

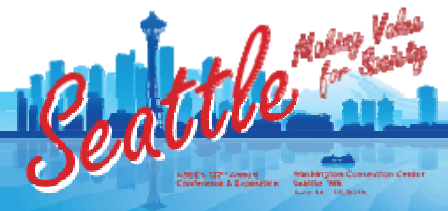
RESULTS & LESSONS LEARNED FROM A CHEMICAL ENGINEERING FRESHMAN DESIGN LABORATORY

Anthony Butterfield

Kyle Branch

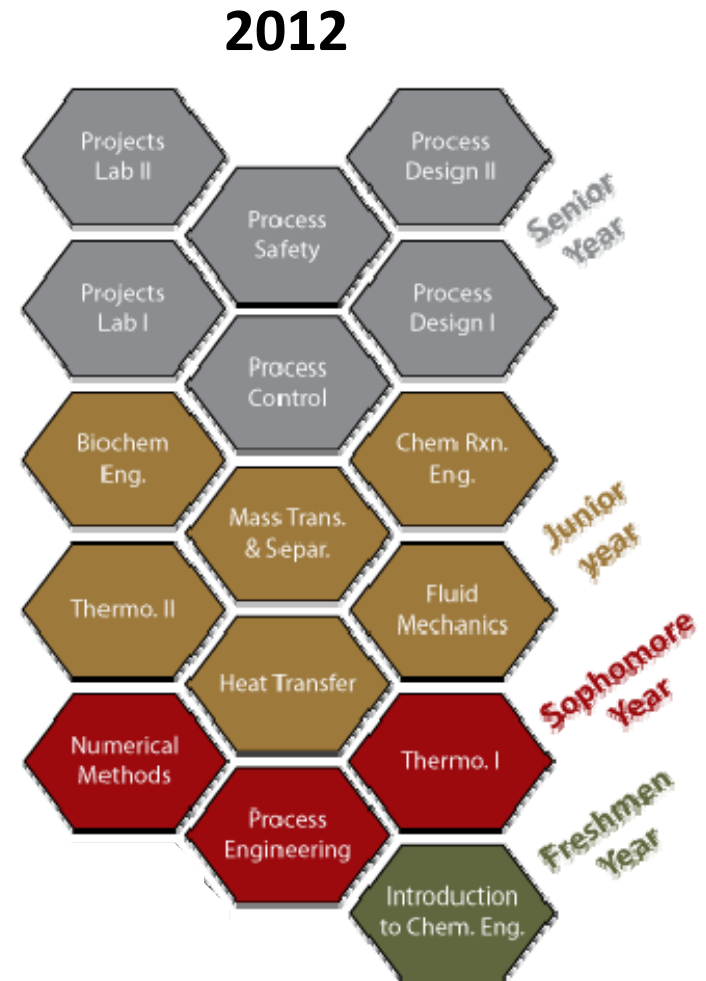
University of Utah, Department of Chemical Engineering

Tuesday, June 16, 2015

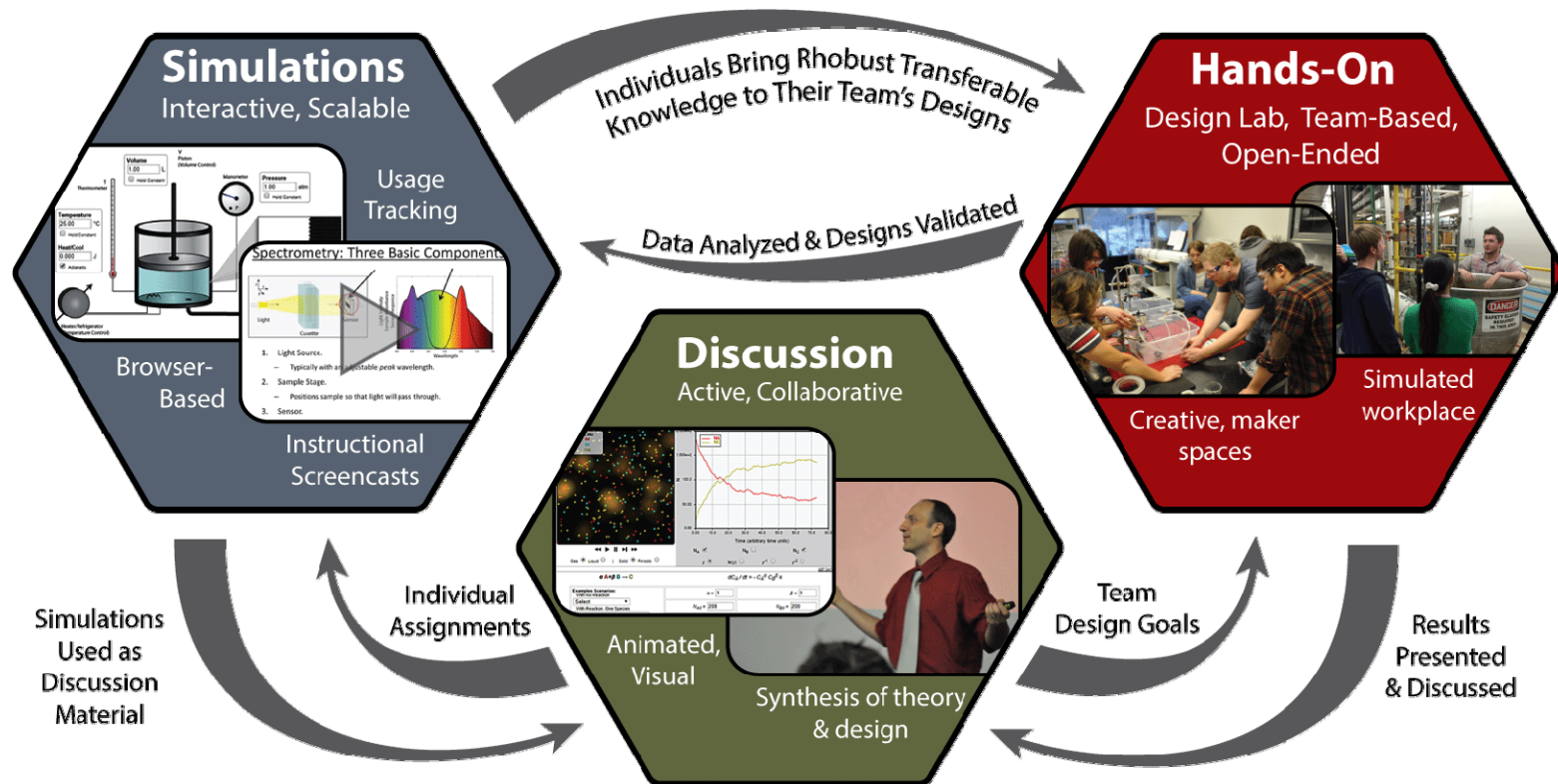


Motivation

- Traditional pedagogy up to senior year.
 - High rate of attrition.
- Evidence on effective teaching suggested we could serve our students better.
 - And try something new...

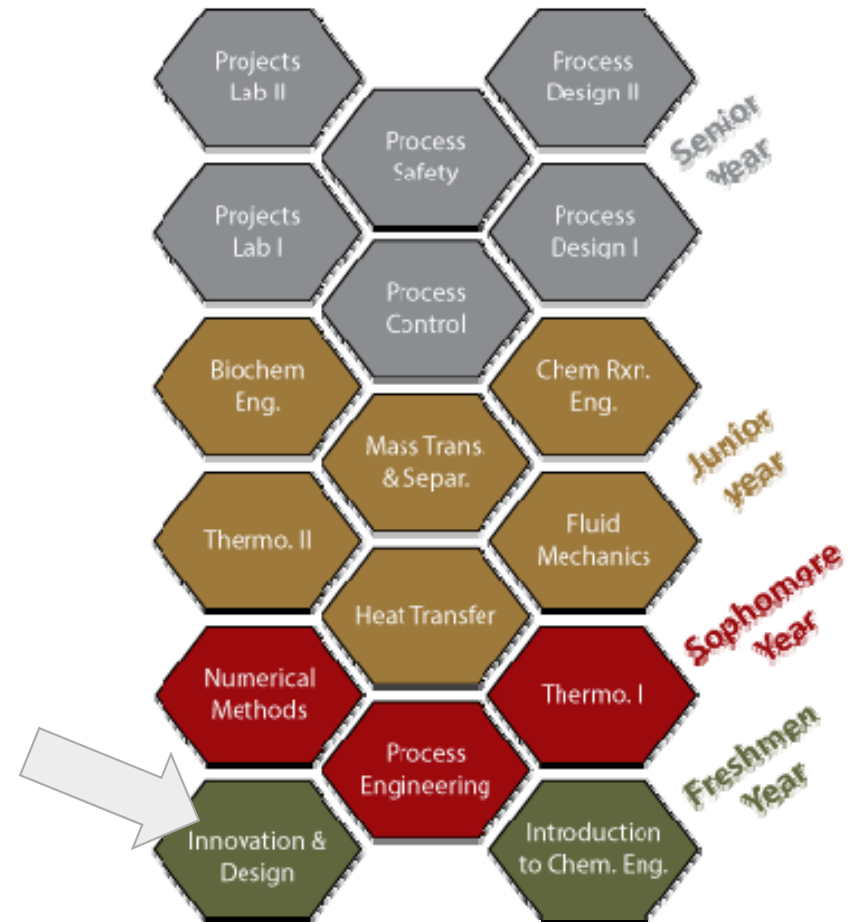


BROAD PEDAGOGICAL MODEL



The Details

Year	Freshman
Semester	Spring
Credit Hours	3
Required	Yes
Discussion	1 hr / week
Lab	3 hr / week
Lab Fee	\$50
Sections	2 – 3 / semester
Students	< 39 / section
Instructors	1 / section
TAs	1 / section



Space

- “We don’t have room for this.”
- Record number of students.
 - More than doubled in last 3 years.
- 70 seniors in capstone lab space.
 - Now add 100 freshmen.



