

Implementation and Usage of an Online Environment in a Chemical Engineering Curriculum

Kyle Branch

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University of Utah

ASEE Annual Conference

New Orleans, June 27, 2016

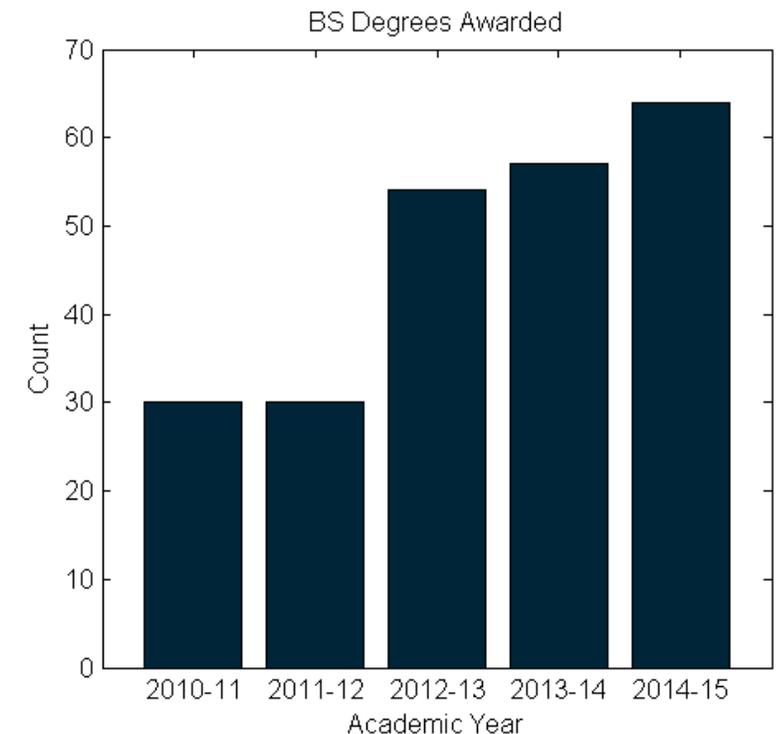
Our Freshman Lab Course

- Very open-ended design laboratory course
 - Students design and build equipment to assist in their production process or experimental analysis
- Students work in teams of three on projects typically lasting 2-3 weeks
- They are given individual and team-based homework assignments
- Our projects lab can accommodate a maximum of 30-40 students



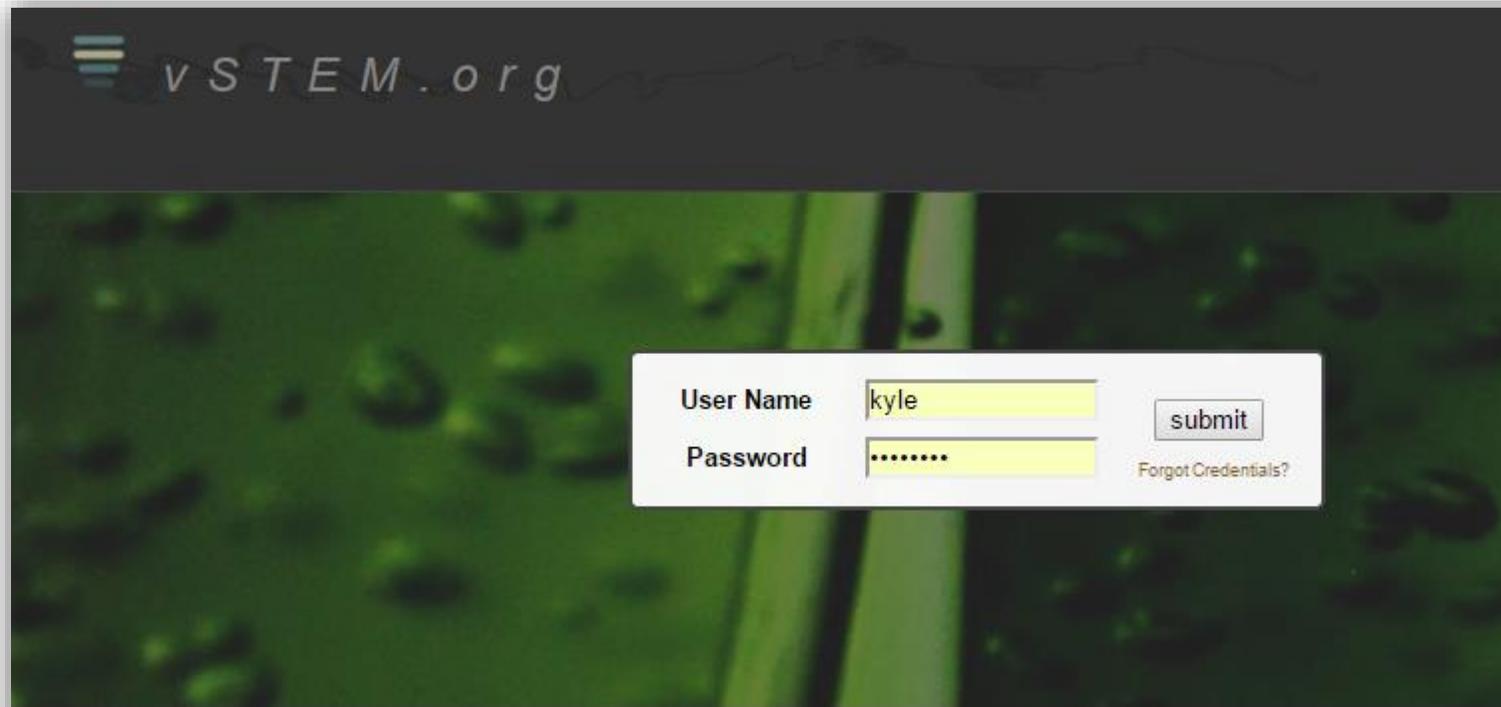
Large Class Sizes

- Our department has been growing significantly
- Over the past four years, course enrollment increased from 74 to 108 students
 - Increased to three sections, again at full capacity
- Common Difficulties:
 - Knowing each student and their name
 - Significant grading commitment
 - Answering student questions and concerns
 - Safety concerns in a lab setting
 - Need for additional instructors or TAs



Created an Online System

- Developed an online system at vSTEM.org (virtual STEM)
 - Designed to remediate some of the difficulties of large classes
- Open-source
- Browser-based
 - Easy to access
 - Chrome, IE, Firefox, Safari
 - PC, tablet, phone
- HTML, JavaScript, PHP
 - No download necessary



User Hub

- Designed to help navigate the site
- Some areas are only visible by instructors or admins
- Includes links to User Profile and Assignments
 - In the User Profile, students can change their user information and settings

The screenshot displays the vSTEM.org User Hub interface for a user named Kyle (Administrator). The interface includes a navigation bar with tabs for HOME, USER HUB, USER PROFILE, and ASSIGNMENTS. The user's level is 15, Maxwell's Demon, with 31,562 imaginary experience points. The interface is divided into sections for user profile, training accomplishments, courses taught, team info, and available applets. Annotations highlight various features and user actions.

