasizing creativity, defining final product and requirements

http://abc.go.com/shows/shark-tank



Traditional Approach

Revised Approach



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?

1. Students were formed into pitch teams focused on sectors

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‘Green’ or ‘sustainable’ consumer products

1 Ethyl vanillin

2 Herbal bite-blocker

3 Alkyl poly glycosides (APG)

Processes with natural gas as chemical feedstock

4 Methanol from natural gas

5 Ammonia from pure methane

Commodity chemicals from non-petroleum feedstock

6 Poly lactic acid from sugar beets

7 Ammonia from landfill gas

Renewable fuels

8 Duckweed

9 Bioethanol from corn stover

10 Who needs paper?

11 Ethanol from switch grass

12 Landfill gas to gasoline

Off-patent pharma

13 Methotrexate

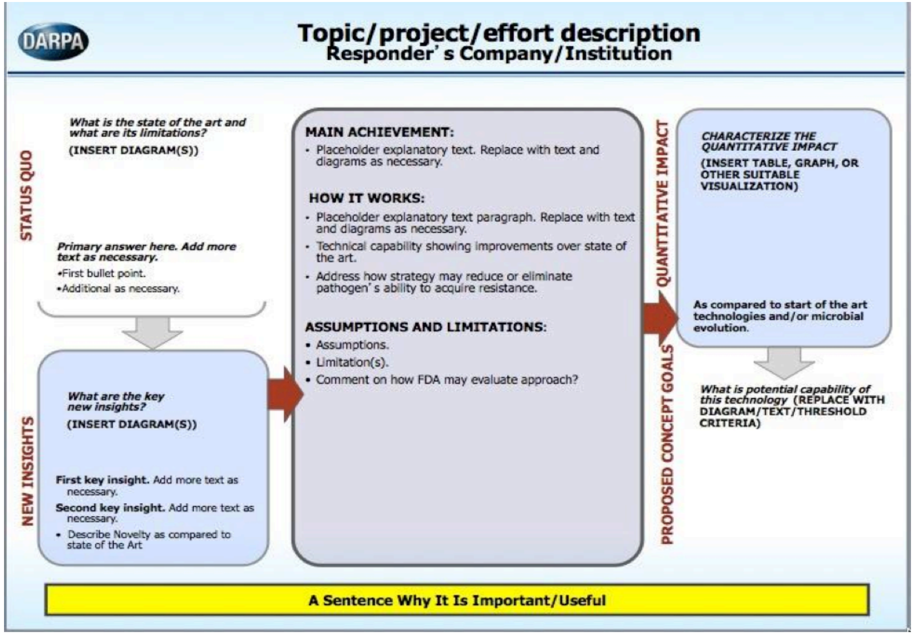
14 HIV medication

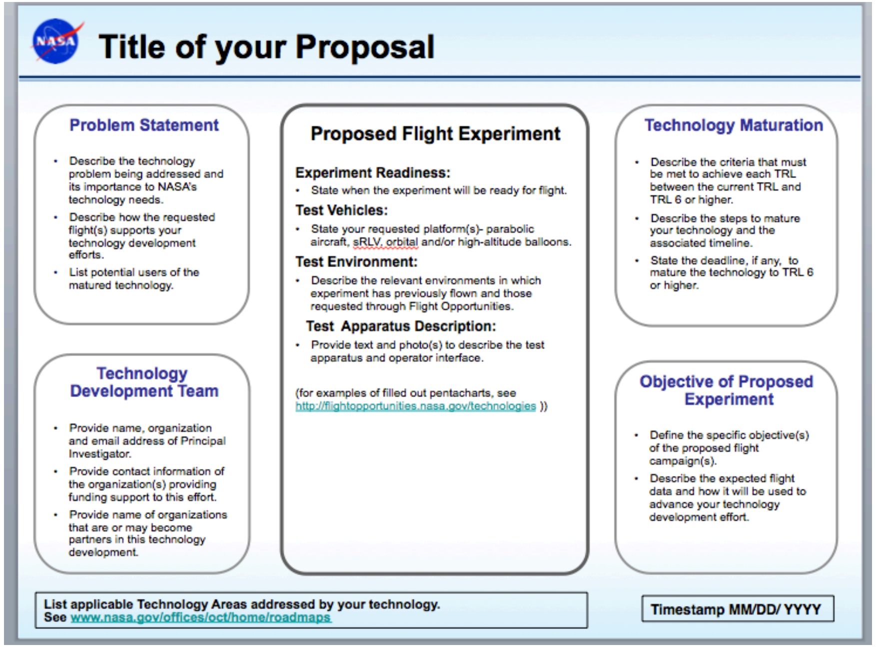
15 Aripiprazole

16 Aripiprazole

17 Aripiprazole

Penta Chart Examples





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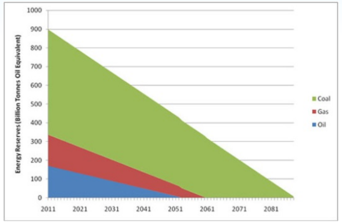
Duckweed as a Renewable Fuel Source

MichiChem at the University of Michigan

STATUS QUO



Worldwide, fossil fuel oils are consumed at 11 billion tons a year, and fossil fuel reserves are depleting at 4 billion tons a year.