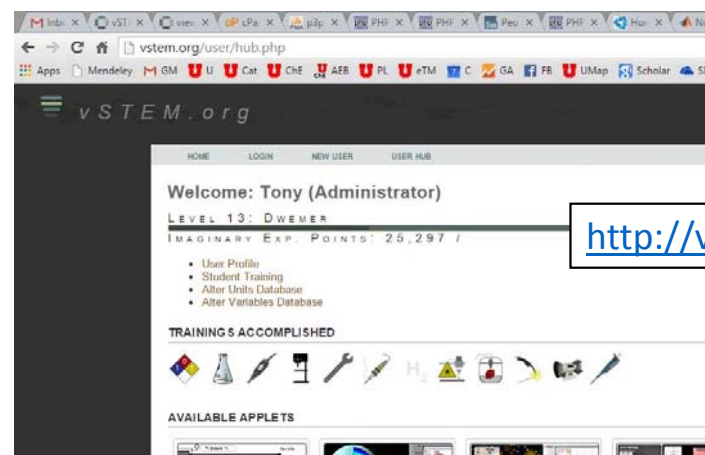
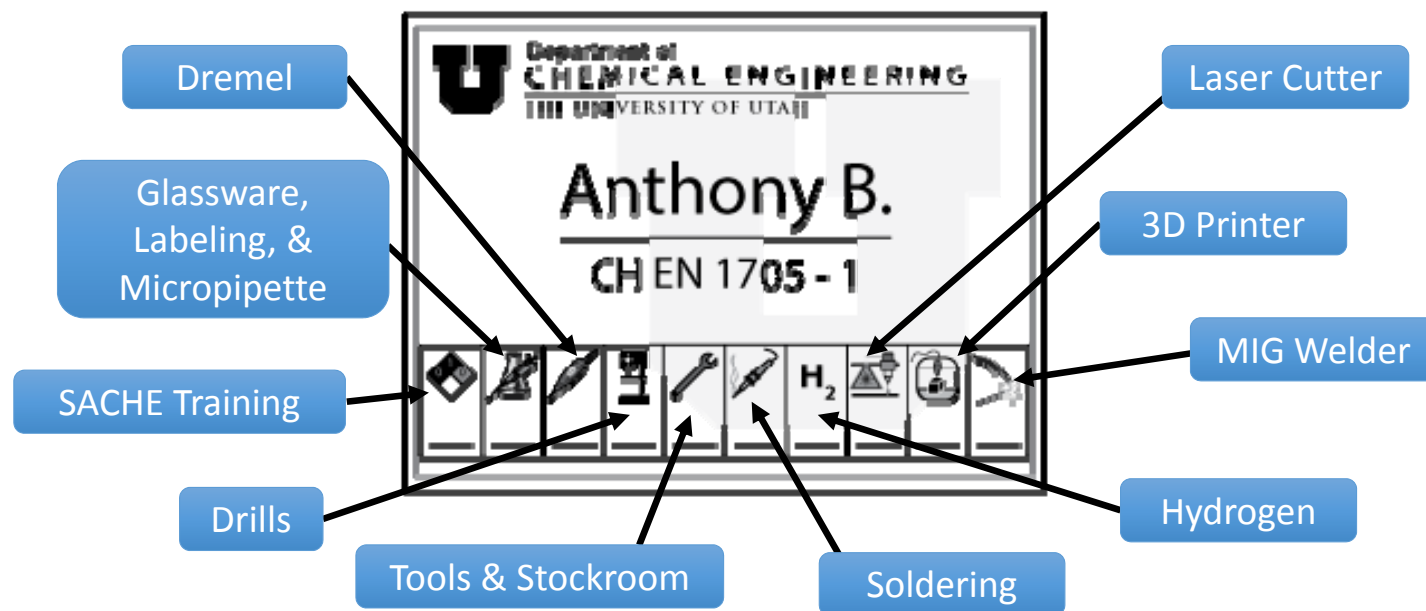
Prototyping Equipment

- Chem Es not know for being skilled machinists...
- Primary Equipment.
 - Dremmels
 - Hot glue gun
 - Soldering irons
 - Fountain and aquarium pumps.
 - Soda bottles, tubing, glassware...
 - **Laser Cutter & 3D Printer**
- All projects < \$10 in consumables/team
 - Final project < \$50/team



Safety

- Name Badges
 - Indicate training at a glance.
 - Online tracking <http://vstem.org/user/hub.php>
- Only materials with minimal safety concerns used.
- Supervision.
 - Instructor, TA, & lab manager.



Using the Arduino Board

- \$20-\$25 DAQ & microcontroller.
- Interface with MATLAB without DAQ toolbox.
 - Works with standard student version.
- Student training.
 - Large online support community:
<http://arduino.cc/forum/>
 - YouTube screencasts
<https://www.youtube.com/channel/UCf3aIYXUCXW4mBJOETDoFUg>