Annotations:

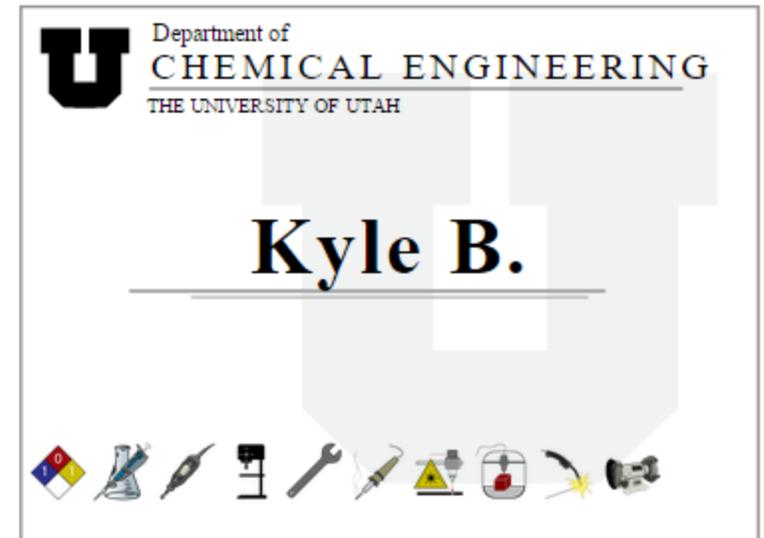
- Various Tabs, Assignments Tab:** Points to the ASSIGNMENTS tab in the navigation bar.
- Username Logout:** Points to the User: kyle logout link in the top right corner.
- Level and Experience Points:** Points to the user's level and experience points information.
- Buttons for Students:** Points to the User Profile and Print Lab Badge buttons.
- Buttons for Instructors:** Points to the Alter Student Training, Alter Units Database, Alter Variables Database, and Alter Form Questions buttons.
- Lab Safety Training Check for Test, Color for In-Person Training:** Points to the icons representing training accomplishments.
- Students Submit Peer Evaluations:** Points to the evaluation table for Week 2 - w21.
- Instructors View Students, Scores, Peer Evaluations:** Points to the evaluation table for Test - Awesome.
- You have 3 peer teamworking evaluations left to complete. Click on the red X next to the team member's name to be all judgemental.** Points to the red X next to Tony B's name in the evaluation table.

Available Applets:

The bottom section displays several available applets, including a simulation of a chemical process, a 3D molecular model, a graph of data, and a simulation of a chemical reaction.

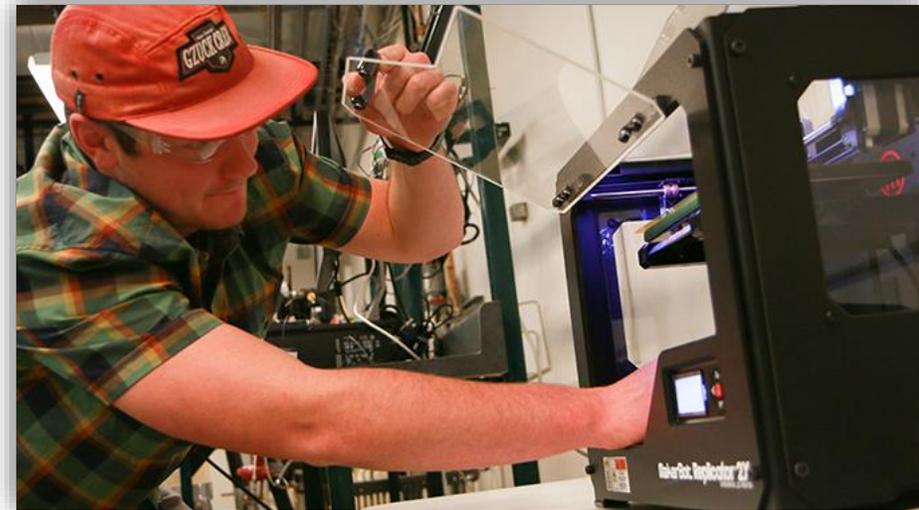
Student Name Badges

- Helps instructors, TAs, and fellow students learn names
- Badges indicate which equipment they have been trained to use
- Students are given a name badge and the ability to print them as they gain new skills
- Allows for an easy check if a student is trained to use particular equipment
 - Improves lab safety



Lab Equipment Training

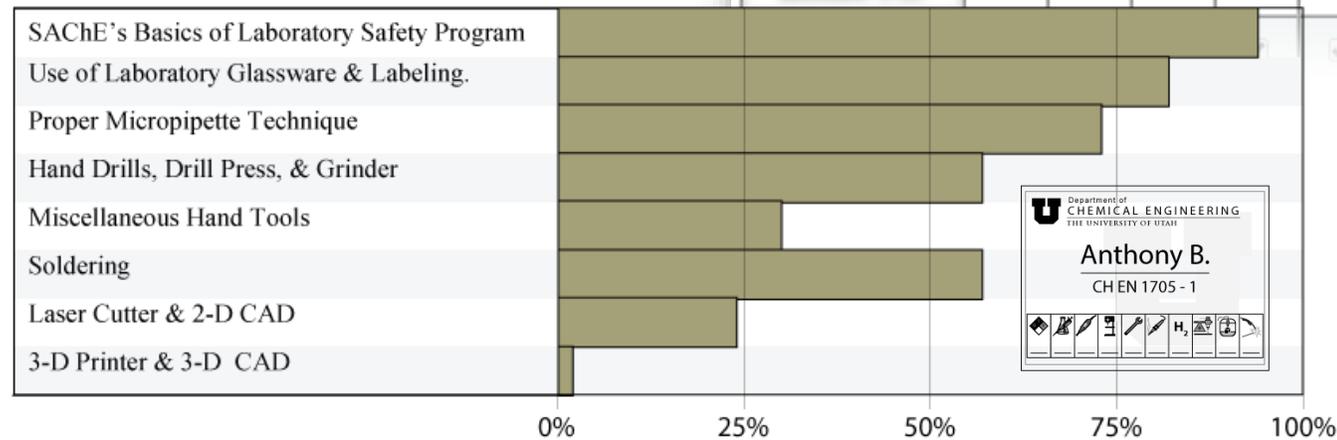
- Students using lab equipment:
 - Complete a safety and operating quiz online
 - Students are always able to go back and review their quiz
 - Trained by an instructor
- The delay helps students retain the material
- Reduces the training burden
 - Originally, they would pass an oral safety quiz



