Managing Expanding Class Sizes in an Expanding Chemical Engineering Laboratory

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AIChE Annual Meeting

Salt Lake City, November 9, 2015

Department of
CHEMICAL ENGINEERING
THE UNIVERSITY OF UTAH

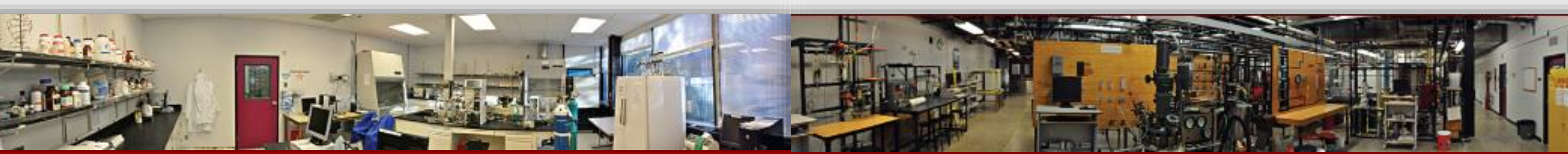
15AIChE
Annual Meeting, Salt Lake City, UT

Difficulties of Large Class Sizes

- Knowing each student and their name
- Significant grading commitment
- Answering student questions and concerns
- Minimizing classroom disruptions
- Safety concerns in a lab setting
- Need for additional instructors or TAs

Our Freshman Lab Course

- Very open-ended design laboratory course
  - Students design and build equipment to assist in their production process or experimental analysis
- Our projects lab can accommodate a maximum of 30-40 students
- Over the past three years, enrollment increased from 74 to 108 students
  - We have increased the course from two to three sections, and are again at full capacity



A Common Lecture Section

- We created a common lecture section
  - Enables instructors to be available to assist students in all three lab sections
- The lecture section is recorded for students who can’t fit it into their schedule
  - Students appreciate being able to watch lectures again
- The lab is no longer right after the lecture – this gives students time to prepare for the week’s lab project

Minimizing Classroom Disruptions

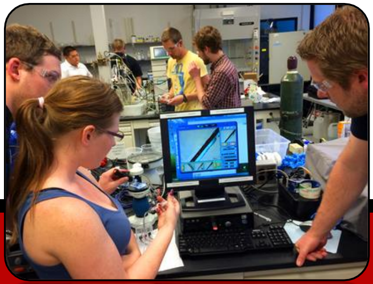
- In order to hold students' attention, we encourage students to participate in classroom discussions
- We try to bring in interesting demonstrations that pertains to the subject matter
- Use of active and collaborative learning to break up long lectures

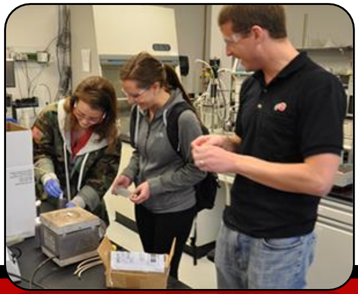




Students Work in Teams

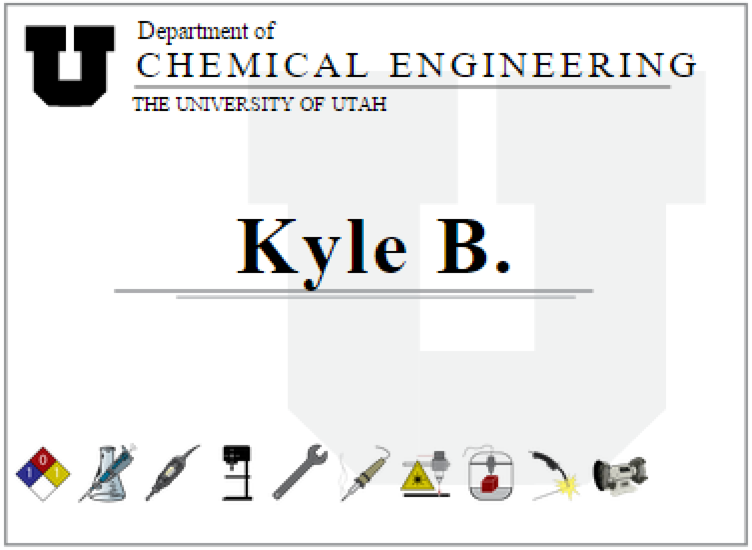
- Students working together can brainstorm through problems, reducing the number of questions
- Team assignments reduces the amount of grading
- Consistently switching teams increases the skillsets that students bring to the projects
  - Reduces the duration students are in a 'bad' team
  - Helps the students meet and form study groups for future courses



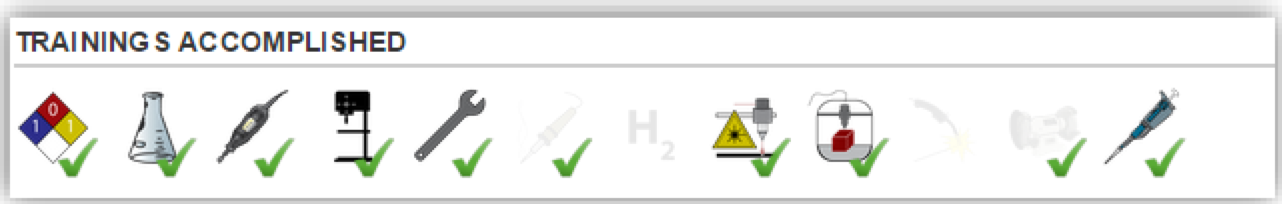
Student Name Badges

- Helps instructors, TAs, and fellow students learn names
- Students are given a name badge and the ability to print off a new one if it's lost
- Badges indicate which equipment they have been trained to use
  - All student training is recorded online
- Allows for an easy check if a student is trained to use particular equipment
  - Improves lab safety



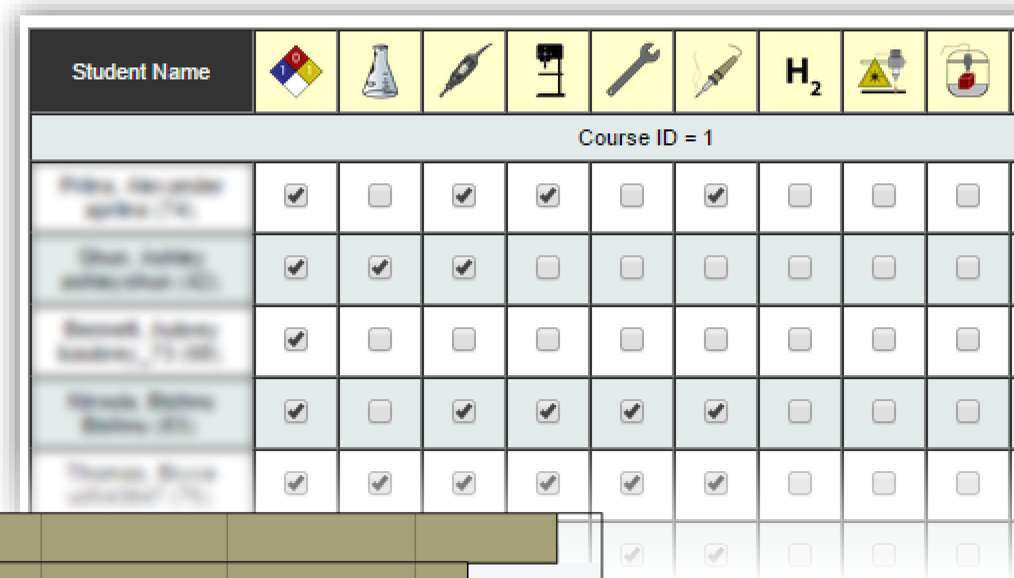
Lab Equipment Training

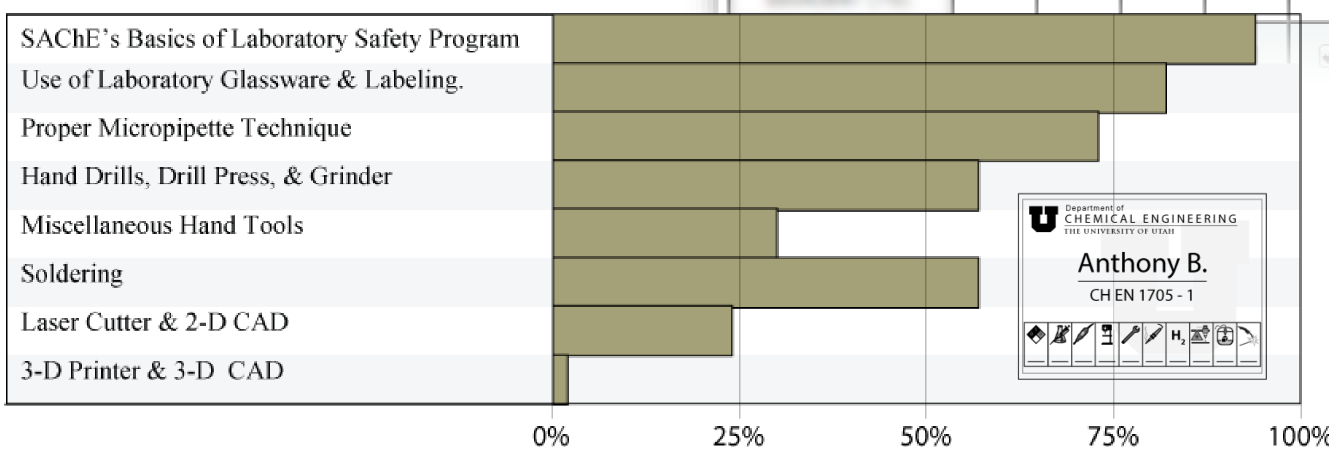
- In order for a student to use lab equipment
  - Complete a safety and operating quiz online
    - Students are always able to go back and review their quiz
  - Trained by an instructor
- This delay helps students retain the material
- Reduces the training burden on instructors
  - Originally, they would pass an oral safety quiz



Measured Lab Skills

- Used for educational research





Peer Mentoring Project

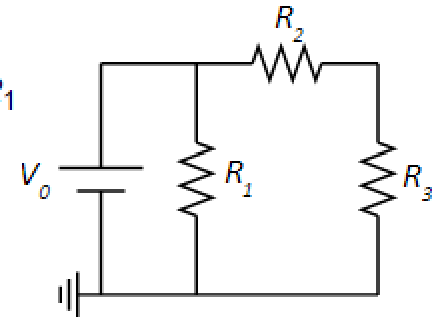
- Freshmen submit resumes and apply to senior projects
- Seniors use resumes to hire freshmen
- Seniors
  - Gain valuable managerial skills
  - Lear job hunting skills from seeing the other side of the interview process
- Freshmen
  - Hone their resumes, and job application skills
  - Gain valuable insight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

Online Homework System

- We have developed a system to administer online homework problems
  - Contains randomized values to minimize cheating
  - Units can be randomized within metric, English, or both
  - Which unknown variable can be selected or randomly chosen based on its difficulty

8. **(0/0.5 points. Out of attempts.)** Sorry, you have reached the maximum number of attempts for this problem.