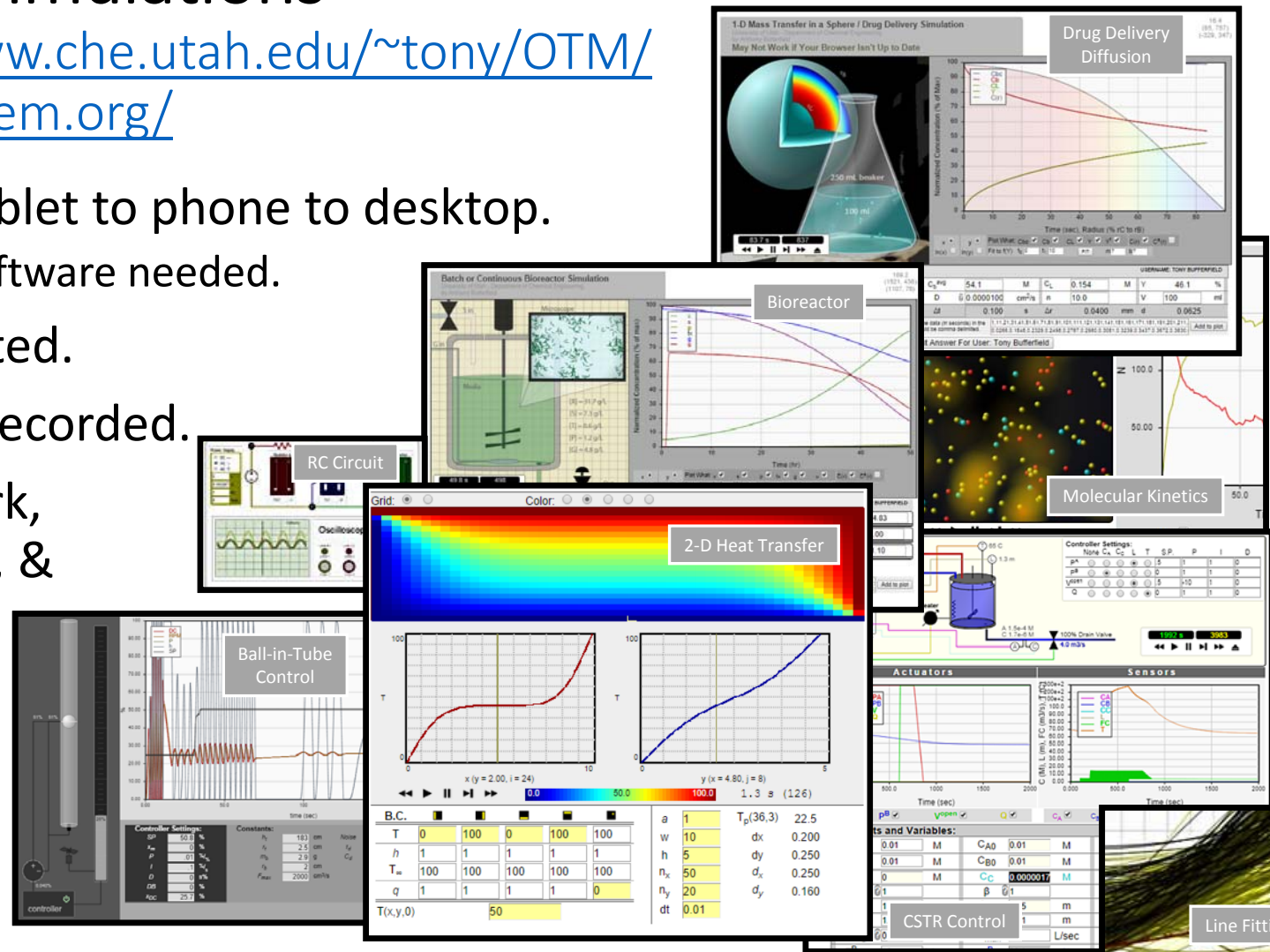


Browser-Based Simulations

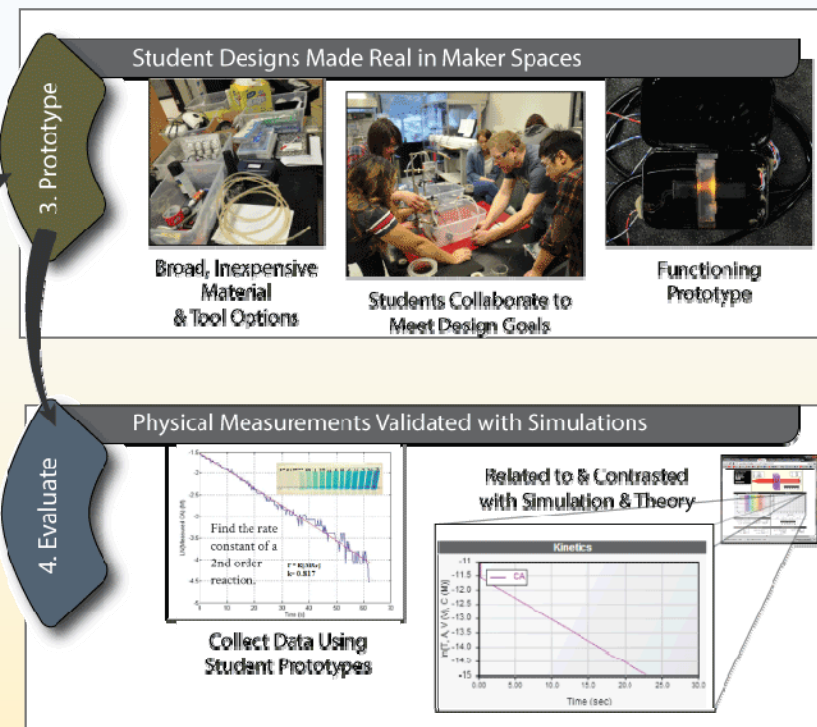
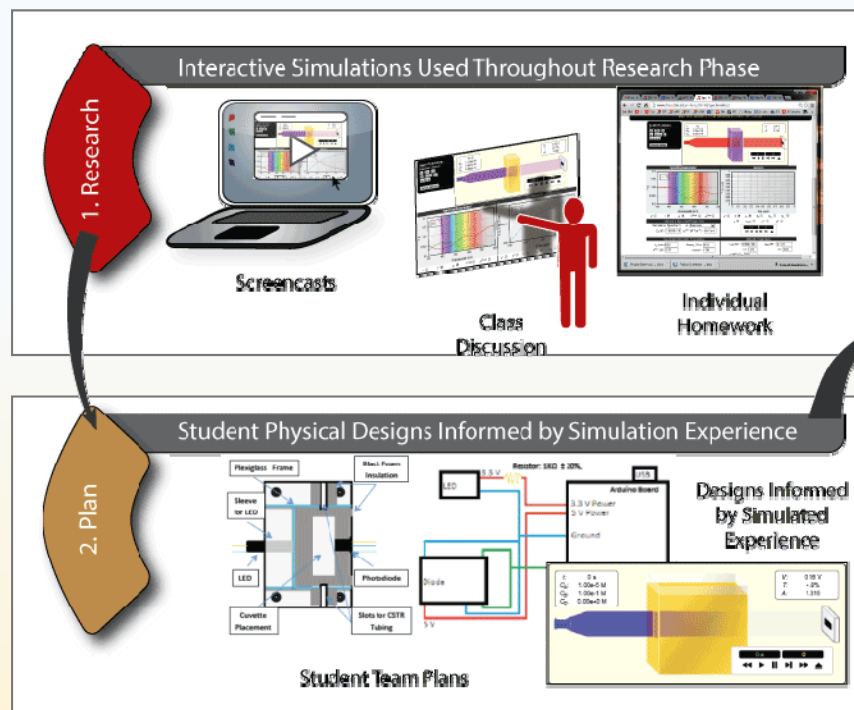
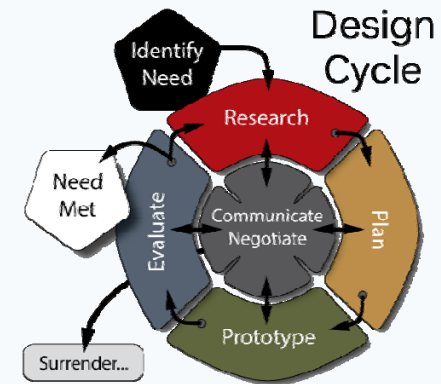
Old Home: <http://www.che.utah.edu/~tony/OTM/>

New Home: <http://vstem.org/>

- Accessible from tablet to phone to desktop.
 - No proprietary software needed.
- Interactive, animated.
- User interactions recorded.
- Used for homework, in-class discussion, & validation of data from design projects.



Simulation-Enhanced Design Cycle Projects



Basic DAQ & Sensors Project

- Use microcontroller to confirm performance of various sensors.



ID	
S01	Ethanol S
S02	Methane
S03	CO Sens
S04	Humidity
S05	Force Se
S06	Pressure
S07	Pressure
S08	Amplifie
S09	Photores
S10	Uni-Pola
S11	Linear H
S12	Peltier D
S13	Thermoc
S14	Thermist
S15	IR Thern
S16	IR Proxi
S17	US Rang
S18	Gyro Breakout Board
S19	Amplified Microphone
S20	Ammeter

Methods

Ethanol Sensor (MQ-3)

Circuit

Setup

Results

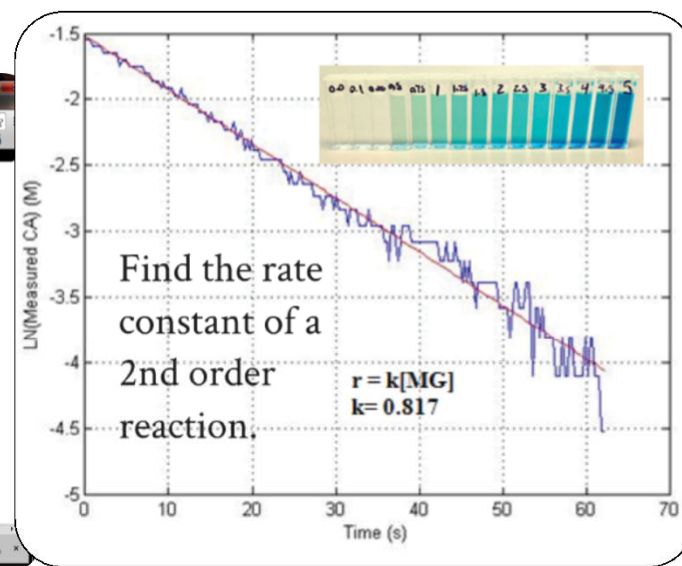
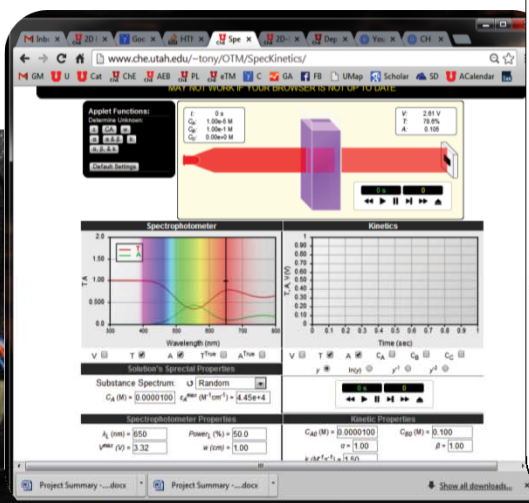
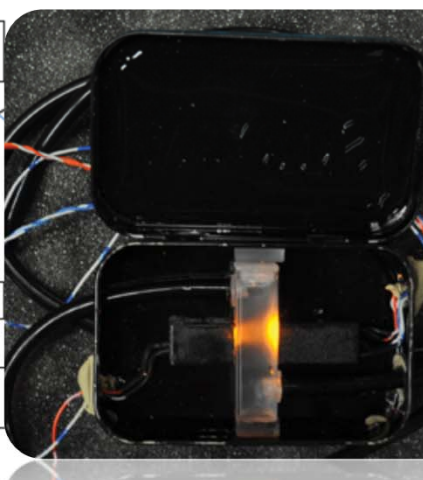
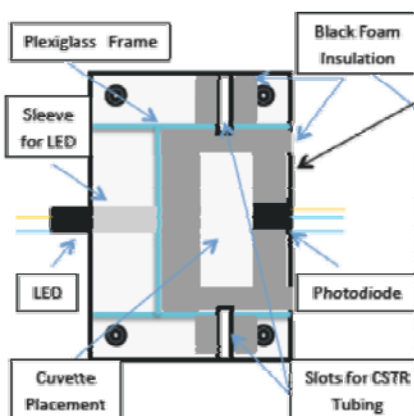
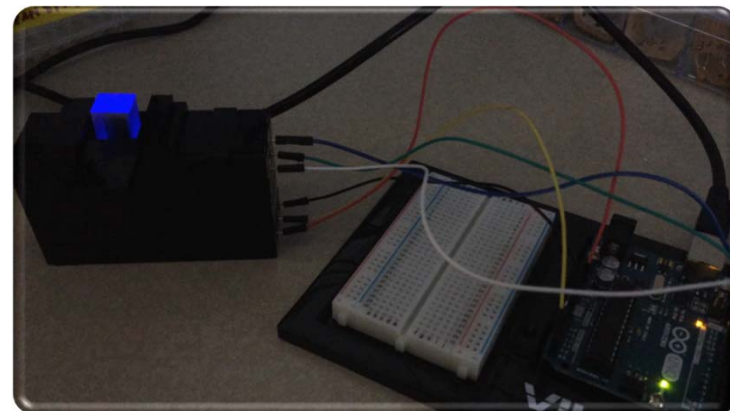
- Before Step-Change:
 - mean = 3.504 V
 - std = 0.042 V
- After Step-Change:
 - mean = 4.815 V
 - std = 0.210 V
- Time value (95%) between 1st steady state and mean of the 2nd: 0.735 s