Measured Lab Skills

- All student training is recorded online
 - Used for educational research

Student Name							H ₂			
Course ID = 1										
[Student Name]	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
[Student Name]	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
[Student Name]	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
[Student Name]	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
[Student Name]	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>						



Department of CHEMICAL ENGINEERING
 THE UNIVERSITY OF UTAH
Anthony B.
 CHEN 1705 - 1

Student Teams

- Students are assigned into teams of three for each lab project
 - Teams are displayed on vSTEM
- If permitted, their team members can view their phone number or email address
- Students submit team evaluations
 - Displayed to the instructor in a form easy to read
 - At the end of the semester, students receive anonymized peer feedback

Teamworking Evaluation for:
Tony B
Project: Final Project (5)
Chemical Engineering Design & Innovation
2016 • CH EN 1705-4

1. EFFORT? (25 PTS)

My team member is a hard worker. They put in their fair share of effort and took on an appropriate percentage of complete the lab work and written reports. When working on the project, they took our work seriously and remained the tasks at hand.

50

2. TIME? (25 PTS)

My team member was always on time. They were reasonably accommodating when scheduling meetings, lab work consistently met the deadlines agreed to by the team.

50

Online Homework System

- Developed a system to administer online homework problems
- Shows current and past courses
- Specifies:
 - Due Dates
 - Current and max score
 - Number of questions
 - Late penalty
 - Points lost for being late

The screenshot shows the vSTEM.org website interface. At the top right, it says "User: kyle" and "logout". The main navigation bar includes "HOME", "USER HUB", "USER PROFILE", and "ASSIGNMENTS". The current page is titled "Assignments - CH EN 1705". Below this, there is a table with columns: "Score", "Assignment", "Questions Completed", "Due Date", and "Current Late Penalty".

Score	Assignment	Questions Completed	Due Date	Current Late Penalty
No Credit	1. Pretest	0/15	CLOSED	—
2.39/10	2. Basic Circuits	6/10	Jan 22, 2016 at 2:00PM	-46%
17/15	3. Basic Spectrophotometer, Kinetics	6/5	Jan 29, 2016 at 11:59PM	Late Penalty: -1.61 points

Below the table, there is a section for "Past Courses" with a link "View Prior Courses" and a heading "Assignments - CH EN 1703, Fall 2015". A table below this shows the start of a new assignment table with columns "Score", "Assignment", "Questions Completed", and "Due Date".

Score	Assignment	Questions Completed	Due Date
No Credit	1. Pretest	0/16	CLOSED

Annotations on the screenshot include:

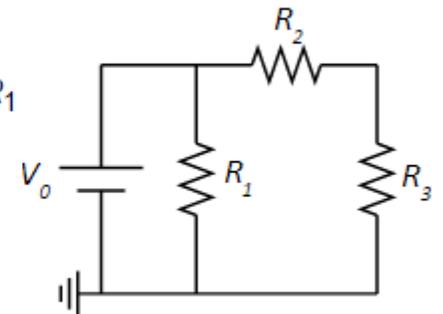
- "Course Name" pointing to the course title.
- "Current Score, Can Contain Extra Credit" pointing to the score column.
- "Problems Completed or Out of Attempts" pointing to the "Questions Completed" column.
- "Late Penalty Column is Only Visible if an Assignment is Late" pointing to the "Current Late Penalty" column.
- "Late Penalty: -1.61 points" pointing to the specific late penalty value.
- "Mouseover to See Late Points Lost" pointing to the late penalty tooltip.
- "View Prior Courses" pointing to the link.

Homework Questions

- Assignments are highly customizable by the instructor
- 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 k Ω . Therefore, the current through Resistor 2 is I_1 mA.



$$I_1 = \text{[]} \text{ mA}$$

Submit

Online Homework System

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

15. (1.75/1.75 points. Attempt 1 of 3.) In a barrel containing V_1 gal of water containing 0.001 M blue dye you pour 19.2 pint of water containing 3.74 mol/L of the dye. The final concentration of dye in the barrel is 0.0171 M after it's well

$V_1 =$ gal 

2. (0/0.25 points. Attempt 1 of 1.) Following a voltage increase, minus the sum of all voltage drops across the circuit is

- A. Decreasing if there is a power supply
- B. Constant (not necessarily zero)
- C. Zero, only at equilibrium
- D. Increasing if there is a power supply
- E.  Zero