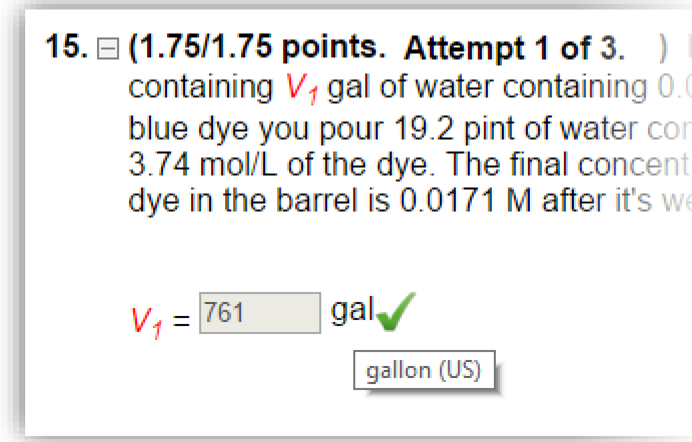
9. **(1 point. Attempt 1 of 2.)** Refer to the circuit diagram on the right. The power supply V_0 has a voltage of 9.33 V, the resistor R_1 has a resistance of 10700 Ω, the resistor R_2 has a resistance of 901 Ω, and the resistor R_3 has a resistance of 9.9 kΩ. Therefore, the current through Resistor 2 is I_1 mA.

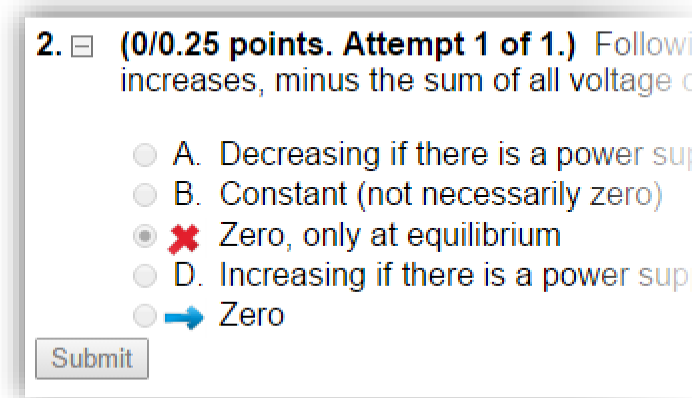


I_1 = ______ mA

Online Homework System

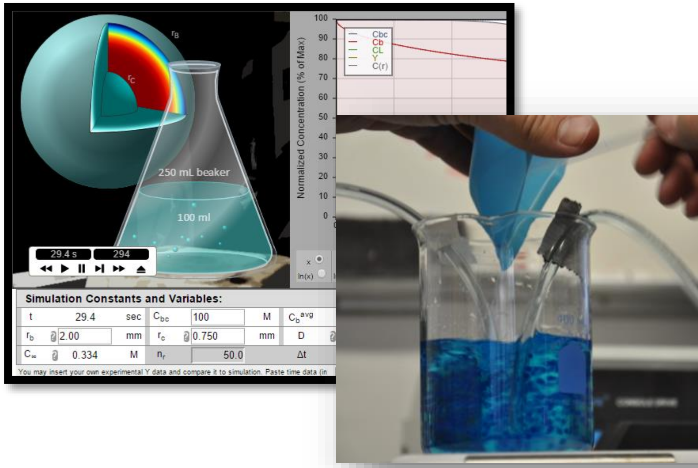
- We use this to administer a variety of course materials:
  - Homework assignments
  - Pre- and post-tests
  - Student surveys
  - Safety training quizzes
- They can give students instantaneous feedback on their submissions
- TAs can spend more time helping students in the lab

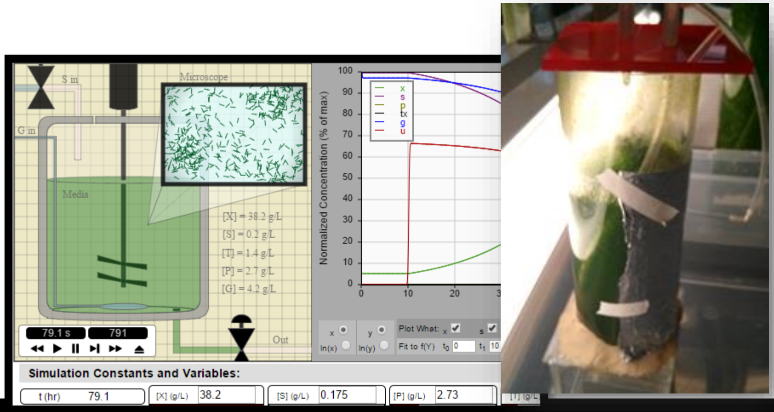


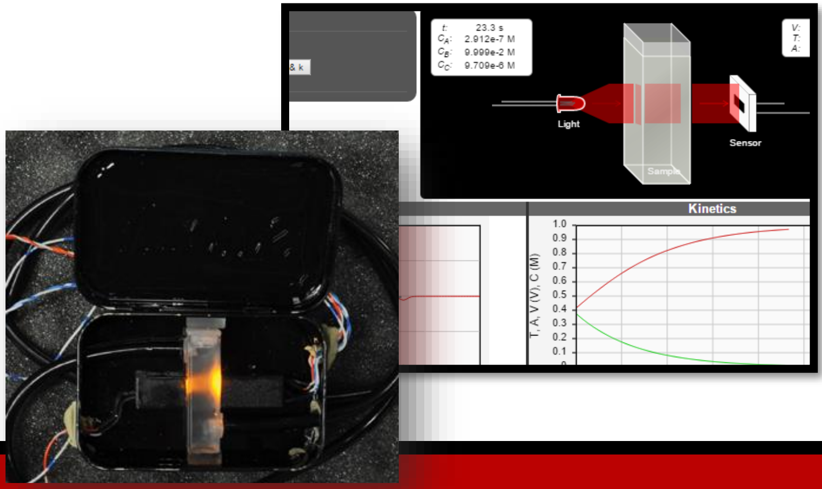


Interactive Simulations

- Simulate lab experimentation
  - Coupled with hands-on projects
- Used in our freshman and senior laboratory courses
  - Soon to be implemented in our mid-curriculum courses







Benefits to Students

- Get a realistic sense of how adjusting parameters affects the system
- Students can move at their own pace
  - Unlimited practice attempts
- Instantaneous feedback

RESULTS		
Your Stoichiometric Coefficient on A	=	2
Correct Stoichiometric Coefficient on A	=	2
Percent Error	=	0.00%
Total Error	**=**	**0.0%**
Max Error	**=**	**5.0%**

Correct Within Error. Good Job!
Reset Applet?
Results for Kyle Branch successfully recorded in database.
See All Your Recorded Use Data

CONSTANTS		
Chemical	=	Random
Concentration of A (M)	=	1.001e-5
Max Molar Extinction Coefficient (1/M/cm)	=	1.32e4
Primary Wavelength of the Light (nm)	=	720
Power of the Light Source (%)	=	50.0
Voltage at 100% Transmittance (V)	=	3.32
Cuvette Width (cm)	=	2.20
Initial Concentration of A (M)	=	0.0000410
Initial Concentration of B (M)	=	0.0200
Stoichiometric Coefficient on B	=	2.00
Reaction Rate Constant ($1/M^{(\alpha+\beta-1)}/s$)	=	1.50e6

Benefits to Instructors

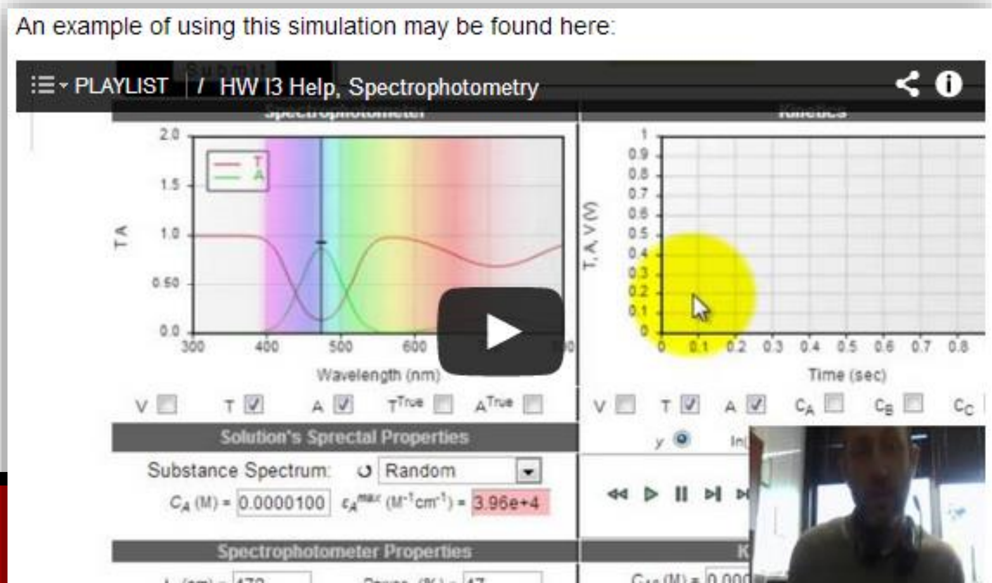
- Saves lab time and resources
- Automatically graded assignments
  - Student summary generated
- Track students' usage for further optimization