Ethanol Sensor Voltage vs. Time



Photometry & Kinetics

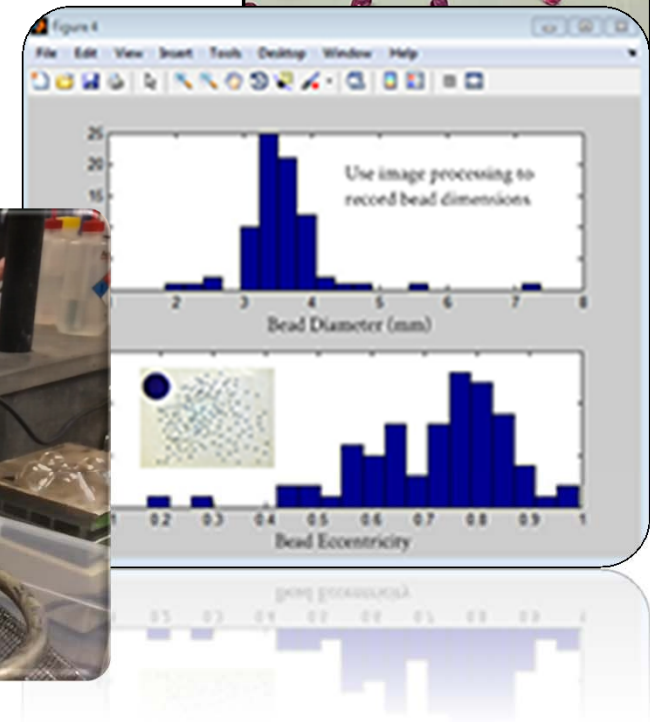
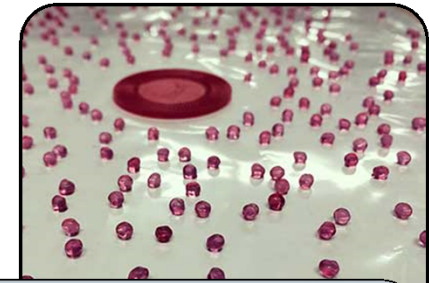
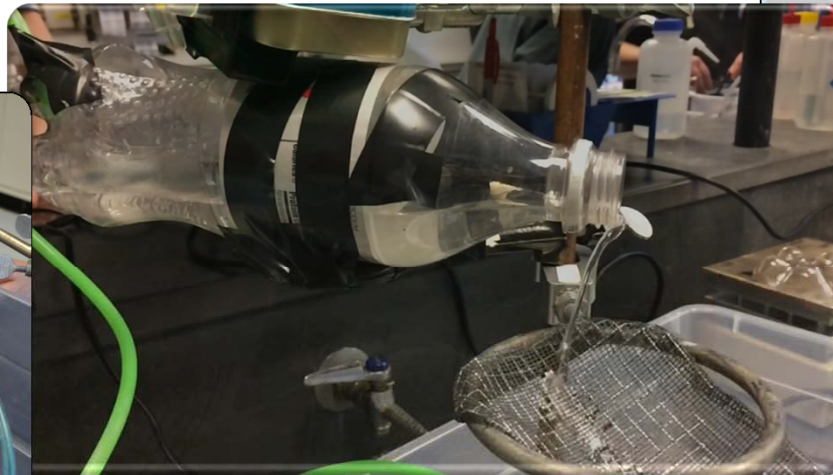
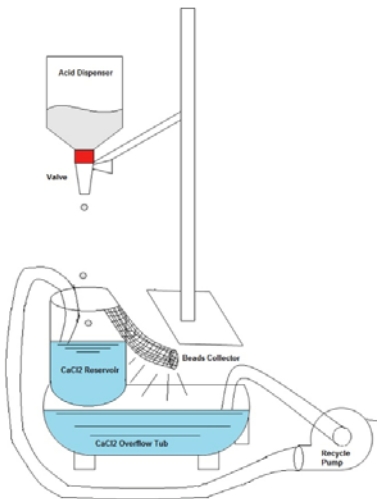
- Design and build a spectrophotometer.
- Use it to find kinetic constants for a reaction.
 - Alkali bleaching of phenol red or malachite green.
- Compare to theory.



Butterfield A, Young C. An Effective and Economical Photometer for Classroom Demonstrations and Laboratory Use. *Chem Eng Educ.* 2012;46(3):152–156.

Mass Transfer / Drug Delivery

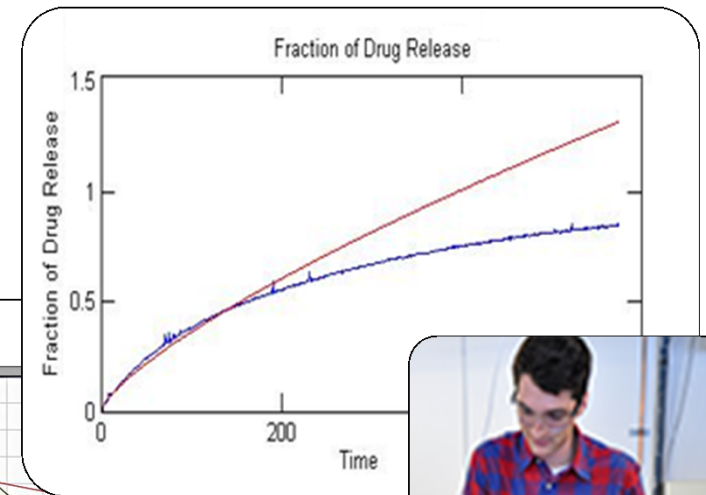
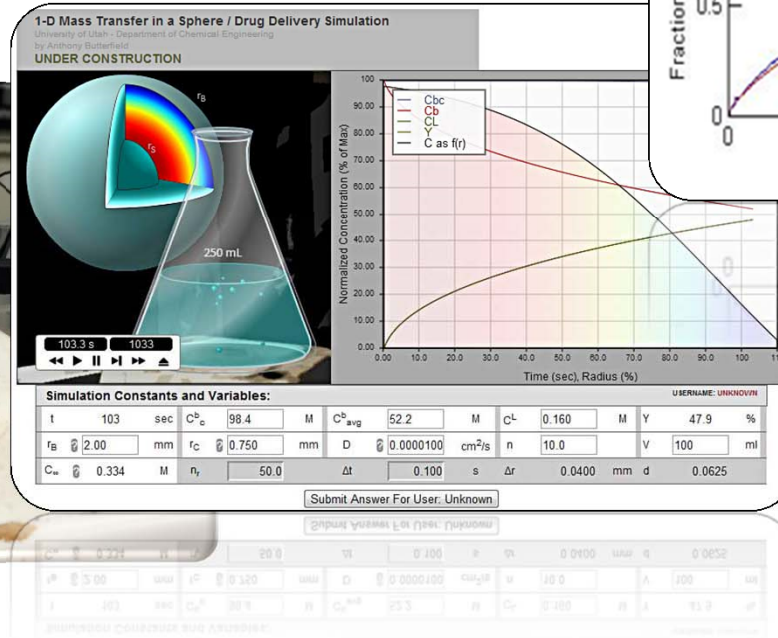
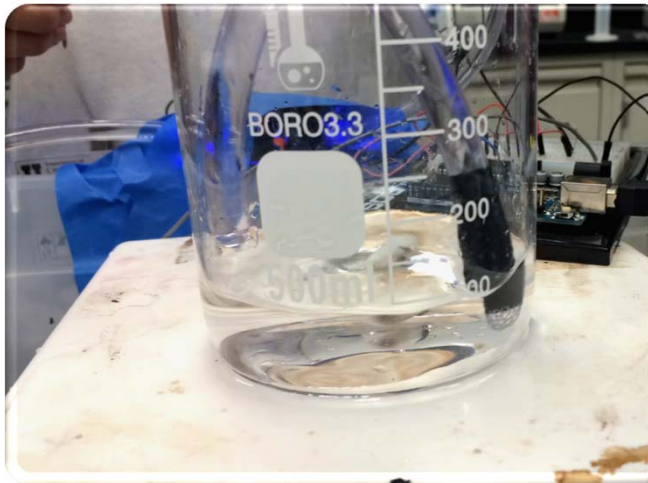
- Design a process to mass produce homogenous and spherical alginate beads for drug delivery.



Farrell, Stephanie, and Jennifer Vernengo. "A Controlled Drug-Delivery Experiment Using Alginate Beads." *Chemical Engineering Education* 46.2 (2012): 97-109. Print.