Benefits to Instructors

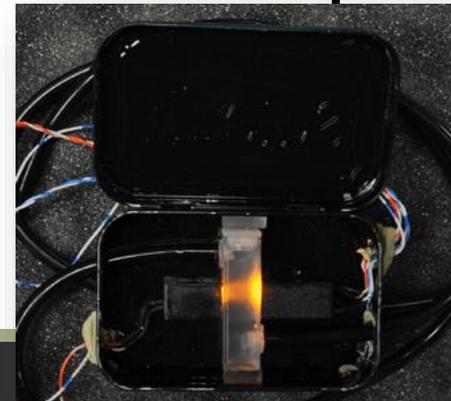
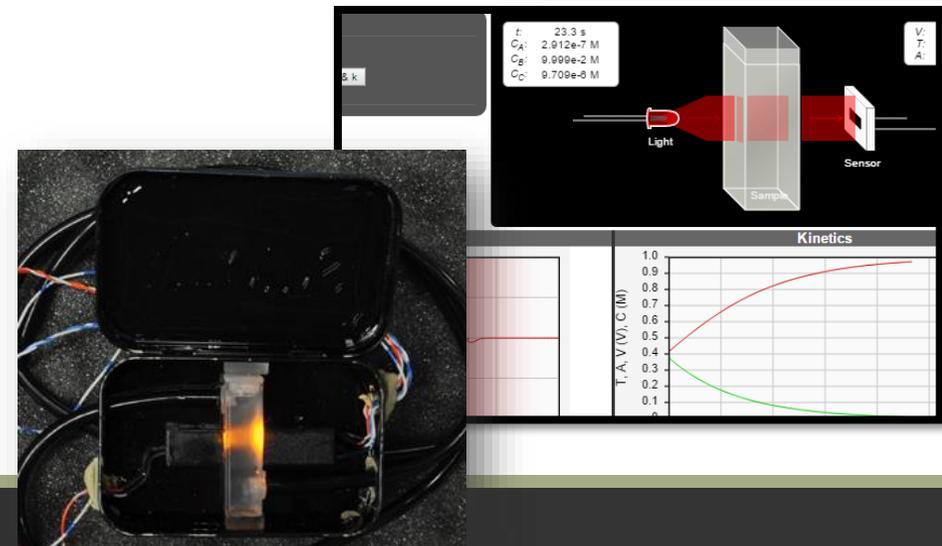
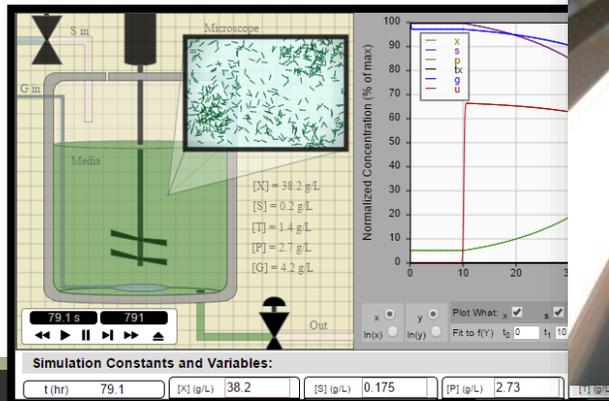
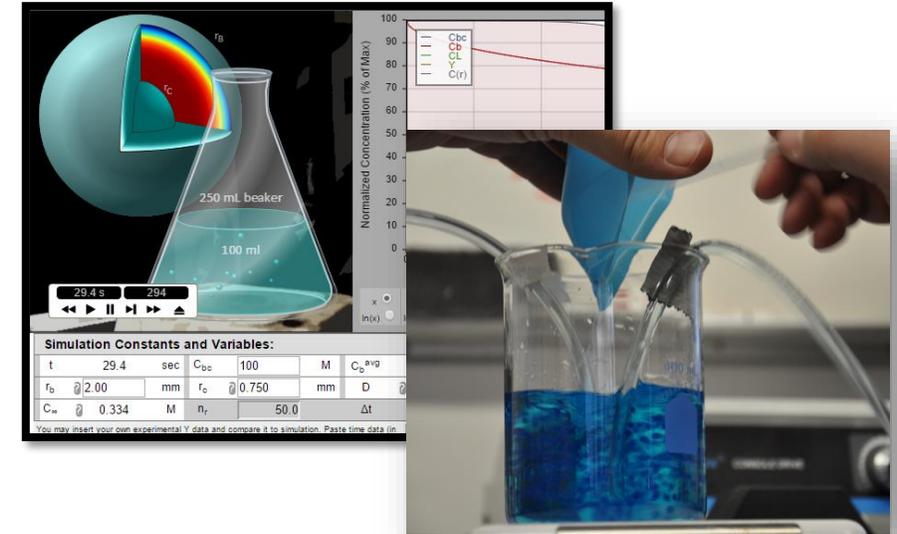
- Automatically graded assignments
 - Student summary generated and color coded based on different criteria
- Helps instructors determine where students are struggling

Assignments – CH EN 1703

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

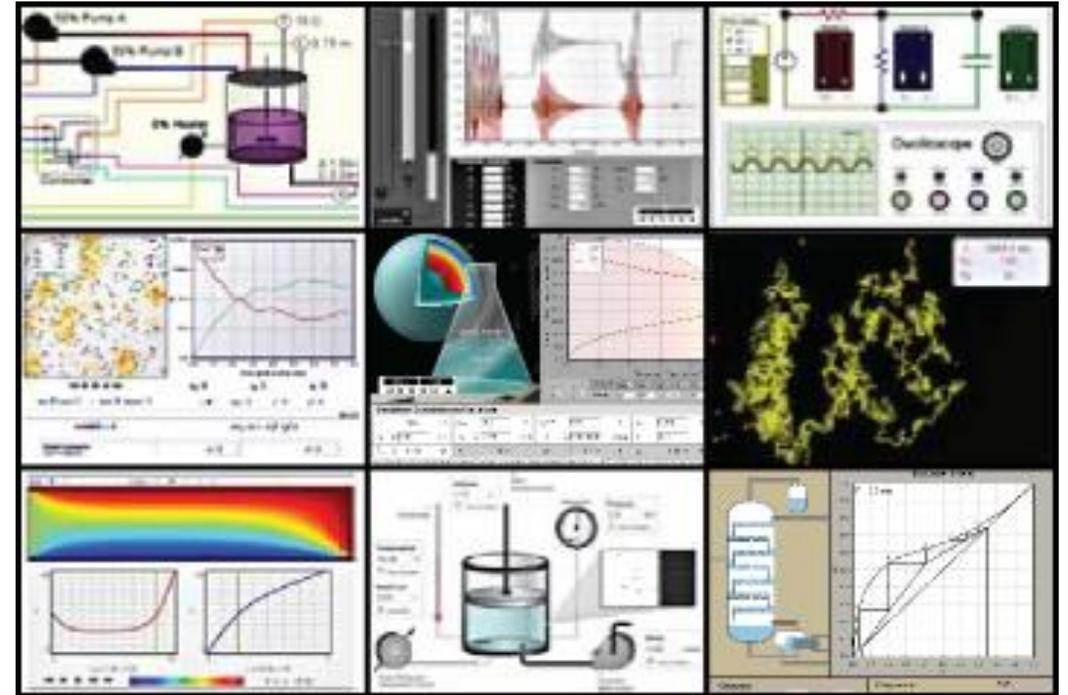
Interactive Simulations

- 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



Our Simulations

- Cover a wide variety of chemical engineering disciplines
 - Chemical kinetics
 - Biochemical engineering
 - Thermodynamics
 - Reactor design
 - Process control
 - Heat and mass transfer
 - Fluid mechanics
- Includes written instructions and screencast tutorials



Existing Online Applets

colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_en.html

Microwave Infrared Visible

Higher Energy →

Light

The screenshot shows a simulation interface with three light source icons: Microwave, Infrared, and Visible. An arrow labeled 'Higher Energy' points from left to right. Below the icons, the word 'Light' is written. The background shows a browser window with various tabs and a URL.

www.myphysicslab.com/molecule6.html

This site uses a plugin (Java(TM)) that is unsupported. Learn more

List Previous Next FAQ? Source Code

Molecule 6

This simulation shows 6 masses connected by springs and free to move in 2 dimensions.

You can change parameters in the simulation such as gravity, mass, spring stiffness, and friction (damping). You can drag any mass with your mouse to change the starting position.

(If you don't see the simulation try [instructions for enabling Java.](#))

Click the buttons below for various combinations of parameter settings. Can you find all the stable configurations?