Assignments – CH EN 1703

Students	Pretest CR/NC	Units 11 pts	Circuits 6 pts
[illegible]	CR	5.5	3.5
[illegible]	CR	4.25	6
[illegible]	CR	3.5	6
[illegible]	CR	0.5	0.18
[illegible]	CR	9.75	4.5
[illegible]	CR	7.75	5
[illegible]	CR	11	3.25
[illegible]	CR	8.25	2.5

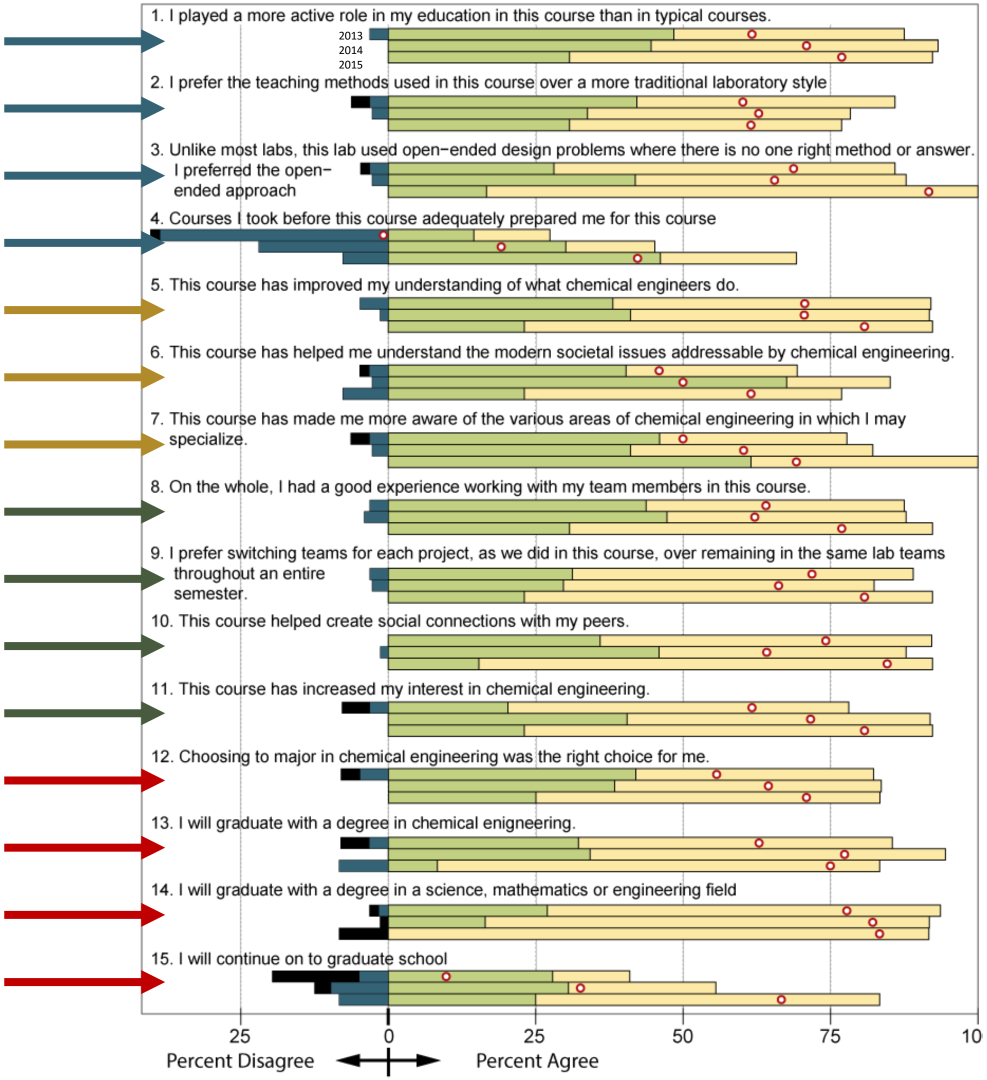
Worked Examples

- Worked examples help students with their homework
  - Video screencasts and written instructions
- We can track which students use the screencasts
- Screencasts are also used to teach useful skills



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

"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."

constantly have us answer questions in class that help everyone stay engaged. The simulations are very helpful for conceptualizin

"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 is 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."

"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."

"Very fun and useful class. Do more!"

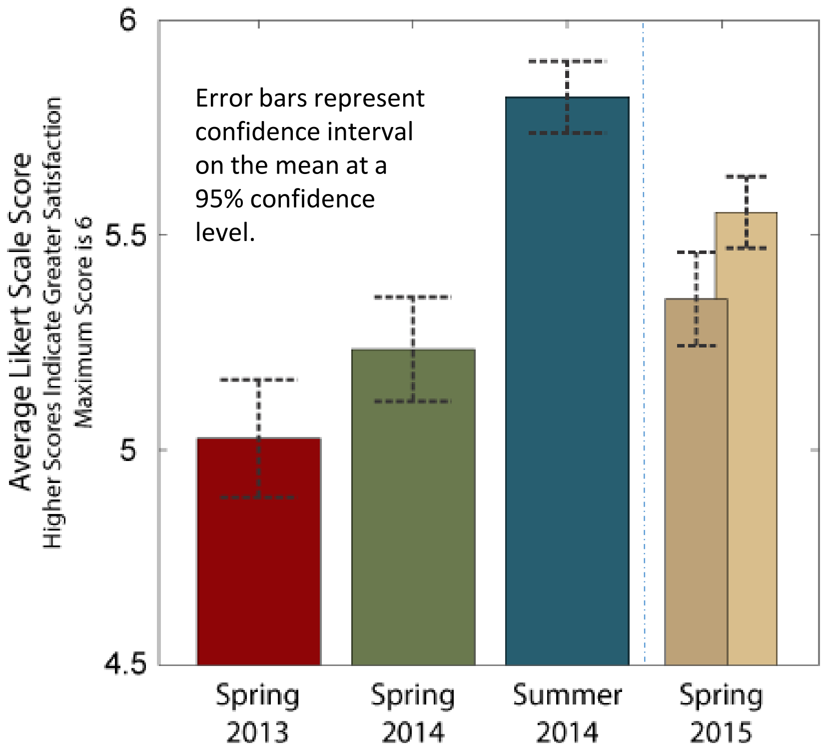
"The design of the course really forced students to take initiative and not rely on instructors to tell them what to do, it really helped me be more confident in coming up with and developing my own ideas."

"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."

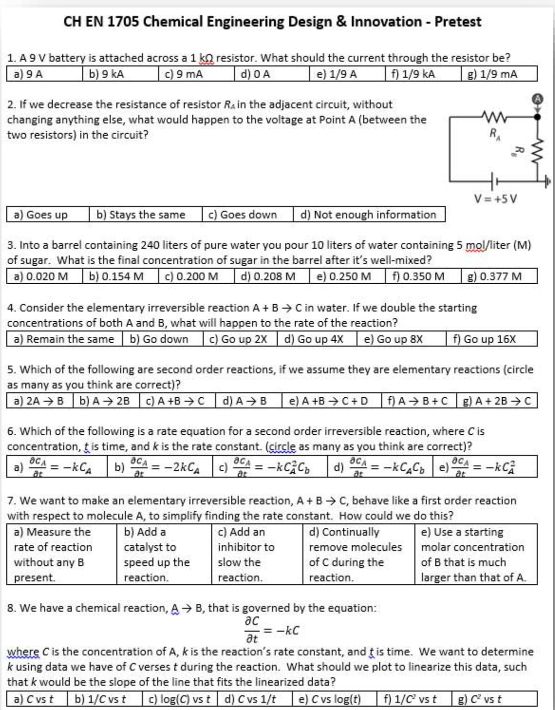
"It was nice to finally get some hands on engineering in the curriculum."

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



Pre- Post-Test Results



CH EN 1705 Chemical Engineering Design & Innovation - Pretest

1. A 9 V battery is attached across a 1 kΩ 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 → 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 → B	b) A → 2B	c) A +B → C	d) A → B	e) A +B → C + D	f) A → B + C	g) A + 2B → 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) $\frac{\partial C_A}{\partial t} = -kC_A$	b) $\frac{\partial C_A}{\partial t} = -2kC_A$	c) $\frac{\partial C_A}{\partial t} = -kC_A^2C_b$	d) $\frac{\partial C_A}{\partial t} = -kC_AC_b$	e) $\frac{\partial C_A}{\partial t} = -kC_A^2$

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

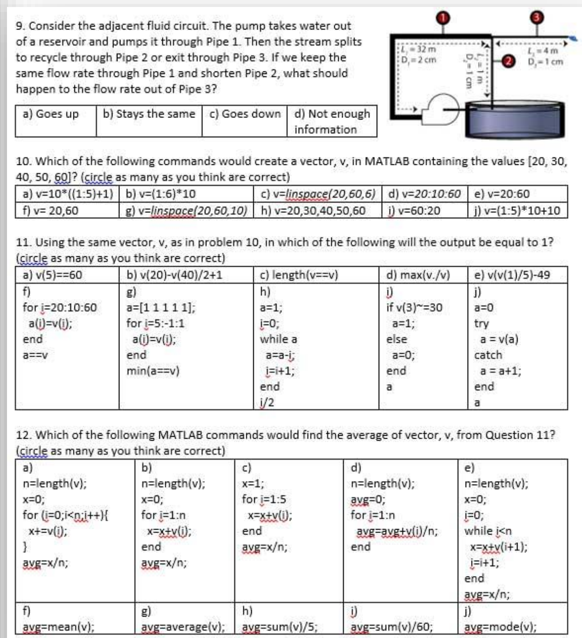
a) Measure the rate of reaction without any B present.	b) Add a catalyst to speed up the reaction.	c) Add an inhibitor to slow the reaction.	d) Continually remove molecules of C during the reaction.	e) Use a starting molar concentration of B that is much larger than that of A.