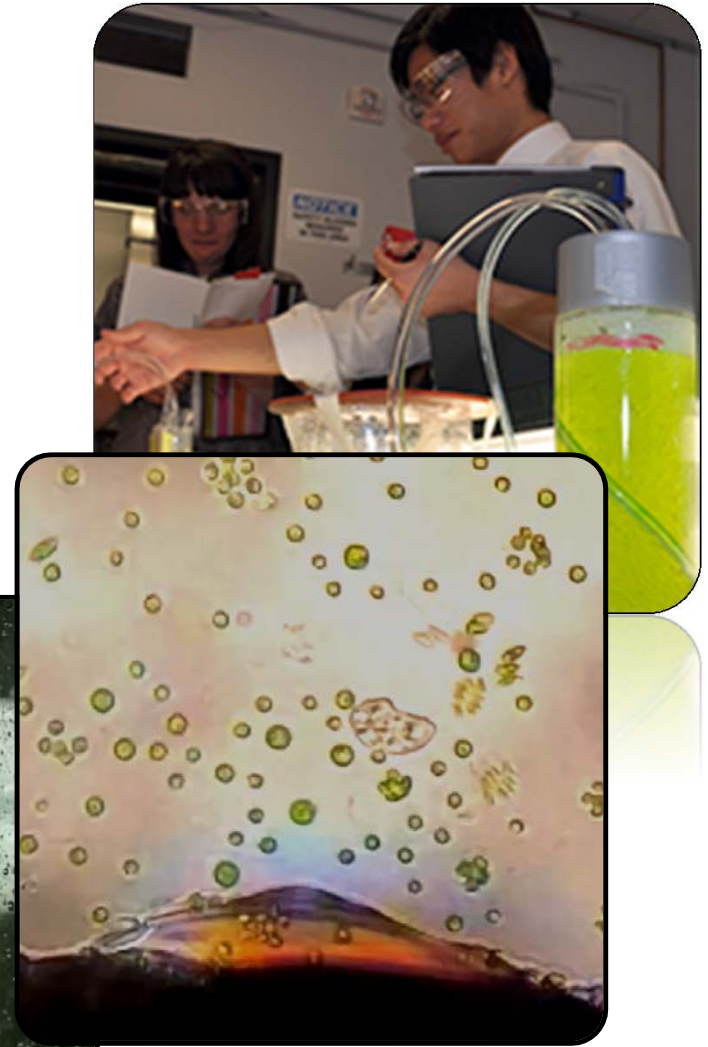
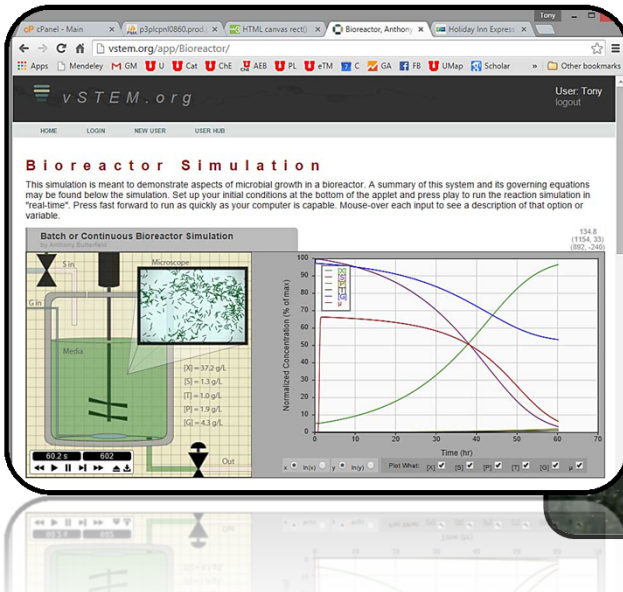
Mass Transfer / Drug Delivery

- Analysis of mass transfer of model drug out of beads.



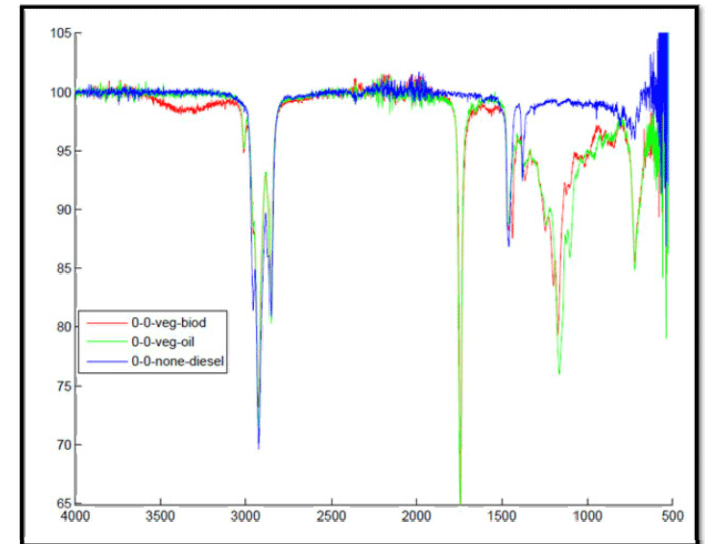
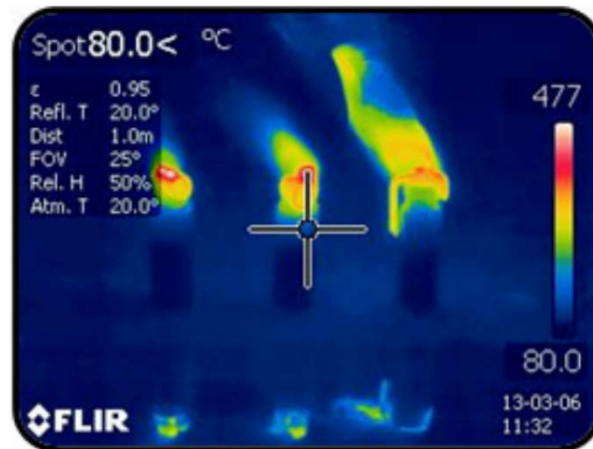
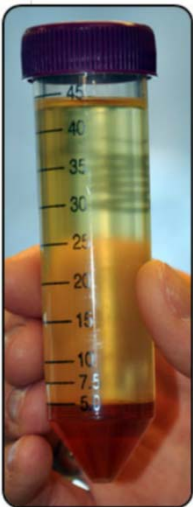
Photobioreactor

- Design a photobioreactor to produce algae as efficiently as possible for use in our algal oil research programs.
- <http://vstem.org/app/Bioreactor/>



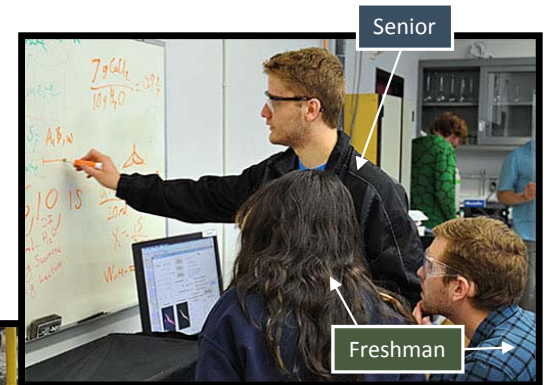
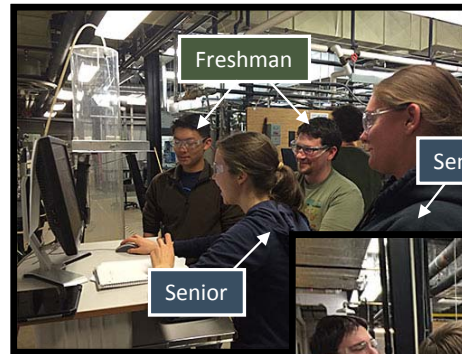
Biodiesel

- Analyze the properties of biodiesels from competing plant oils.



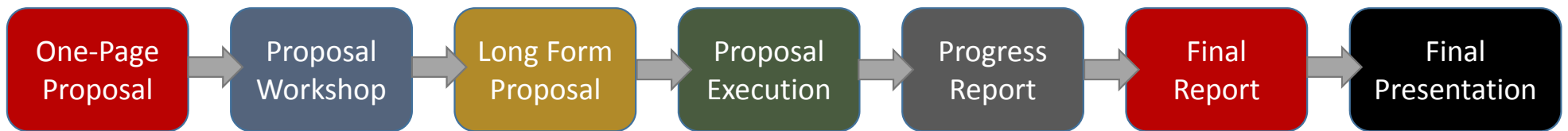
Three-Week Collaborative Project

- Freshmen submit resumes and apply to desired senior projects.
- Seniors use resumes to hire freshmen.
- Seniors
 - Gain valuable managerial skills.
 - Learn job hunting skills from seeing the other side of the interview process.
- Freshmen
 - Hone their resumes, and job application skills.
 - Gain valuable insight into their academic trajectory.
 - Learn of internship and job opportunities from graduating seniors.

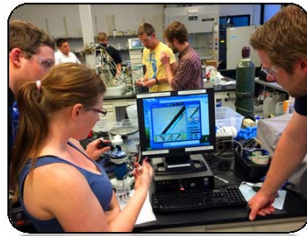


Final Projects

- Proposal novel project that brings value to the department, and puts their new skills to use.
 - **Research:** Conduct a small portion of a faculty research project.
 - **Education:** Conduct research that improves teaching modules.
 - **Service:** Create an outreach teaching module for K-12 schools.



Fresnel Lenz Teaching Module



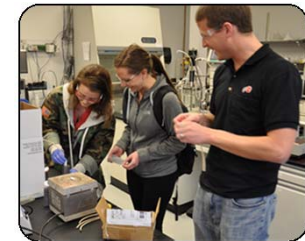
Microfluidics Research Using a Laser Cutter