- red spring stiff 6 8 stable configurations
- red spring stiff 3 6 stable configurations

The screenshot shows a browser window with a Java error message. The page title is 'Molecule 6' and the content describes a simulation of six masses connected by springs. A large grey area with a puzzle piece icon indicates that the Java plugin is not supported. Below the main text, there are two buttons for different parameter settings.

www.colorado.edu/learncheme/kinetics/BatchReactorScaleUp.html

LearnChemE UNIVERSITY OF COLORADO BOULDER

TUTORIALS HOME LEARNCHEM.COM FAQ

The screenshot shows the LearnChemE website header with the University of Colorado Boulder logo and navigation links for Tutorials Home, LearnChem.com, and FAQ.

Use Firefox or Internet Explorer

Batch reactor scale-up interactive simulation!

Batch Reactor Scale-Up (Interactive Simula...)

temperature inside batch reactor

time (sec)

The screenshot shows a video player with a graph of temperature inside a batch reactor over time. The graph shows a peak in temperature followed by a decay. A play button is visible over the graph.

This Demonstration shows why a batch reactor cannot be scaled up geometrically. The larger the reactor increases, the surface area to volume ratio decreases, and thus the maximum temperature inside the reactor increases. For an exothermic, liquid phase reaction, the maximum temperature inside the reactor increases, the maximum adiabatic limit. Adiabatic reactor behavior is independent of reactor size. This is independent of reactor size.

Many won't function on all devices.

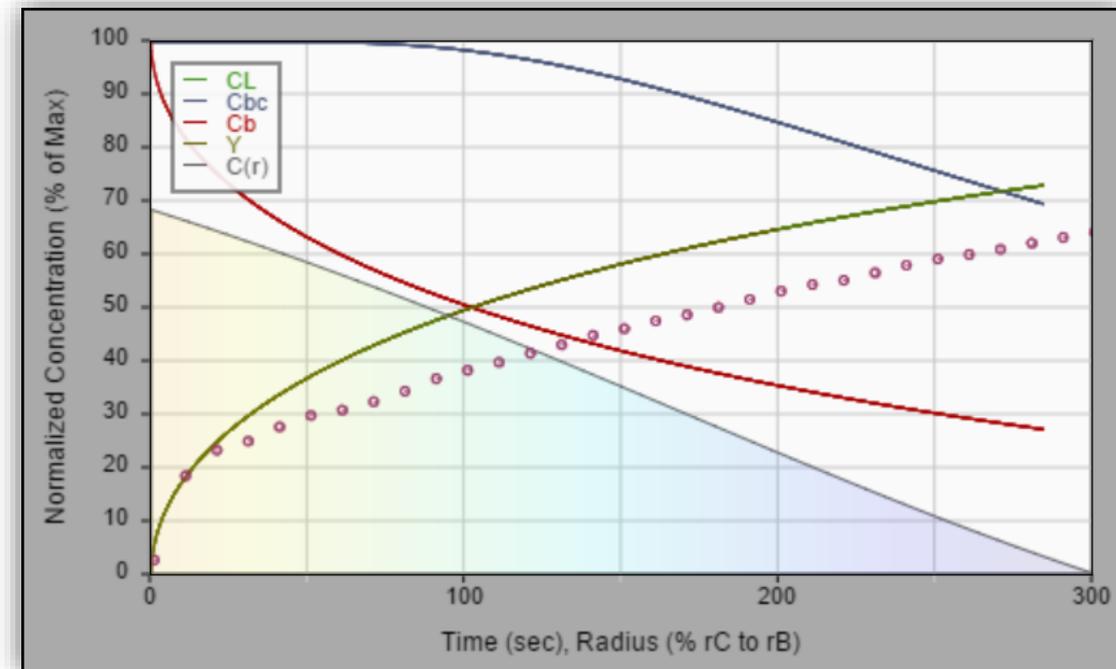
Using the Simulations

- Students select if their submission is for “practice” or “credit”
 - Students have unlimited practice attempts
- Students can input their experimental data and compare it to theory
- The interactive simulation assignments can be linked to the textbook-style homework interface

Submit Answer for User: kyle

FOR PRACTICE

FOR CREDIT



Benefits to Students

- Get a realistic sense of how adjusting parameters affects the system
- Prepares them for their upcoming lab project
 - Saves lab resources and students' time
- 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 ^(α+β-1) /s)	=	1.50e6

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

The screenshot displays a simulation interface for a spectrophotometer. At the top, it shows a progress bar and a warning: "May Not Work if Your Browser is not Up to Date". The main area is divided into several sections:

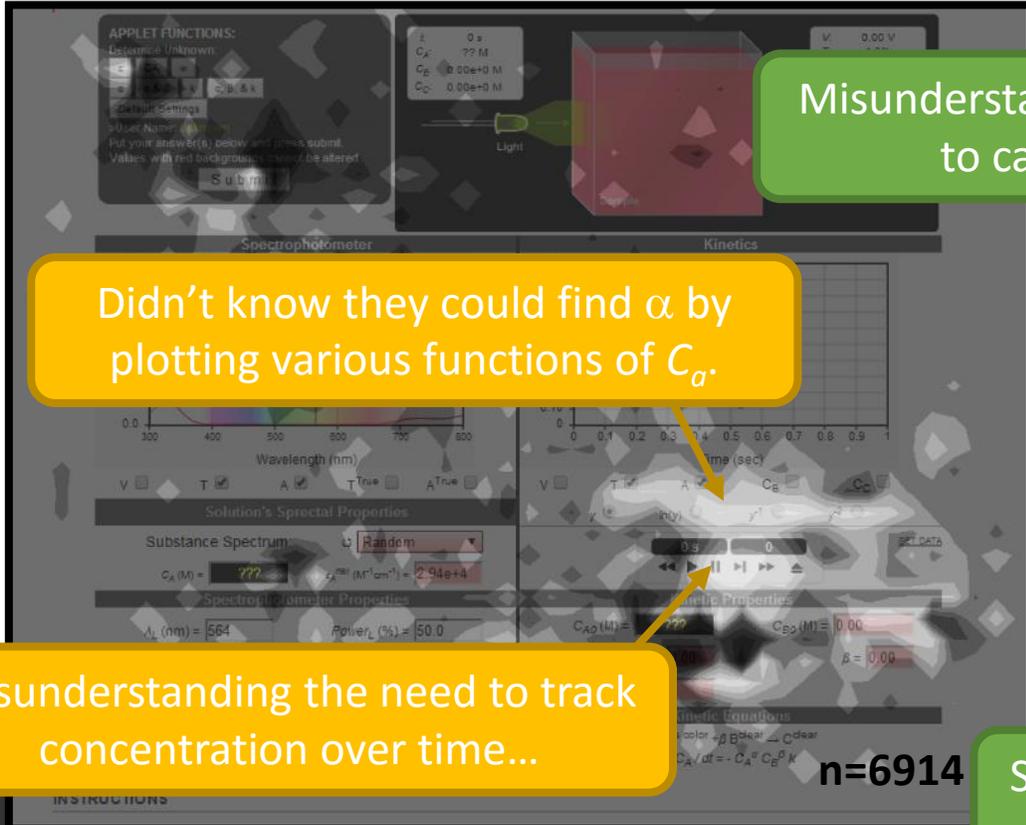
- Beer Lambert Law:** $T = V/V_{max} = 10^{-A}$, $A = wC_A\epsilon_A$
- Reaction Kinetics:** $\alpha A + \beta B \rightarrow C$, $R = C_A^\alpha C_B^\beta k$, $dC_A/dt = -\alpha R$
- Parameters:** $t = 0$ s, $C_A = 1.000e-5$ M, $C_B = 1.000e-1$ M, $C_C = 0$ M, $V = 1.12$ V, $T = 33.9\%$, $A = 0.470$
- Spectrophotometer Graph:** A plot of Transmittance (T) and Absorbance (A) versus Wavelength (nm) from 300 to 800 nm. A vertical red line is drawn at approximately 650 nm.
- Kinetics Graph:** A plot of Concentration (C) versus Time (sec) from 0 to 1.0 s. It shows curves for T and A.
- Tables:**