8. We have a chemical reaction, A → 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* verses *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/C^2 vs *t*	g) C^2 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=*linspace(20,60,6)*	d) v=*20:10:60*	e) v=20:60
f) v= 20,60	g) v=*linspace(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 i=20:10:60
a(i)=v(i);
end
a==v
	g)
	a=[1 1 1 1 1];
	for i=5:-1:1
	a(i)=v(i);
	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)

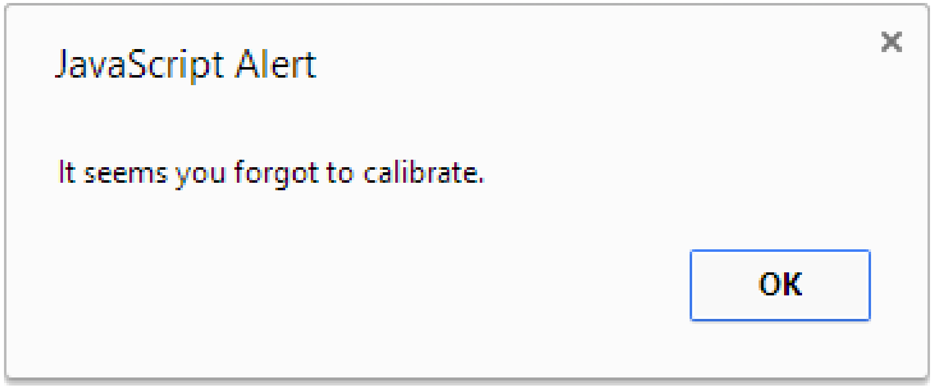
a)
n=length(v);
x=0;
for (i=0;i<n;i++){
x+=v(i);
}
avg=x/n;
	b)
	n=length(v);
	x=0;
	for i=1:n
	x=x+v(i);
	end
	avg=x/n;
		c)
		x=1;
		for i=1:5
		x=x+v(i);
		end
		avg=x/n;
			d)
			n=length(v);
			avg=0;
			for i=1:n
			avg=avg+v(i)/n;
			end
				e)
				n=length(v);
				x=0;
				i=0;
				while i<n
				x=x+v(i+1);
				i=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=mode(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).

Add Automated Interventions

- "You're not logged in, are you sure you want to submit your answer?"
- "It seems you forgot to calibrate."
- "You should double check your units."
- "You seem to be clicking more than necessary."



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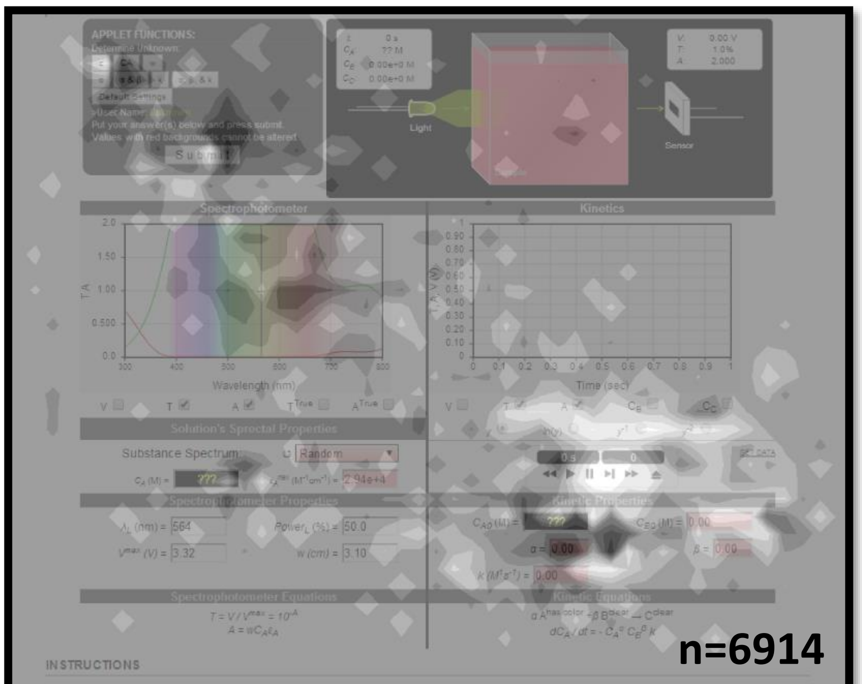
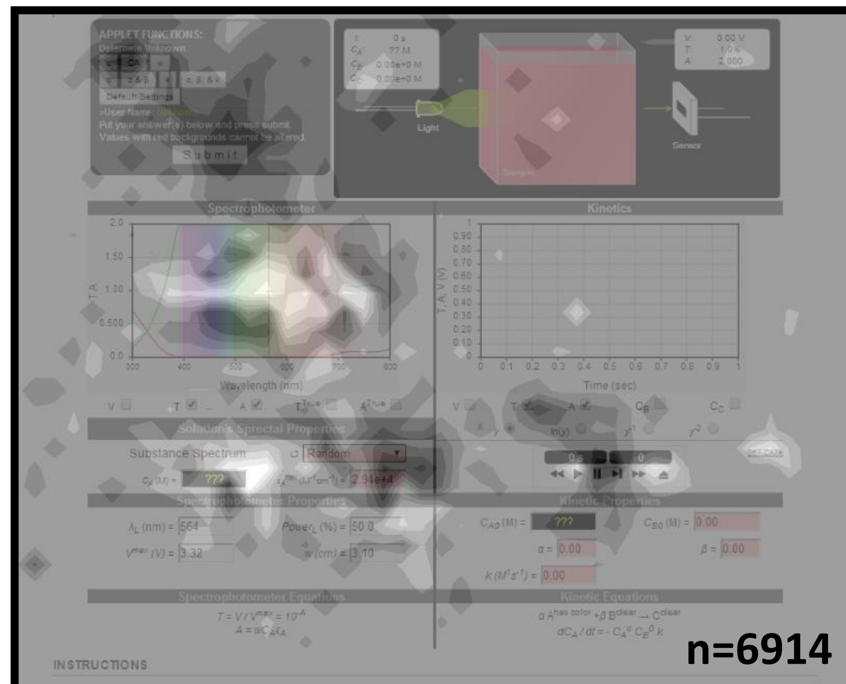
Mouse Location Frequency