Automated Viscometer



Device to Teach Hydraulic Analogy

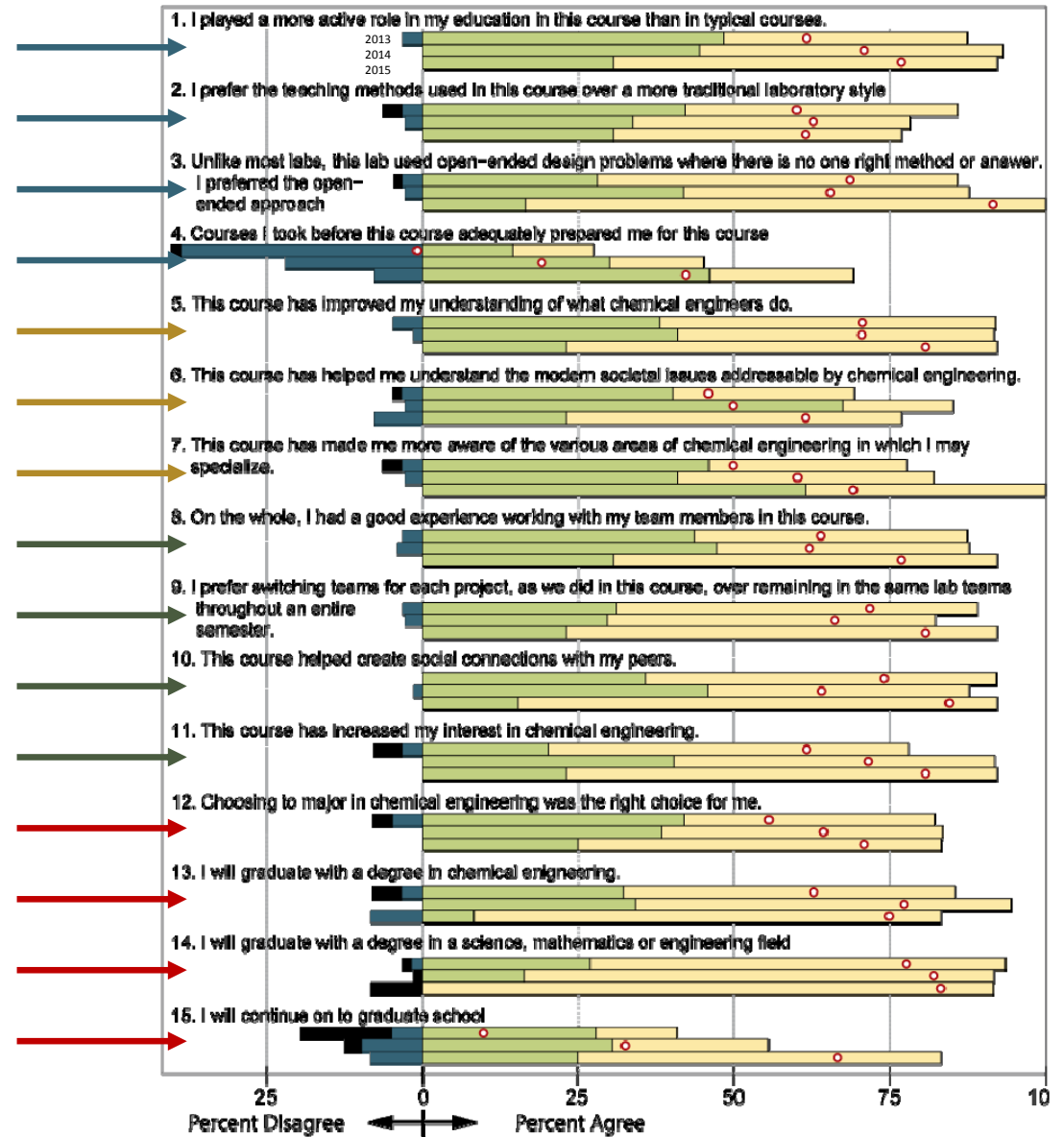


Smoke Bomb Teaching Module

And many other creative and useful projects...

Survey Questions

- Students were almost entirely positive.
 - Enjoyed and recognized the unique teaching methods of the course.
 - Though some felt underprepared.
- Perceived increased in understanding of chemical engineering.
- Made social connections.
- Vast majority state they intend to remain in the major.
 - And go on to graduate school...



Student Free-Form Feedback

- Vast majority were positive.
- Students frequently mentioned:
 - Open ended problems.
 - Exercising their creativity.
 - Mimicking a work environment.
 - Simulations.

"The way the class is presented as the students being engineers and collaborating on projects and presenting reports to the teacher as a business would be fantastic. The very open-ended projects were a VERY educational and eye-opening experience. Working with people you don't know and solving problems with group ideas (not pre-generated guidelines) was something that is sure to come in handy after graduation."

"An excellent course which affords the students the opportunity to apply engineering principles and get them excited to be participating in engineering early on in the major. Also the open endedness of the projects was very refreshing when compared to the heavy theory and rigidity of the rest of the courses that we take up until senior year."

"Very fun and useful class. Do more!"

"I absolutely loved the class, it made me feel more confident in the choice of my profession. Very hands on, the instructors are great. Overall, regardless of the grade I get, it was a great experience."

"You constantly have us answer questions in class that help everyone stay engaged. The simulations are very helpful for conceptualizing problems."

"I thought the hands-on design and prototyping aspects of this course were awesome. The online simulations we did for individual homework were also generally helpful."

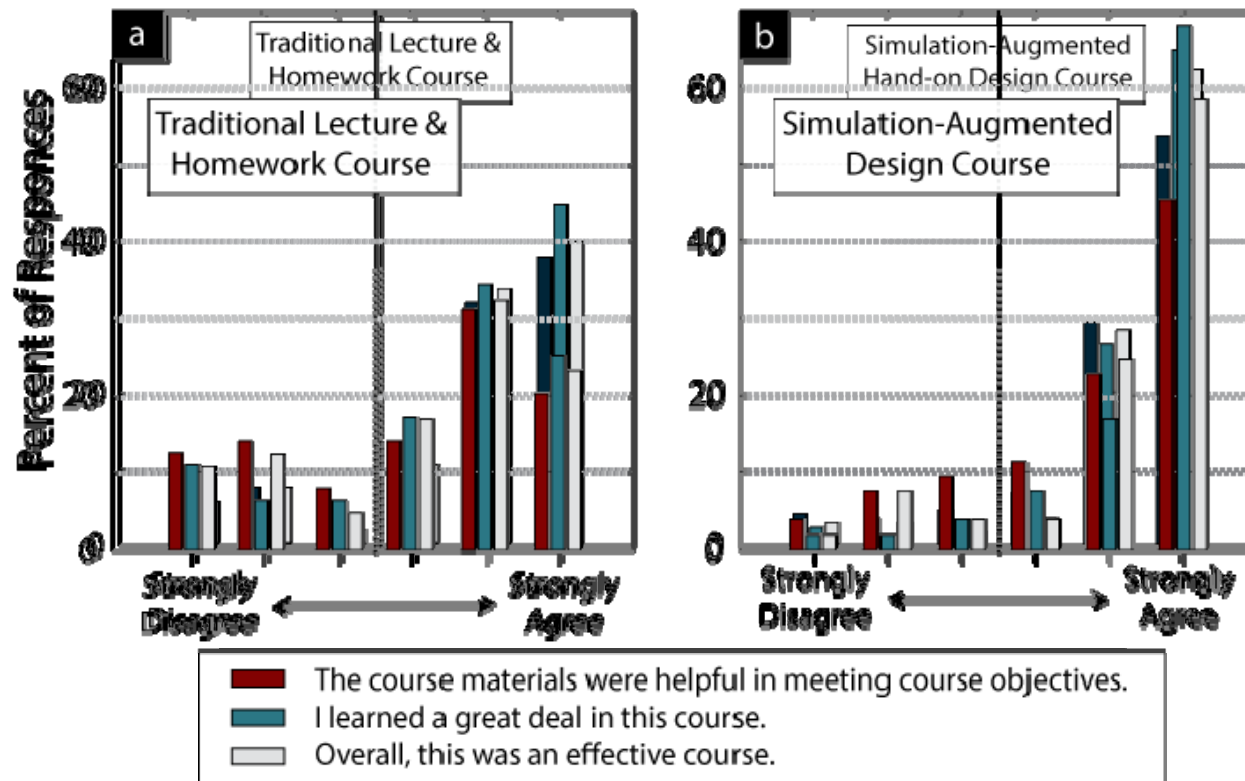
"The design of the course really forced students to take initiative and not rely on instructors to tell them what to do, it really helped me be more confident in coming up with and developing my own ideas."

"This was my absolute favorite class and I really enjoyed every week of it. The hands-on experience was invaluable and the lab experience cannot be replaced."

"It was nice to finally get some hands on engineering in the curriculum."

Same Freshmen, Same Year

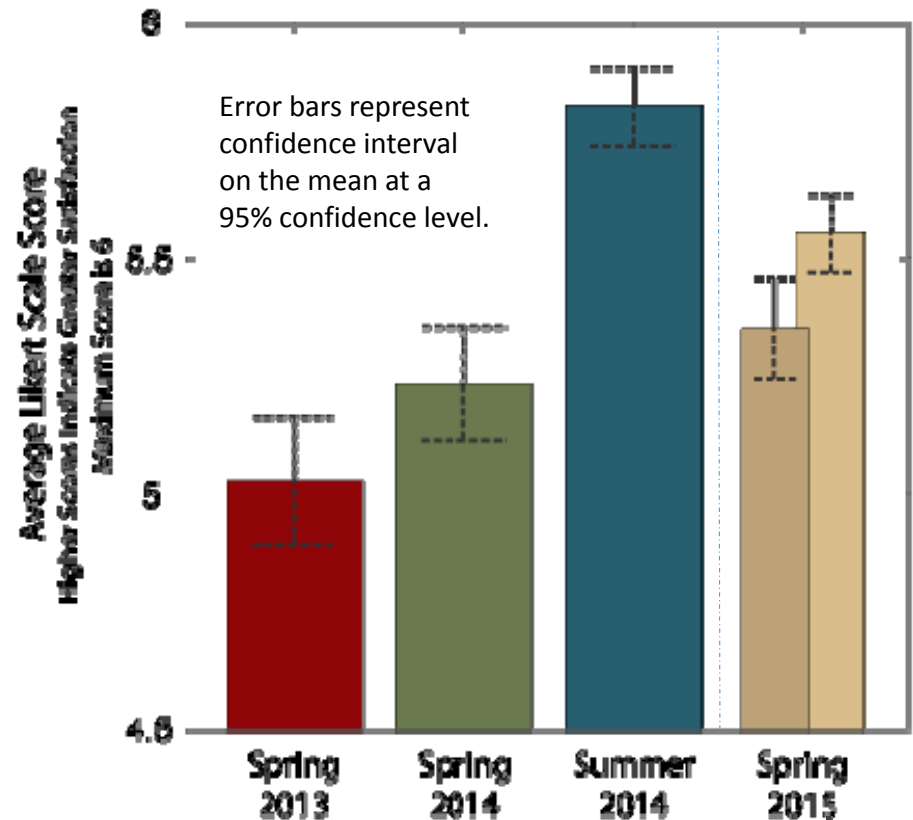
Traditional vs. New Course Model



- Same students take a traditional lecture and textbook introduction to chemical engineering the semester before taking this course.
- On standardized university evaluations, the same cohort was more enthusiastic about the new course.