Spec. Parameters		Spec. Data		Concentrations		Kinetic Parameters	
w	1.00 cm	V	1.12 V	C_{A0}	1.00e-5 M	ϵ_A	1.07e+5 M ⁻¹ cm ⁻¹
λ	650 nm	T	33.9 %	C_A	1.00e-5 M	α	1
P_L	50.0 %	A	0.47	C_{B0}	0.10 M	β	1.50 (M ⁻¹ s ⁻¹)
V_{max}	3.32 V			C_B	0.00e+0 M	t	0.00e+0 s
- Buttons:** "Submit Answer for User: kyle", "FOR PRACTICE", "FOR CREDIT"

What Can We Learn from Averaged Scribbles?

Stoichiometric Coefficient

α



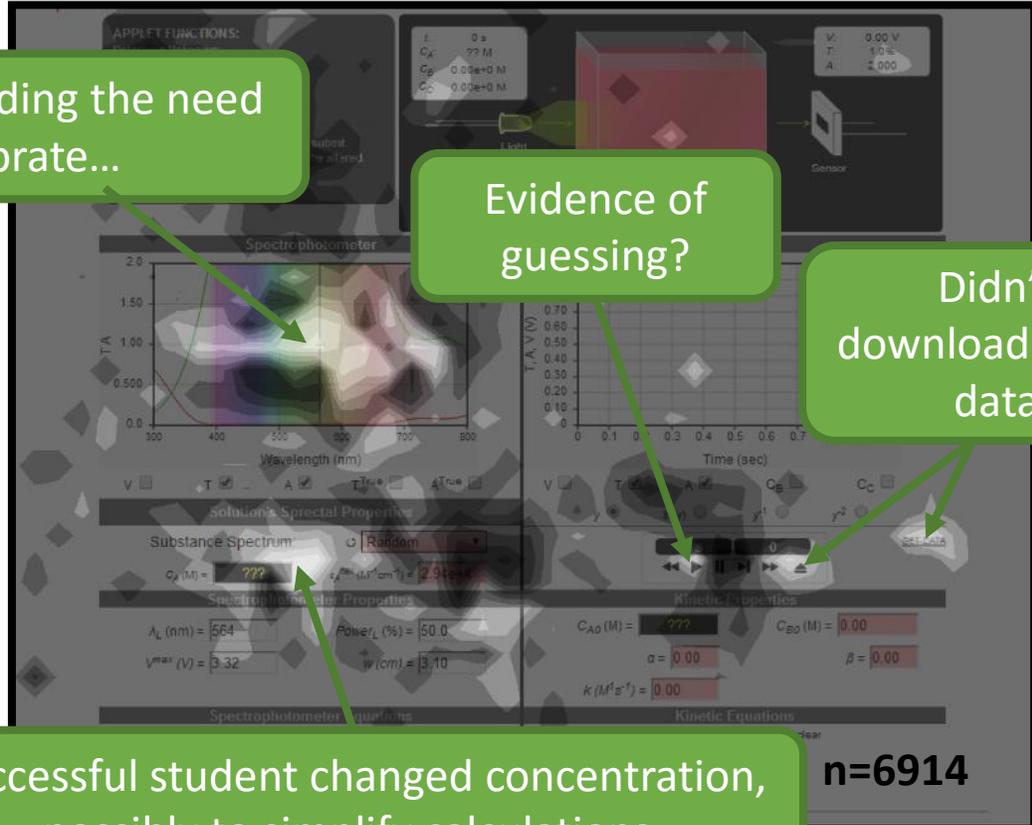
Didn't know they could find α by plotting various functions of C_a .

Misunderstanding the need to track concentration over time...

Misunderstanding the need to calibrate...

Maximum Molar Extinction Coefficient

ϵ_{max}



Evidence of guessing?

Didn't download the data

Successful student changed concentration, possibly to simplify calculations.