- Detect misunderstanding of material

Reaction Order

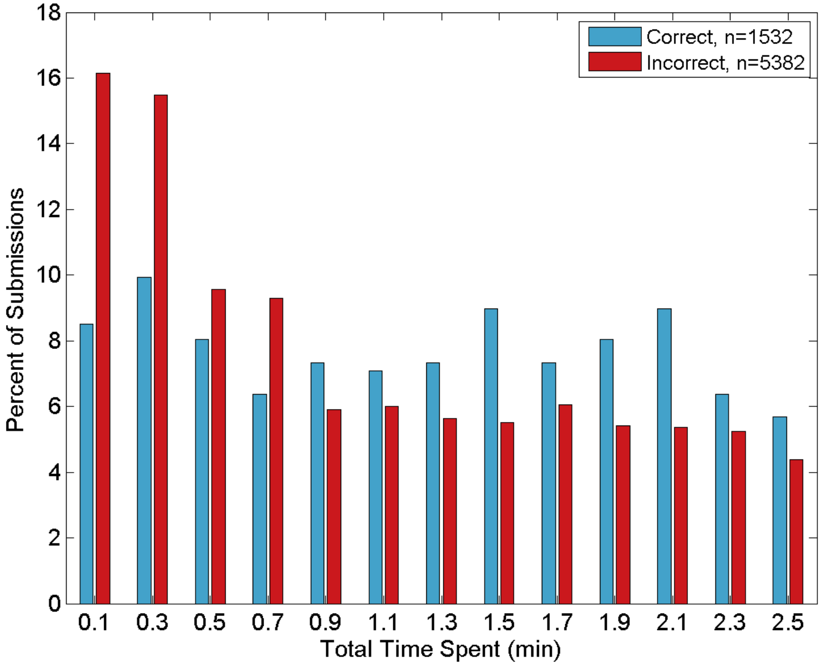


Maximum Molar Extinction Coefficient

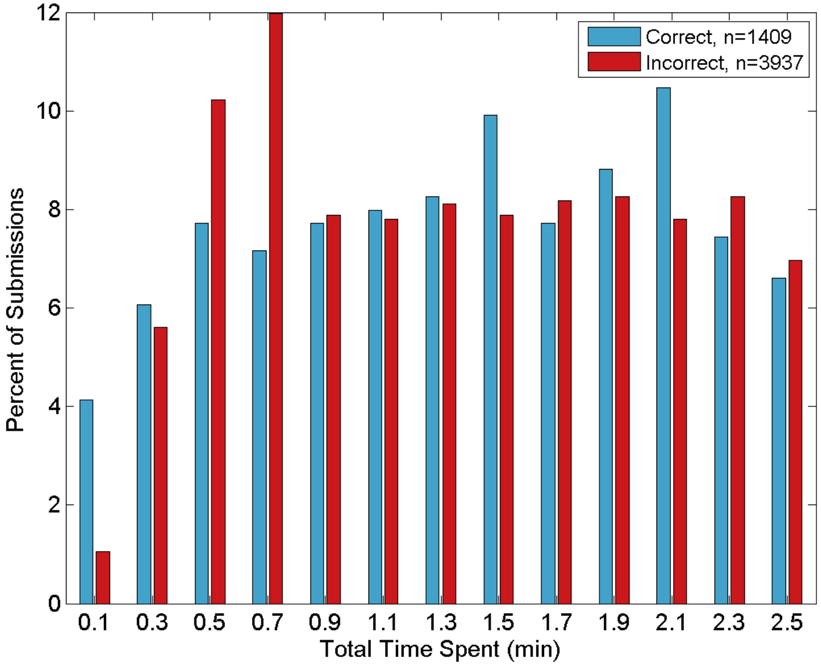


Eliminate Student Guessing

Original data

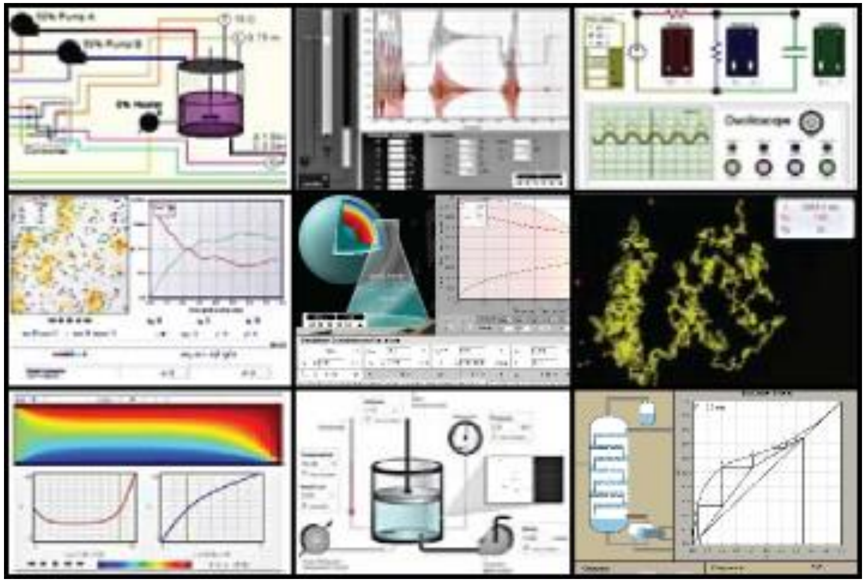


Filtered data



Features of Our Simulations

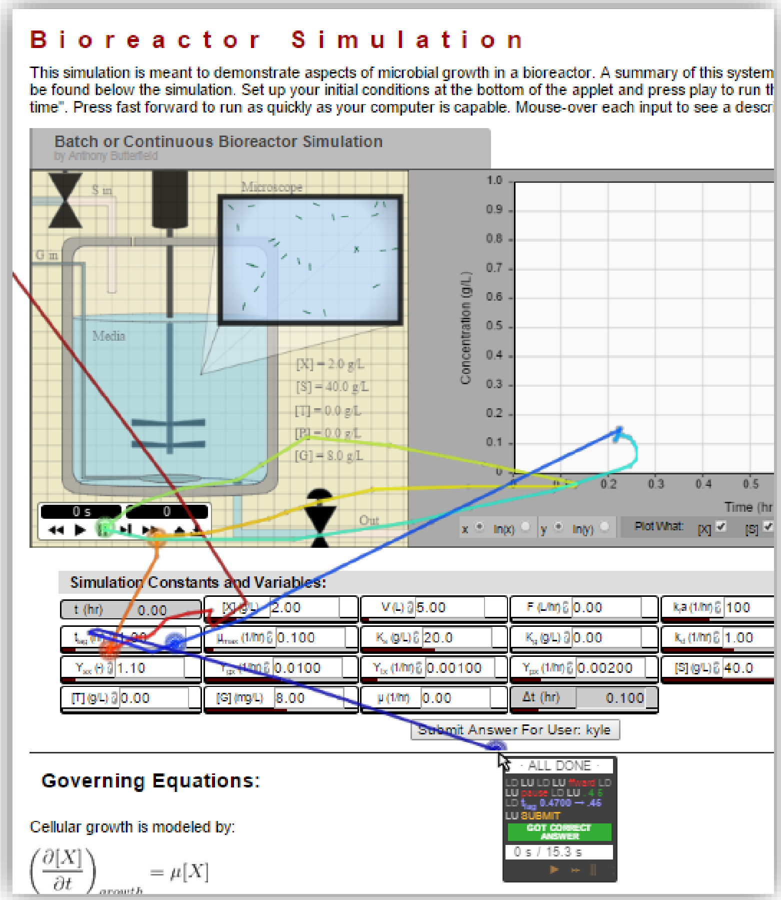
- Cover a wide variety of chemical engineering disciplines
- Open-source
  - Freely accessible http://www.vSTEM.org
- Browser-based
  - Easy to access
  - Chrome, IE, Firefox, Safari
  - PC, tablet, phone
- HTML, JavaScript, PHP
  - No download necessary



Tracking Student Usage

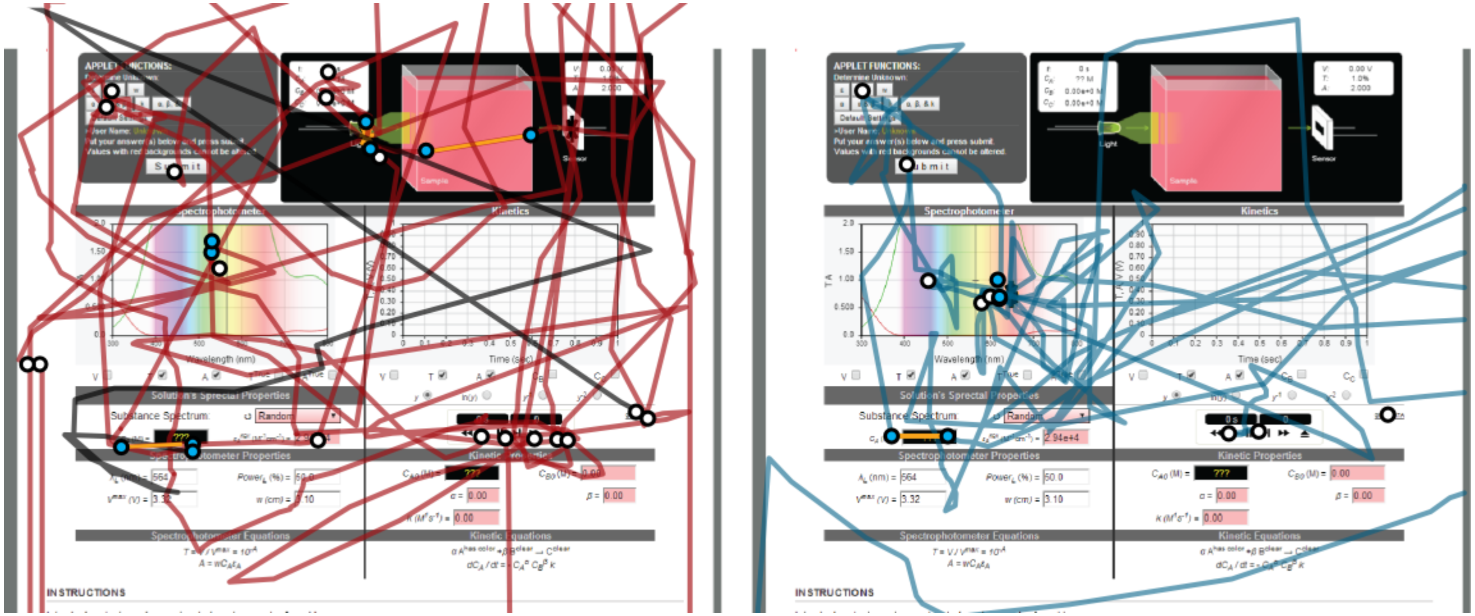
Records

- Which student
- Correct or incorrect
- Submission time
- Time and location of each event
  - Mouse movements, clicks, typing
- All simulation constants
- Browser, IP address, and Operating System



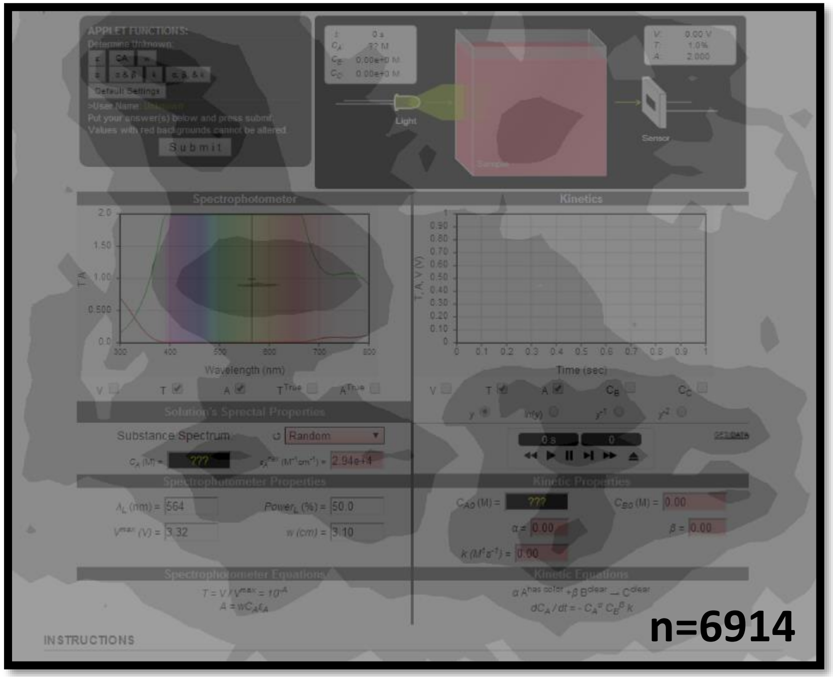
Improve Simulation Interface

- Add more intuitive functionality, based on individual attempts



Misunderstanding of Material

- Can we use ensemble averaged mouse location data to identify student misunderstandings?
- What if we look at differences between correct and incorrect attempts?