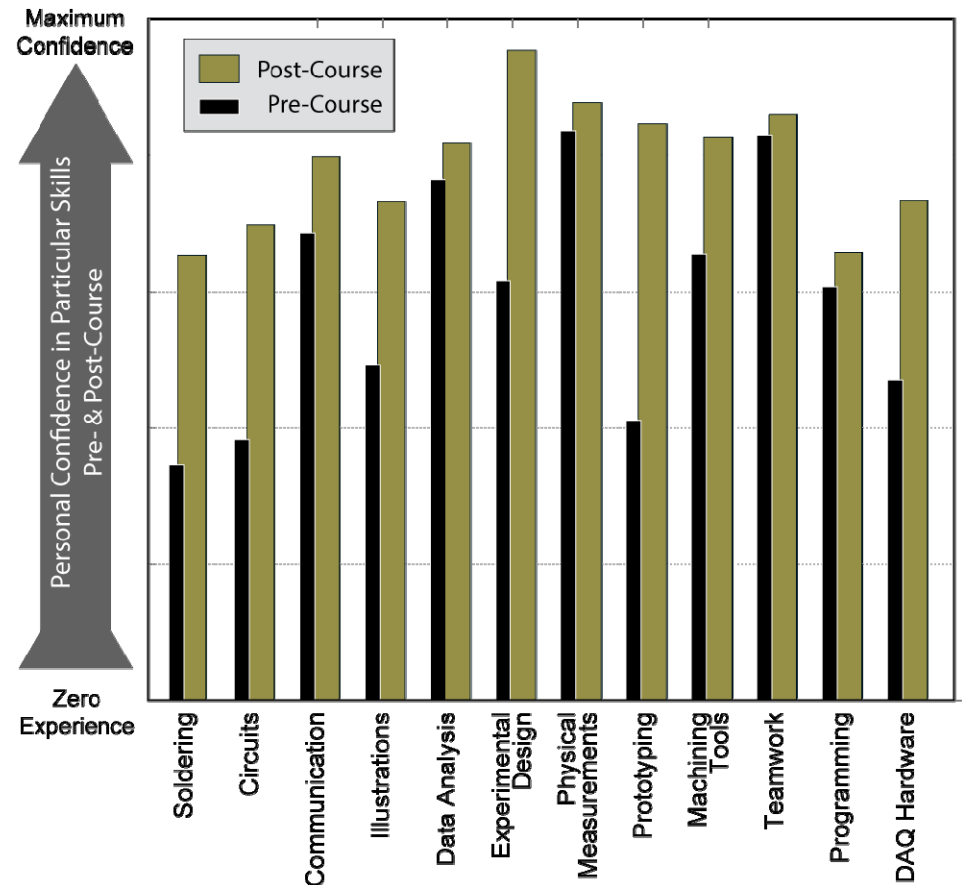
Course Improvement

- Iterative improvements in each simulation and module.
- Average student evaluation has risen significantly.
- The average evaluation is nearing the maximum.
- New model saw some dip:
 - 3 Discussions & 3 Labs
 - vs.
 - 1 Discussion & 3 Labs



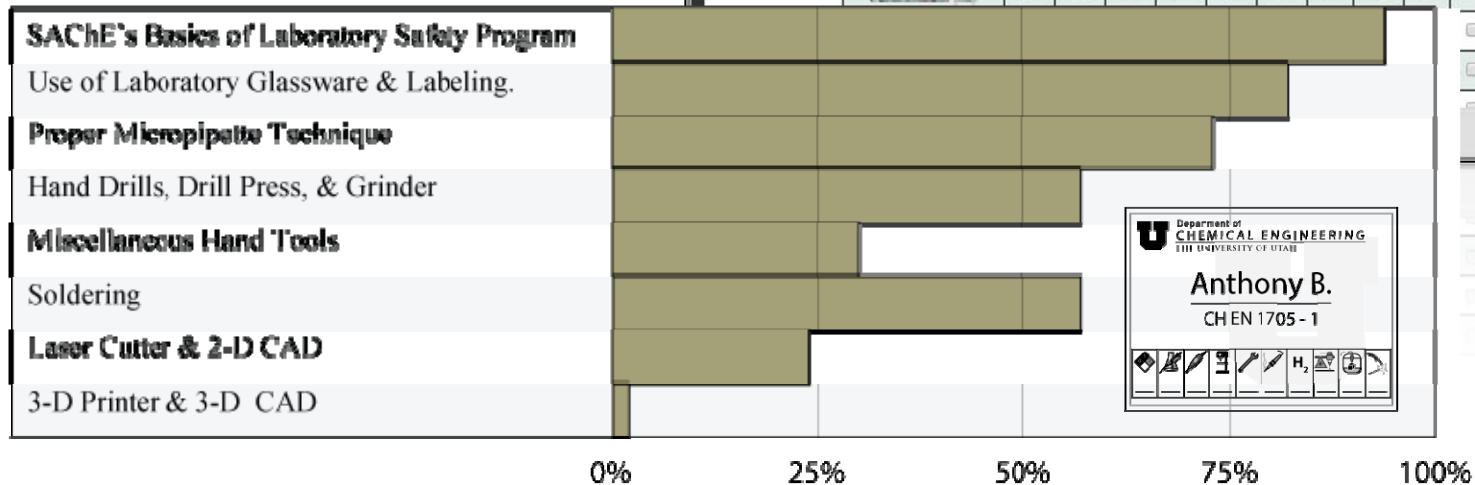
Personal Confidence in Engineering Skills

- A 33% average increase in self-reported student confidence in laboratory project skills.
- Average confidence increased in every category.
- Students left the course *feeling* much more capable.



Measured Lab Skills

- Verified by:
 - Oral examination.
 - Observation of skill's use.



Search results - x p3plcpnl0860... x p3plcpnl0860... x Bioreactor, Ant... x Bioreactor, Ant... x Training Data x

vstem.org/edm/userTraining.php

Apps Mendeley GM U U Cat U CHE U AEB U PL U eTM C GA FB UMap Scholar SD » Other bookmarks

vSTEM.org User: Tony logout

HOME LOGIN NEW USER USER HUB

Training Data for Instructor 1: Tony

Student Name											
Student Name (1)	☒	☐	☒	☒	☐	☒	☐	☐	☐	☒	☐
Student Name (2)	☒	☒	☒	☐	☐	☐	☐	☐	☐	☐	☒
Student Name (3)	☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Student Name (4)	☒	☐	☒	☒	☒	☒	☐	☐	☐	☒	☐
Student Name (5)	☒	☒	☒	☒	☒	☒	☐	☐	☐	☒	☒
Student Name (6)	☒	☒	☒	☒	☒	☒	☐	☐	☐	☒	☒

Course ID = 1

Show all downloads...

Department of CHEMICAL ENGINEERING THE UNIVERSITY OF UTAH

Anthony B.
CH EN 1705 - 1

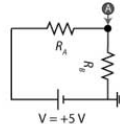
Pre- Post-Test Results

CH EN 1705 Chemical Engineering Design & Innovation - Pretest

1. A 9 V battery is attached across a 1 k Ω resistor. What should the current through the resistor be?

a) 9 A b) 9 kA c) 9 mA d) 0 A e) 1/9 A f) 1/9 kA g) 1/9 mA

2. If we decrease the resistance of resistor R_A in the adjacent circuit, without changing anything else, what would happen to the voltage at Point A (between the two resistors) in the circuit?



a) Goes up b) Stays the same c) Goes down d) Not enough information

3. Into a barrel containing 240 liters of pure water you pour 10 liters of water containing 5 mol/liter (M) of sugar. What is the final concentration of sugar in the barrel after it's well-mixed?

a) 0.020 M b) 0.154 M c) 0.200 M d) 0.208 M e) 0.250 M f) 0.350 M g) 0.377 M

4. Consider the elementary irreversible reaction $A + B \rightarrow C$ in water. If we double the starting concentrations of both A and B, what will happen to the rate of the reaction?

a) Remain the same b) Go down c) Go up 2X d) Go up 4X e) Go up 8X f) Go up 16X

5. Which of the following are second order reactions, if we assume they are elementary reactions (circle as many as you think are correct)?

a) $2A \rightarrow B$ b) $A \rightarrow 2B$ c) $A + B \rightarrow C$ d) $A \rightarrow B$ e) $A + B \rightarrow C + D$ f) $A \rightarrow B + C$ g) $A + 2B \rightarrow C$

6. Which of the following is a rate equation for a second order irreversible reaction, where C is concentration, t is time, and k is the rate constant. (circle as many as you think are correct)?

a) $\frac{dC_A}{dt} = -kC_A$ b) $\frac{dC_A}{dt} = -2kC_A$ c) $\frac{dC_A}{dt} = -kC_A^2C_B$ d) $\frac{dC_A}{dt} = -kC_AC_B$ e) $\frac{dC_A}{dt} = -kC_A^2$

7. We want to make an elementary irreversible reaction, $A + B \rightarrow C$, behave like a first order reaction with respect to molecule A, to simplify finding the rate constant. How could we do this?

a) Measure the rate of reaction without any B present. b) Add a catalyst to speed up the reaction. c) Add an inhibitor to slow the reaction. d) Continually remove molecules of C during the reaction. e) Use a starting molar concentration of B that is much larger than that of A.