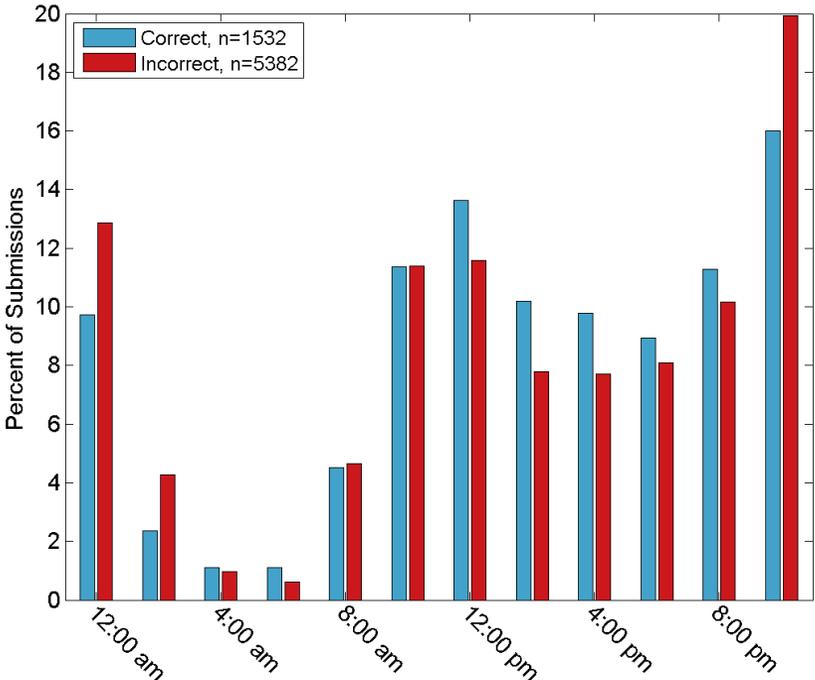
Determine Successful Behavior

Earlier submissions tend to be high percentile students

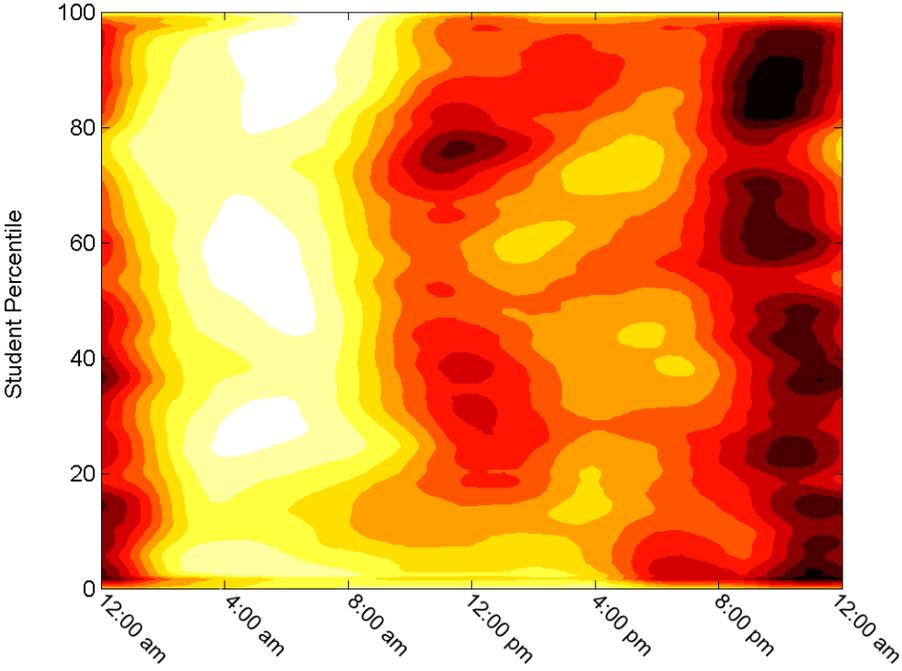
Later submissions tend to be low percentile students

Earlier submissions spend more time exploring the simulations

Students have lower success rates late at night

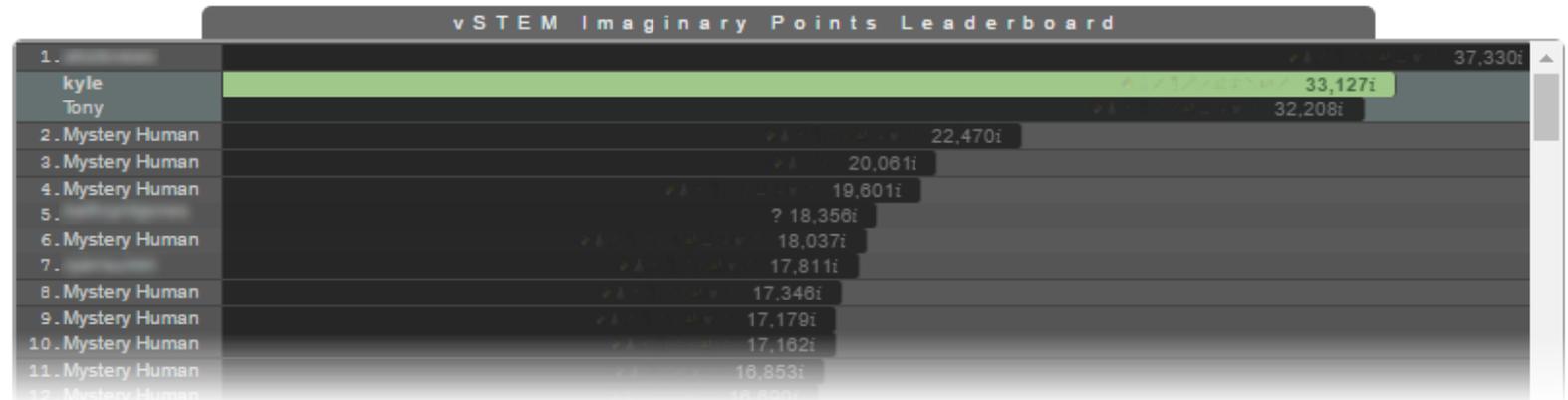


High percentile students do homework earlier in the day



“Imaginary” Experience

- Gamification has shown to improve student engagement
- Gain experience for solving simulation variables, equipment training...
 - Some students solved unassigned variables to gain more experience
- A course leaderboard shows who has the most “experience”*
 - For those who have enabled it in their privacy settings



The screenshot shows a leaderboard titled "vSTEM Imaginary Points Leaderboard". The table lists 12 entries, with the top two being real names and the rest being "Mystery Human". The scores are displayed in a bar chart format with numerical values.