Tracking Student Usage

Records

- Which student
- Correct or incorrect
- Submission time
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  - Mouse movements, clicks, typing
- All simulation constants
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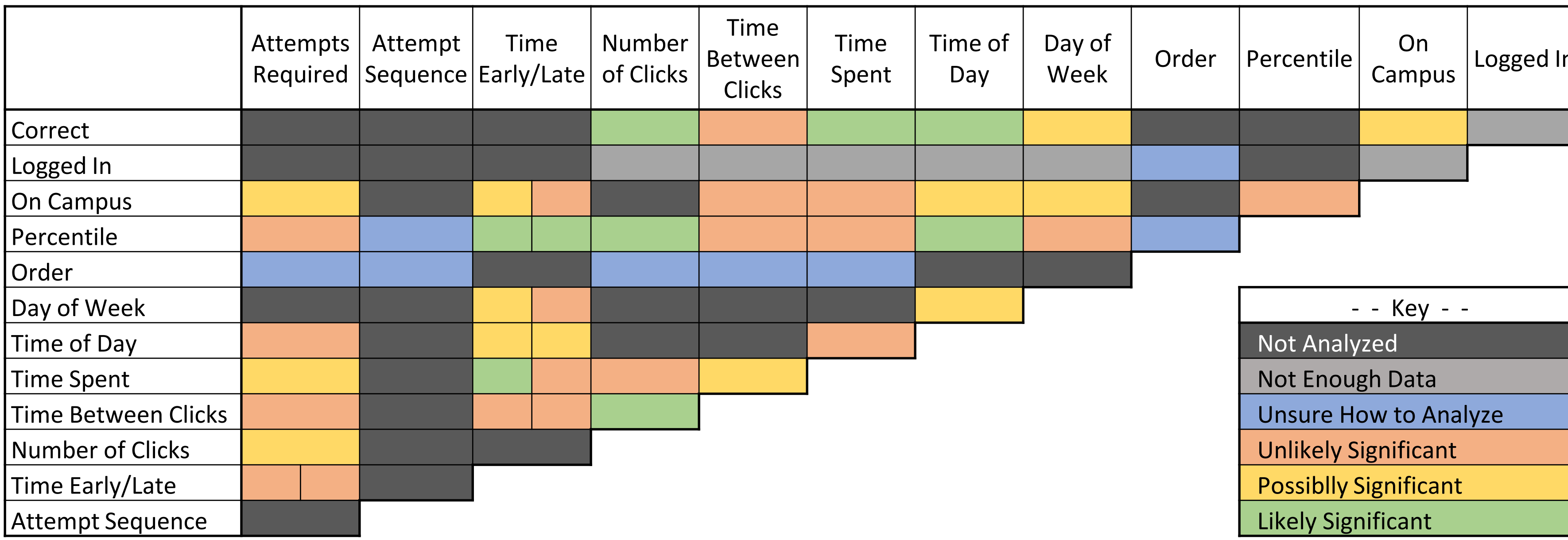
We can determine

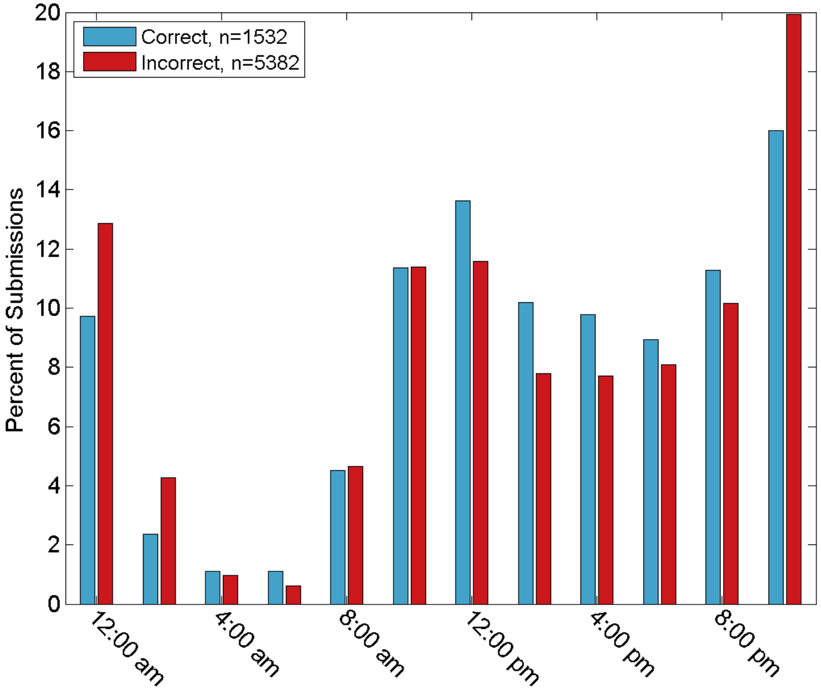
- Time of day/day of week
- Time spent
- Time between clicks
- Number of clicks
- Time early/late
- Attempts required
- On campus or not
- Order of problems