- With no other oil sources, we will run out in approximately year 2052. [1]

NEW INSIGHTS

Using renewable sources , such as plants and vegetables to harvest oil for fuel

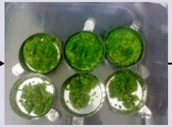
- Duckweed has a rapid growth rate
- Duckweed doesn't effect human food supply
- Duckweed can thrive in wastewaters

Proposal:

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

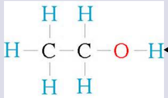
HOW IT WORKS:

Growing duckweed



Harvesting and drying

Ethanol production



Ethanol

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

QUANTITATIVE IMPACT

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

PROPOSED CONCEPT GOALS

Integrate higher percentages of ethanol into biodiesel

Use waste products for animal feed

Wastewater treatment

Increase ethanol production and uses

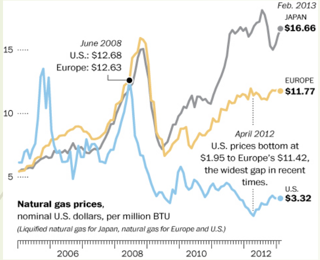
Explore cellulosic ethanol production

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

$$CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$$

- 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:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

1. N_2 (g) → N_2 (ads)	3. H_2 (g) → H_2 (ads)
2. N_2 (ads) → 2N (ads)	4. H_2 (ads) → 2H (ads)
5. N (ads) + 3H (ads) → NH_3 (ads)	
6. NH_3 (ads) → NH_3 (g)	

- 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

Limitations

- High pressure and temperature requirements
- Expensive catalyst

Current Technology Readiness Level

- *Technology currently in use*

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*

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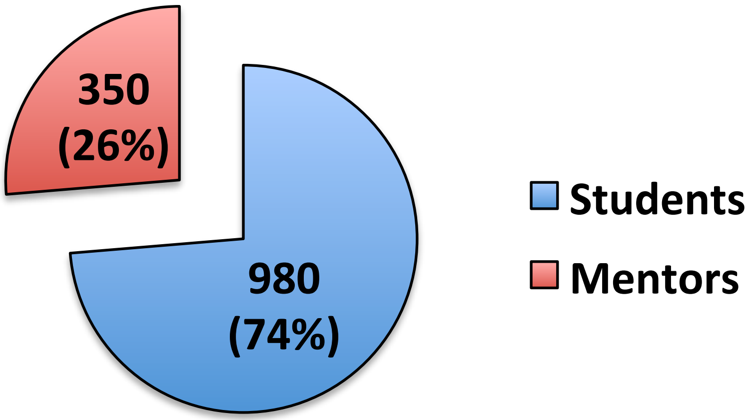
How did we do it?

Voting and Scoring System

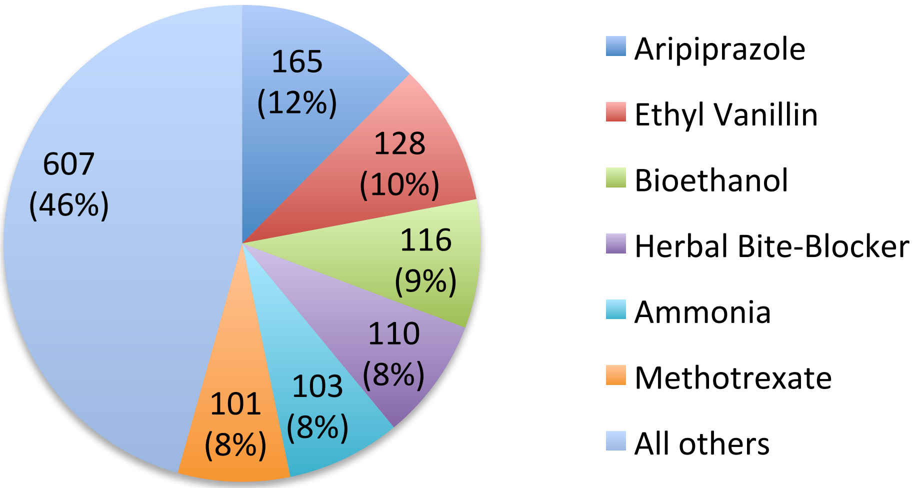
- Pitches presented in one 3-hr class session
- Scoring of pitches by total points
- Students and mentors awarded points to any number of pitches



How did we do it?

Pitch Presentation Results

	Student	Mentor	Total
Aripiprazole	105	60	165
Ethyl Vanillin	68	60	128
Bioethanol	96	20	116
Herbal Bite-Blocker	80	30	110
Methotrexate	76	25	101
Ammonia	83	20	103



'Green' or 'sustainable' consumer products

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- **7 Ammonia from landfill gas**

Renewable fuels

- 8 Duckweed
- **9 Bioethanol from corn stover**
- 10 Who needs paper?
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Off-patent pharma

- **13 Methotrexate**
- 14 HIV medication
- **15 Aripiprazole**
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Off-patent pharma

- otrexate
- HIV ation
- 15 Aripiprazole
- 16 Aripiprazole
- 17 Aripiprazole

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?

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