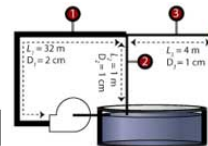
8. We have a chemical reaction, $A \rightarrow B$, that is governed by the equation:

$$\frac{\partial C}{\partial t} = -kC$$

where C is the concentration of A, k is the reaction's rate constant, and t is time. We want to determine k using data we have of C versus t during the reaction. What should we plot to linearize this data, such that k would be the slope of the line that fits the linearized data?

a) C vs t b) 1/C vs t c) log(C) vs t d) C vs 1/t e) C vs log(t) f) 1/C² vs t g) C² vs t

9. Consider the adjacent fluid circuit. The pump takes water out of a reservoir and pumps it through Pipe 1. Then the stream splits to recycle through Pipe 2 or exit through Pipe 3. If we keep the same flow rate through Pipe 1 and shorten Pipe 2, what should happen to the flow rate out of Pipe 3?



a) Goes up b) Stays the same c) Goes down d) Not enough information

10. Which of the following commands would create a vector, v, in MATLAB containing the values [20, 30, 40, 50, 60]? (circle as many as you think are correct)

a) `v=10*((1:5)+1)` b) `v=(1:6)*10` c) `v=inspace(20,60,6)` d) `v=20:10:60` e) `v=20:60`
f) `v= 20,60` g) `v=inspace(20,60,10)` h) `v=20,30,40,50,60` i) `v=60:20` j) `v=(1:5)*10+10`

11. Using the same vector, v, as in problem 10, in which of the following will the output be equal to 1? (circle as many as you think are correct)

a) `v(5)==60` b) `v(20)-v(40)/2+1` c) `length(v==v)` d) `max(v./v)` e) `v(v(1)/5)-49`
f) `for j=20:10:60; a(j)=v(j); end; a==v` g) `a=[1 1 1 1 1]; for j=5:-1:1; a(j)=v(j); end; min(a==v)` h) `a=1; i=0; while a; a=a-i; i=i+1; end; i/2` i) `if v(3)~=30; a=1; else; a=0; end; a` j) `a=0; try; a=v(a); catch; a=a+1; end; a`

12. Which of the following MATLAB commands would find the average of vector, v, from Question 11? (circle as many as you think are correct)

a) `n=length(v); x=0; for (j)=0;<n;i++){ x+=v(j); } avg=x/n;` b) `n=length(v); x=0; for j=1:n; x=x+v(j); end; avg=x/n;` c) `x=1; for j=1:5; x=x+v(j); end; avg=x/n;` d) `n=length(v); avg=0; for j=1:n; avg=avg+v(j)/n; end` e) `n=length(v); x=0; j=0; while j<n; x=x+v(i+1); j=i+1; end; avg=x/n;`
f) `avg=mean(v);` g) `avg=average(v);` h) `avg=sum(v)/5;` i) `avg=sum(v)/60;` j) `avg=modes(v);`

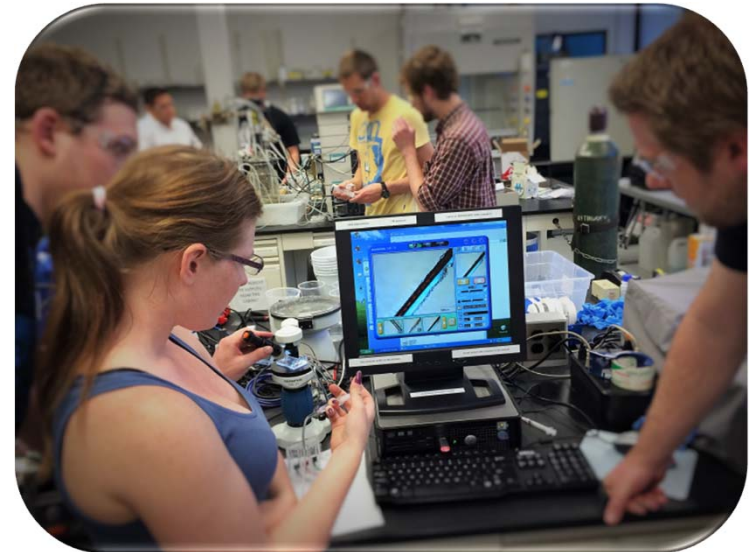
- Written test at start and end of semester.

- Topics include those covered in previous courses, but now addressed with hands-on design course.

- 38% average improvement over the lab (n=170).
 - 56% improvement in the most recent semester (n=80).

Retention & Underrepresented Groups

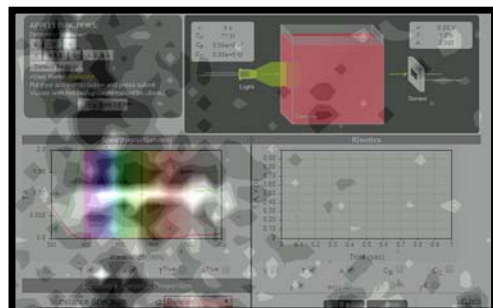
- Historically:
 - Freshmen to sophomore $\cong$ 60% retention.
 - Freshmen to graduation $\cong$ 45% retention.
- Over 90% agreed with both statements:
 - “Choosing to major in chemical engineering was the right choice for me”
 - “I will graduate with a degree in engineering”
- No other statistical differences between racial and ethnic groups or genders detected.
- Except... Women perform better than men ($P=0.014$).
 - On average by 8.7 percentage points.



Insights: Web Simulation Usage Database

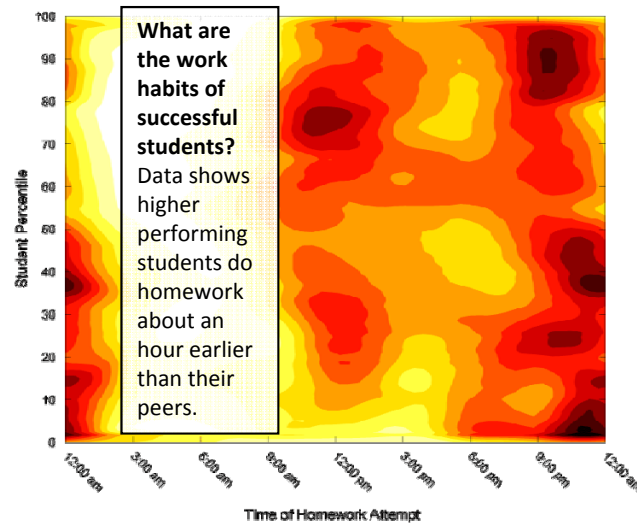
- Simulation interaction data reveal important information about successful modes of learning, and how to improve browser-based simulations.

<http://vstem.org/app/Bioreactor/?playid=6248>



What Are Unsuccessful Students Misunderstanding?

Darker shades indicate more time spent by students who were unsuccessful. Plot shows successful students understood the need to calibrate the sensor, indicating calibration should become a target for automatic intervention and classroom discussion.



Industry & Research Program Support

- Department's Industrial Advisory Board is wholly supportive.
- Course now used to funnel undergraduates into researcher labs.
 - Freshmen take internships left by their senior managers in collaborative project.
 - Faculty hire freshmen based on skills developed and performance in course.

"[IAB Member] commented that these experiences should help students get internships and noted that the professional skills they are developing are particularly important."

"This innovation was enthusiastically welcomed by the IAB."

"[The skills developed in this course] are the skills we look for in the students we hire."

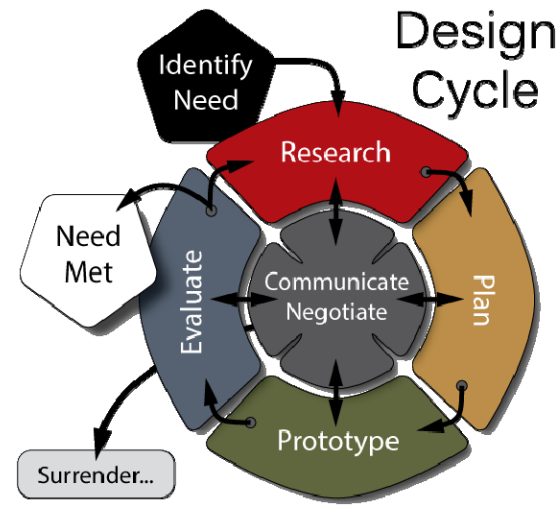
Professional Side Effects

- Student recognition:
 - Department Teaching Awards.
- Faculty recognition:
 - College of Engineering Teaching Award.
- University recognition:
 - University of Utah “Beacons of Excellence” Award.

“Recognizing excellence in providing transformational experiences to undergraduate students.”

Future Plans

- Disseminate tools & methods
 - Fall semester freshman course.
 - Create a coherent first year.
 - Design → Evaluation → Redesign → Evaluation .
 - Then move into remaining core courses.
- Create a persistent virtual space for our students.
 - vSTEM.org
 - Disseminate simulation use



- Track students through curriculum.
- Real-time online educational data mining.
- Incorporate automated training through peer examples.



RESULTS & LESSONS LEARNED

FROM A CHEMICAL ENGINEERING FRESHMAN DESIGN LABORATORY

Anthony Butterfield

Kyle Branch

University of Utah, Department of Chemical Engineering

Tuesday, June 16, 2015