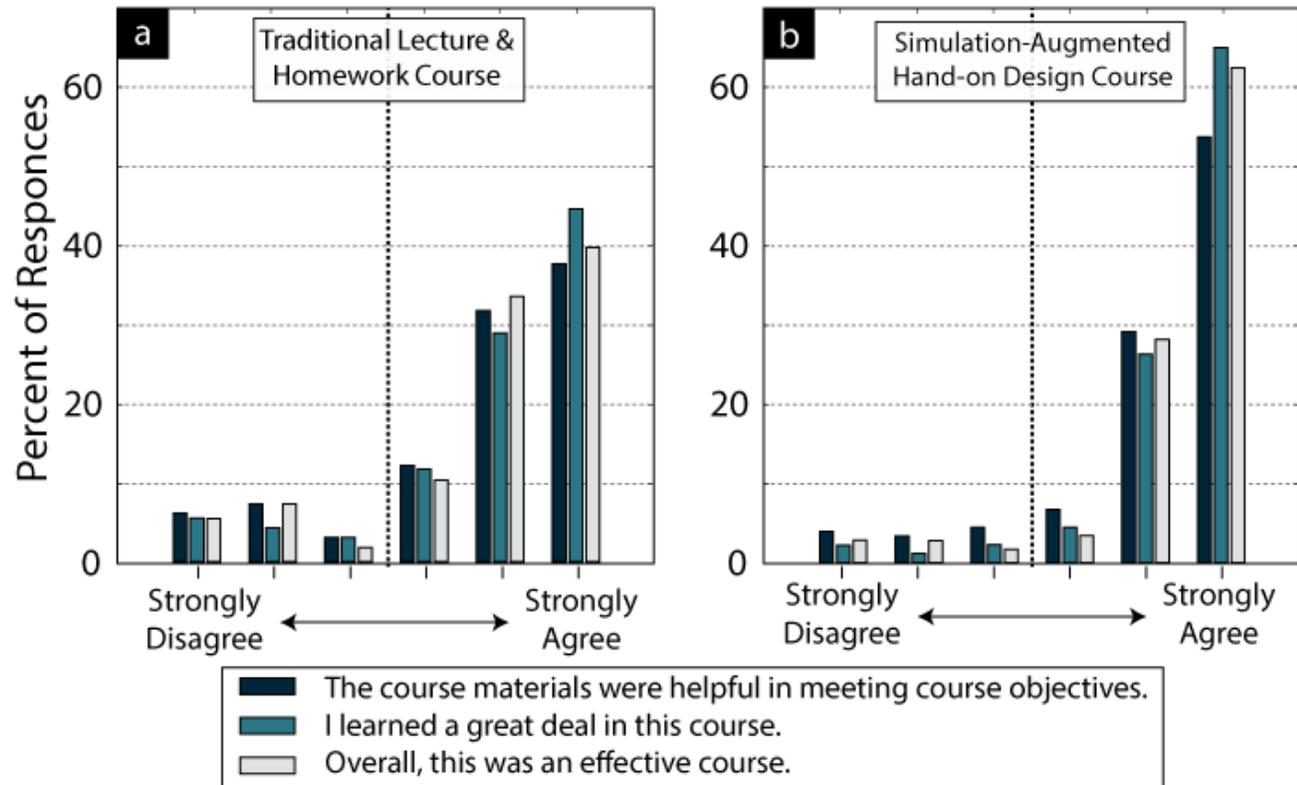
Rank	Name	Points
1.	kyle	37,330i
	Tony	33,127i
2.	Mystery Human	32,208i
		22,470i
3.	Mystery Human	20,061i
4.	Mystery Human	19,801i
5.		? 18,356i
6.	Mystery Human	18,037i
7.		17,811i
8.	Mystery Human	17,346i
9.	Mystery Human	17,179i
10.	Mystery Human	17,162i
11.	Mystery Human	16,853i
12.	Mystery Human	16,829i

LEVEL 15: MAXWELL'S DEMON

IMAGINARY EXP. POINTS: 31,974 i

Same Freshmen, Same Year

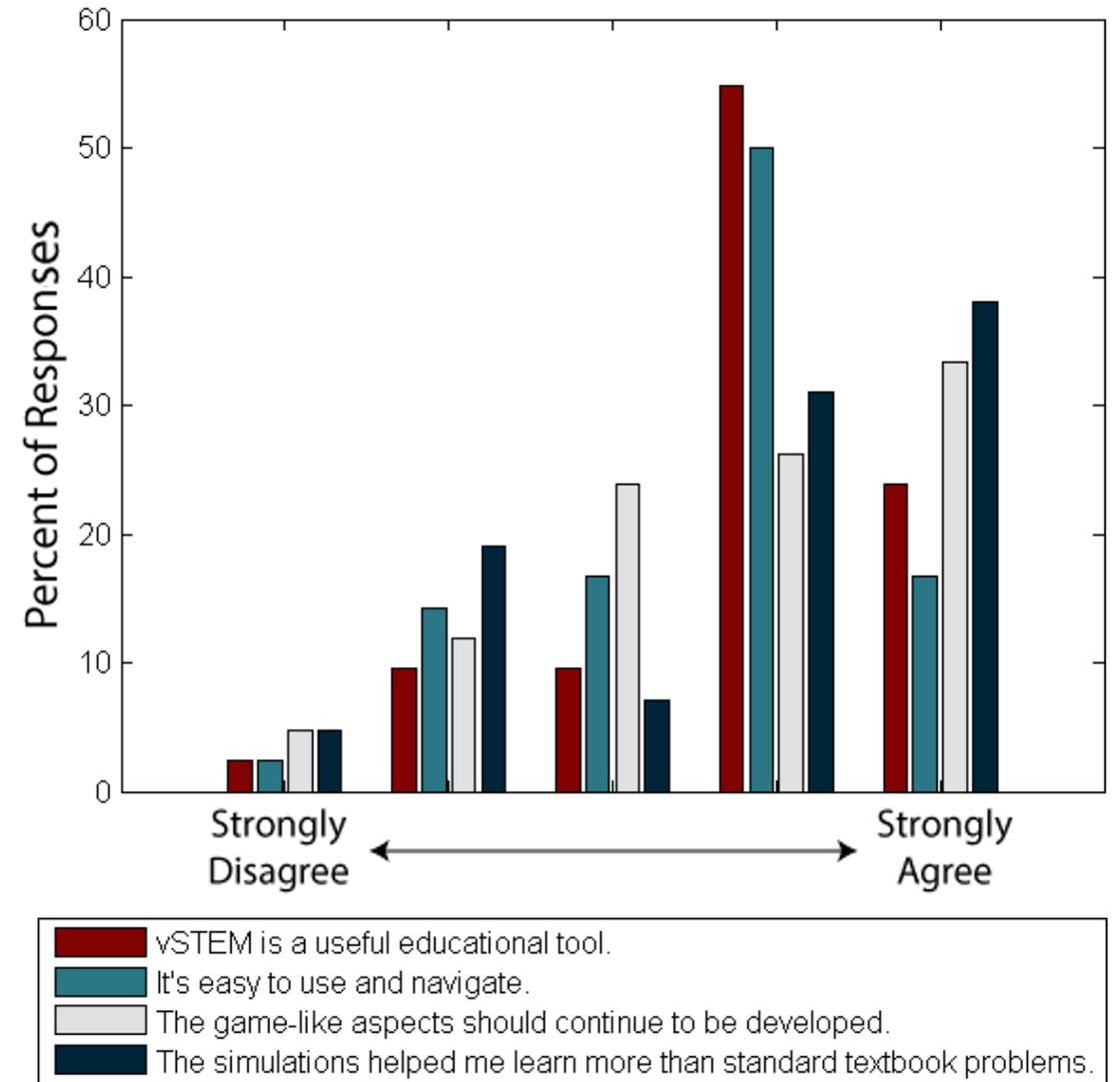
Traditional vs. New Course Model



Students prefer this course to a traditional textbook and lecture style course covering the same material

Student Response

- Students found using vSTEM to be a fairly positive experience
- Some additions for Phase II:
 - Make adjustments to improve navigation
 - Add a tutorial
 - Add awards and achievements that students can unlock
 - Add automated interventions to simulations
 - Easier to adopt the system



Implementation and Usage of an Online Environment in a Chemical Engineering Curriculum

Kyle Branch

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University of Utah

ASEE Annual Conference

New Orleans, June 27, 2016