Preliminary Analysis: Pairwise Relationships

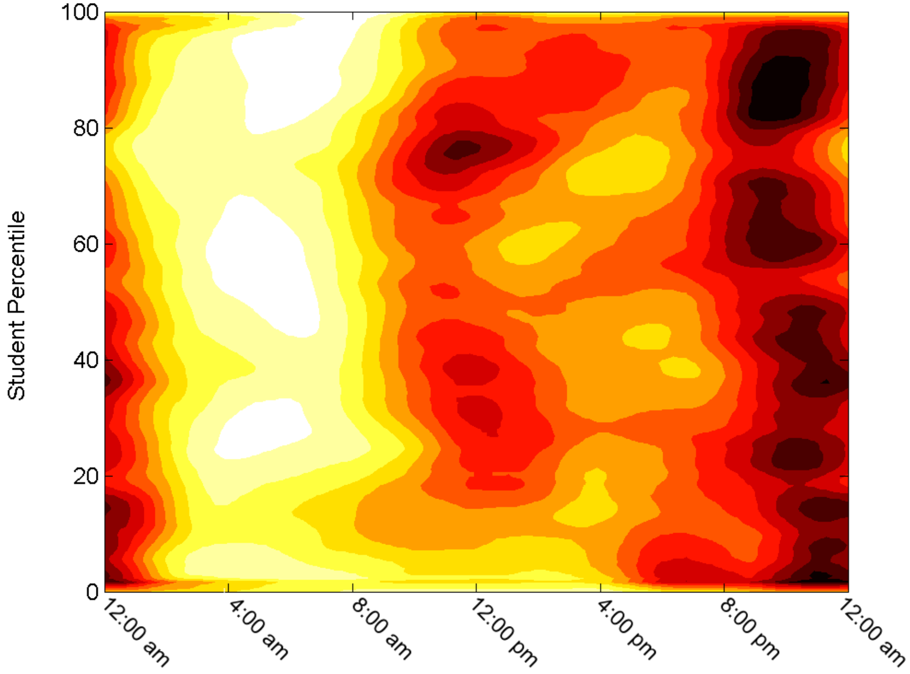


Determine Successful Behavior

Students have lower success rates late at night

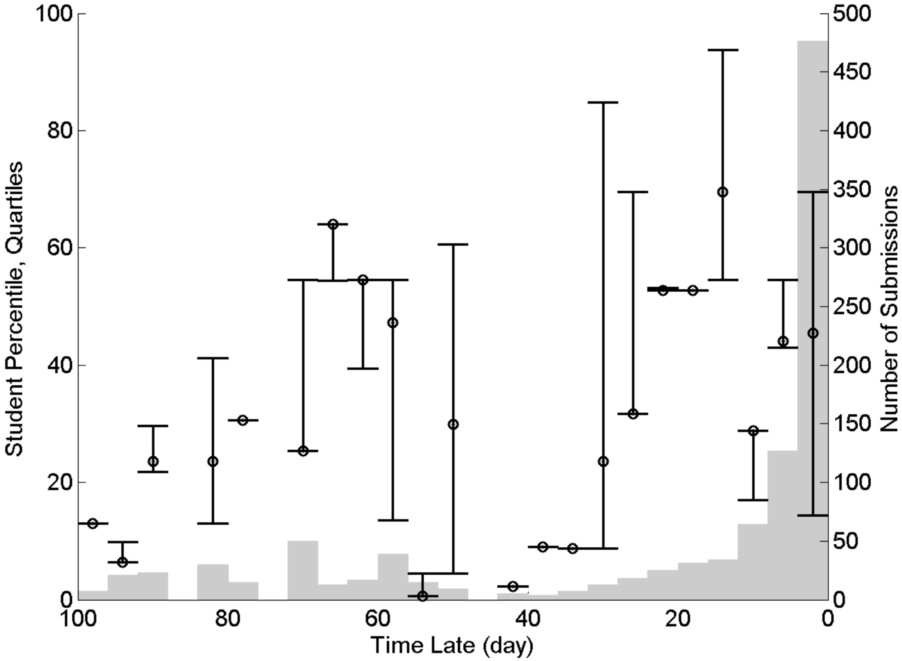


High percentile students do homework earlier in the day

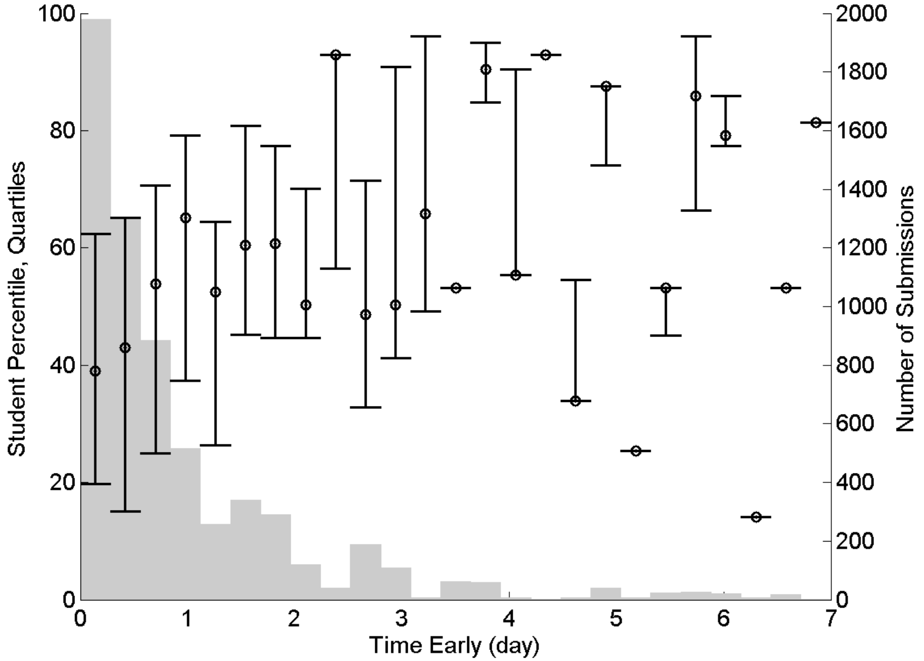


Determine Successful Behavior

Later submissions tend to be low percentile students

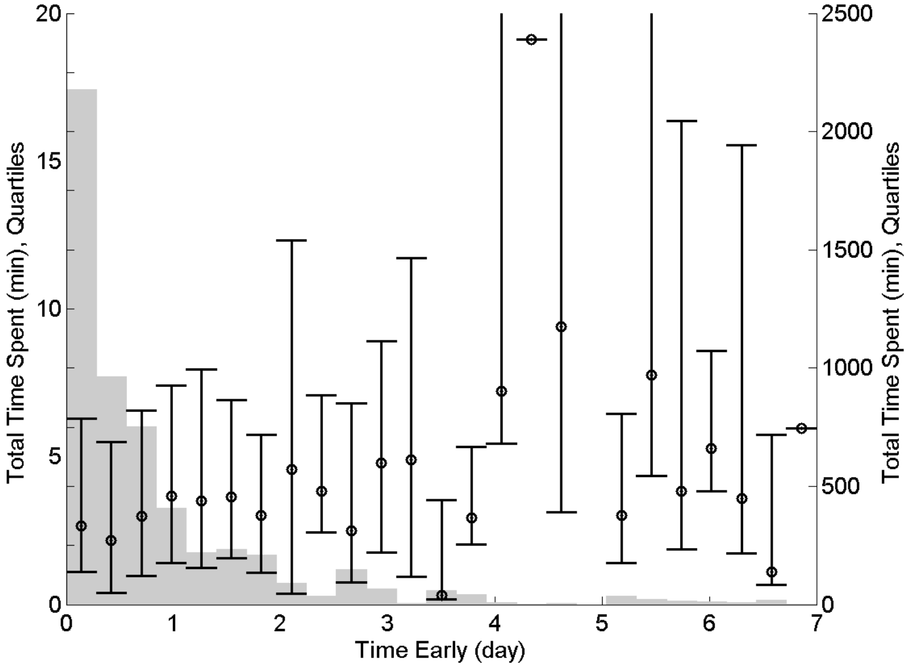


Earlier submissions tend to be high percentile students

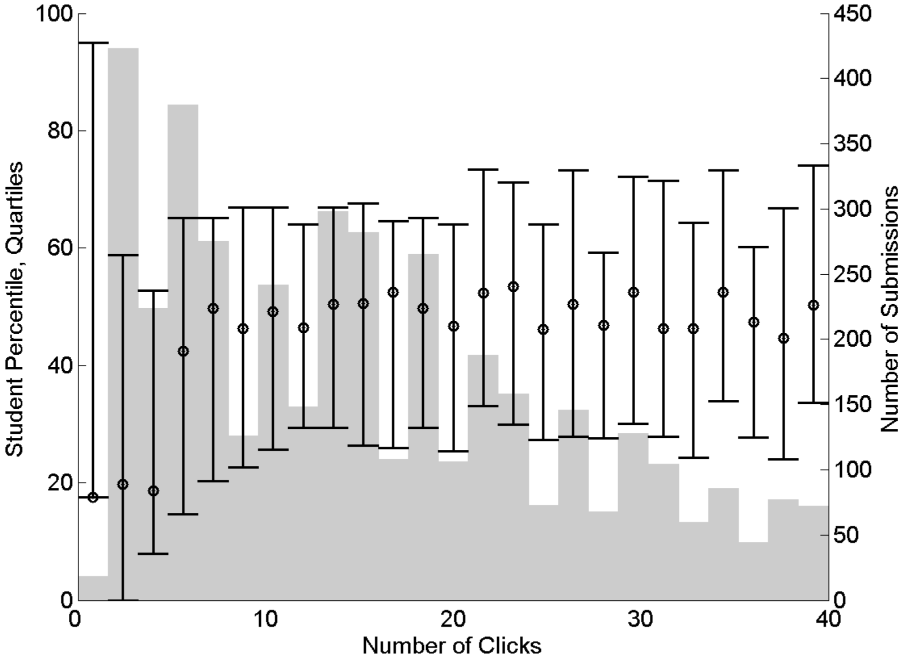


Determine Successful Behavior

Earlier submissions spend more time exploring the simulations



Low number of clicks correlates with lower percentile students (guessing?)

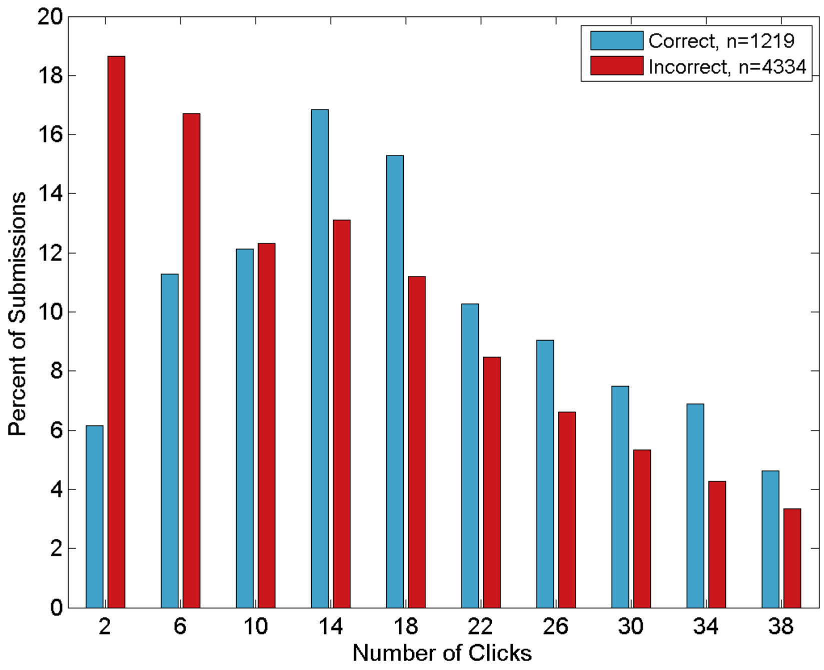


Eliminate Student Guessing

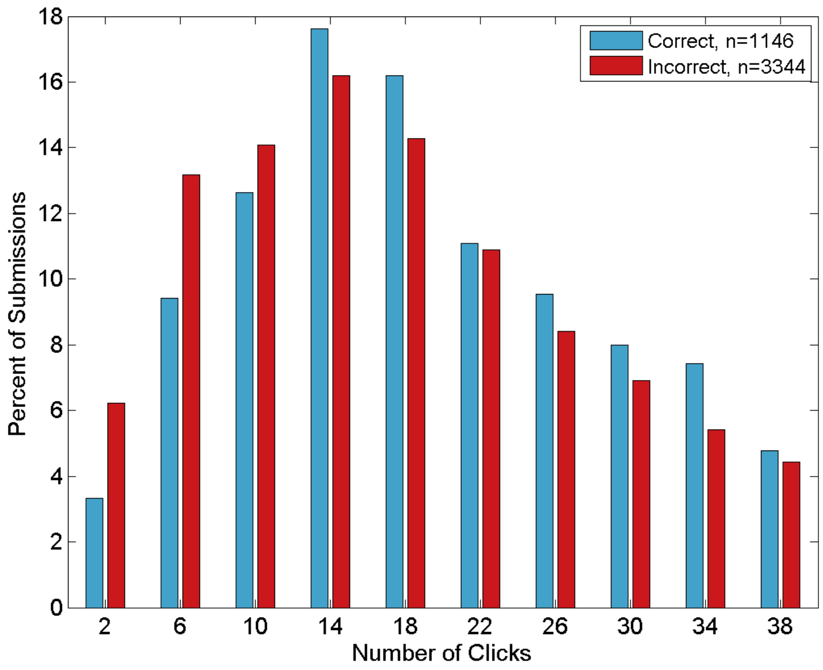
- Typical criteria of student guessing:
  - Less than 20 sec
  - Less than 6 clicks
  - More than 5 attempts
  - Guessing the same answer, or the previous correct answer
  - Guessed before
- Using a combination of these, we can detect student guessing

Eliminate Student Guessing

Original data



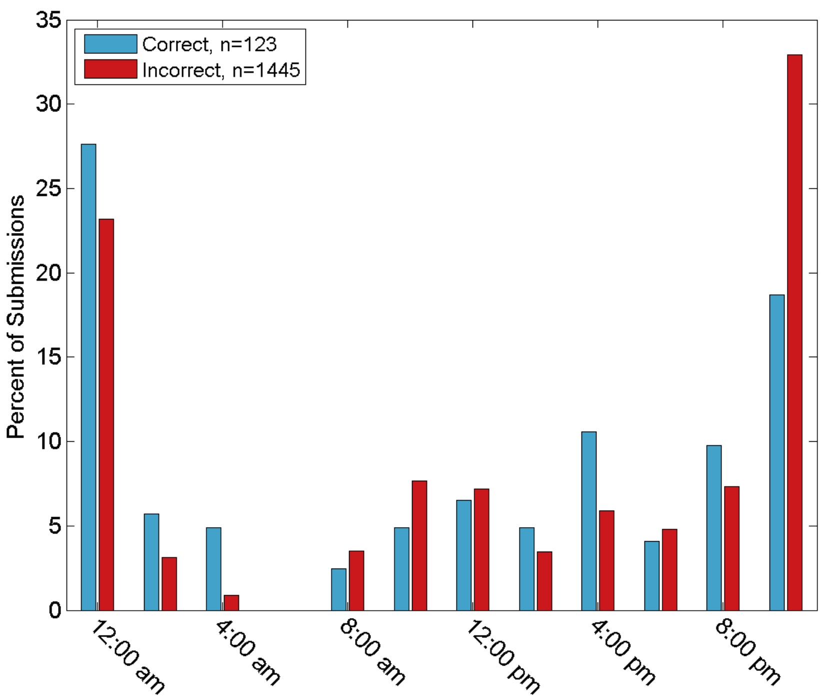
Filtered data



Eliminate Student Guessing

- Students are much more likely to guess late at night

Guessing data



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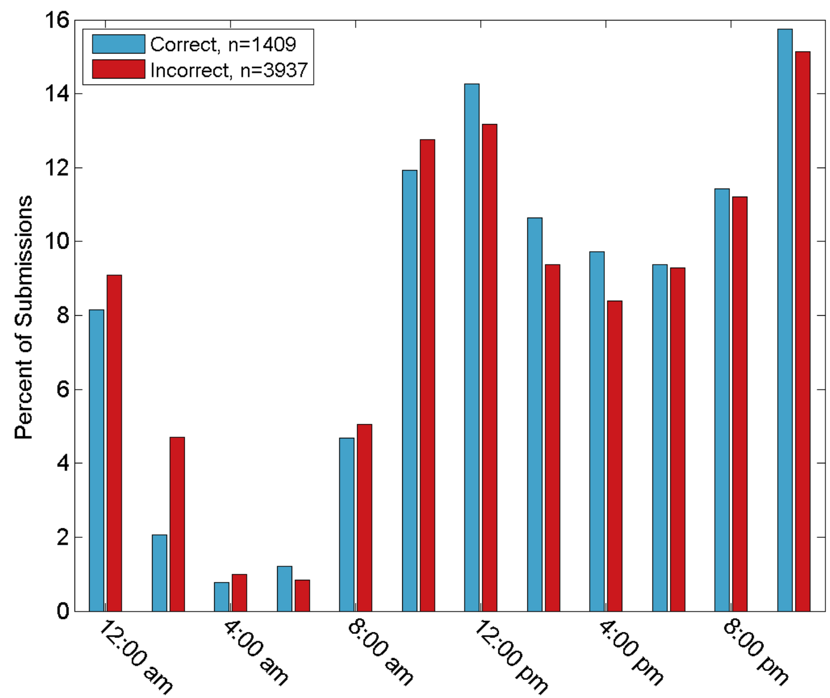
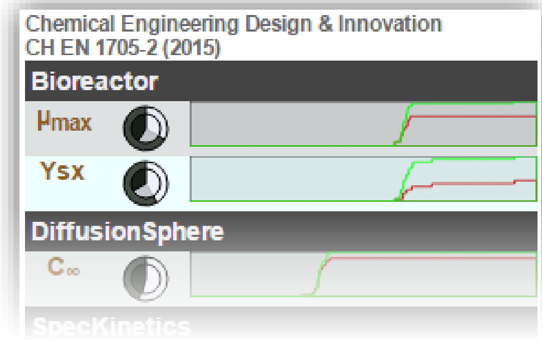
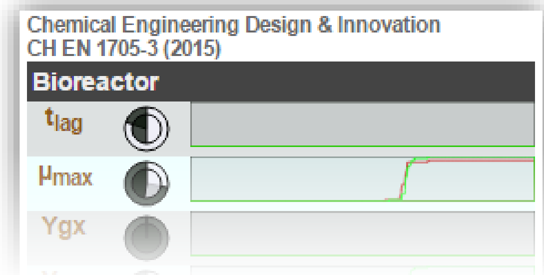
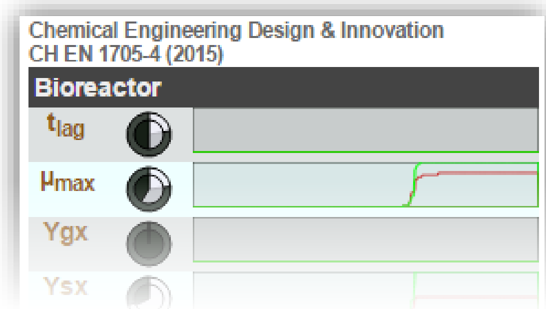


Future Work

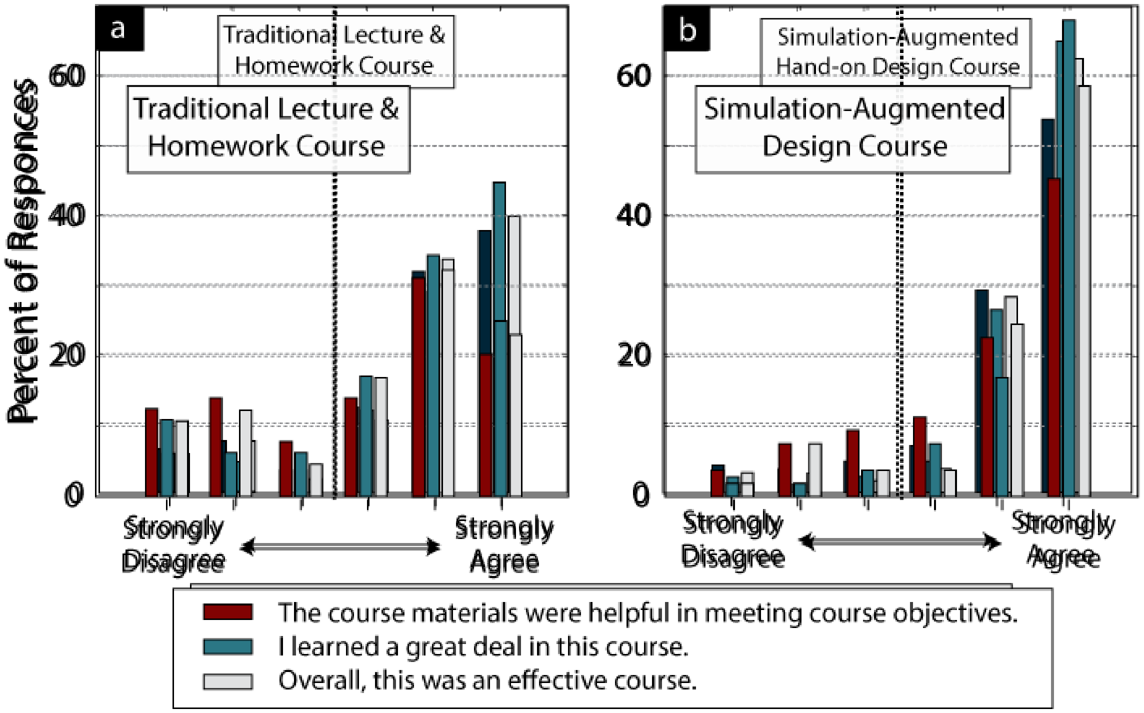
- Real time educational data-mining
  - For students to see when their peers do their homework, if they are struggling with similar problems, etc.
- Develop simulations with textbook and conceptual questions for comparison
  - Can randomize unknown, value, and units







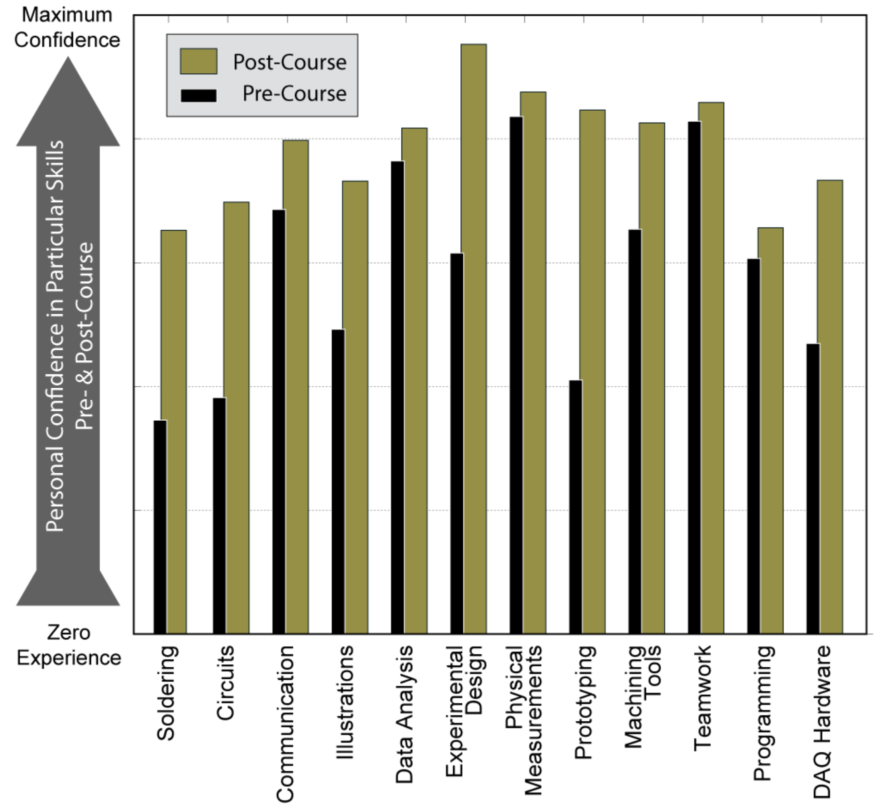
Same Freshmen, Same Year
Traditional vs. New Course Model



- 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.

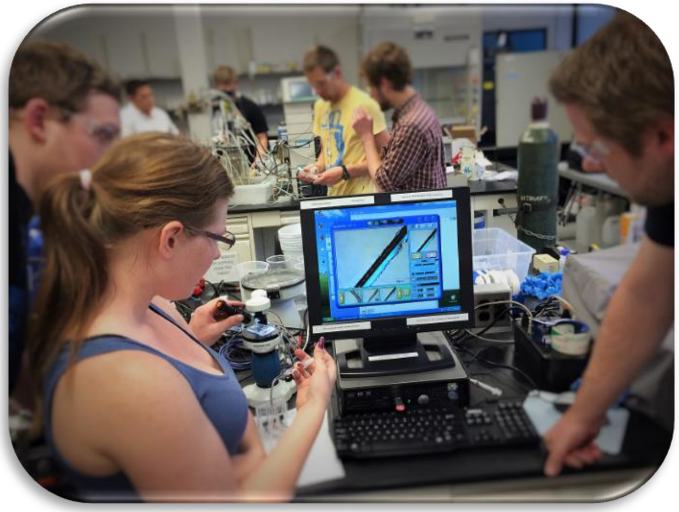
Personal Confidence in Engineering Skills

- 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.



Retention & Underrepresented Groups

- Historical retention rates:
    - Freshmen to sophomore ≅ 60%
    - Freshmen to graduation ≅ 45%
- Over 90% agreed:
    - "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