Department of
CHEMICAL ENGINEERING
THE UNIVERSITY OF UTAH

A Collection of Virtual Experiments with Tracking of Student Interaction Data

Anthony Butterfield
Kyle Branch

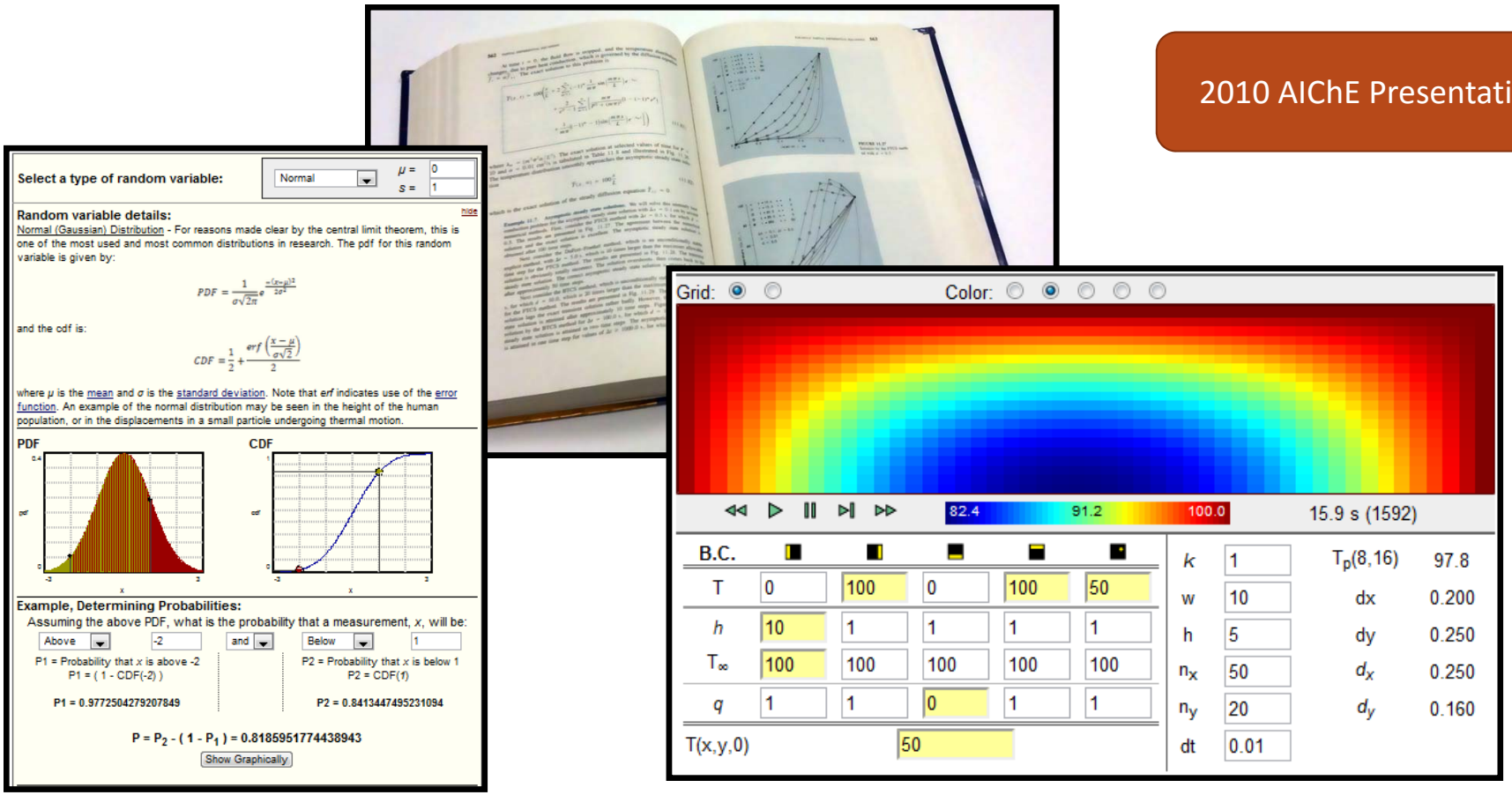
November 11, 2015
Best Practices of Online Courses and Virtual Environments

15AIChE
Annual Meeting, Salt Lake City, UT

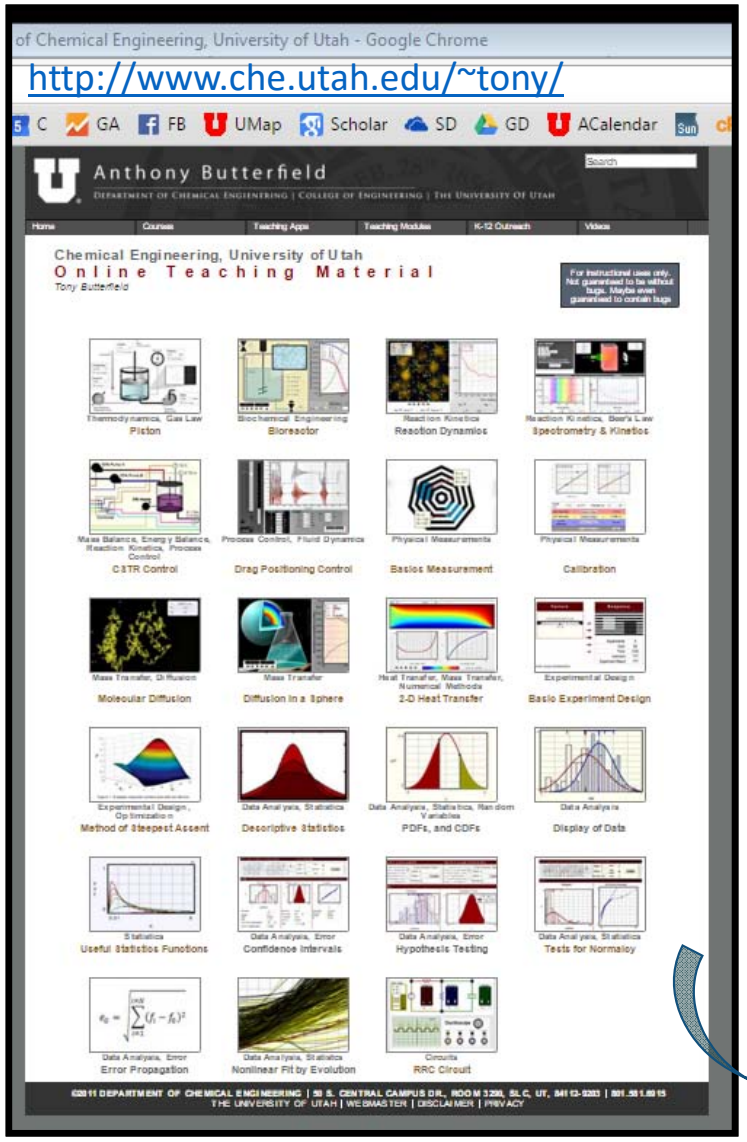
Example of Browser-Based Teaching Tools

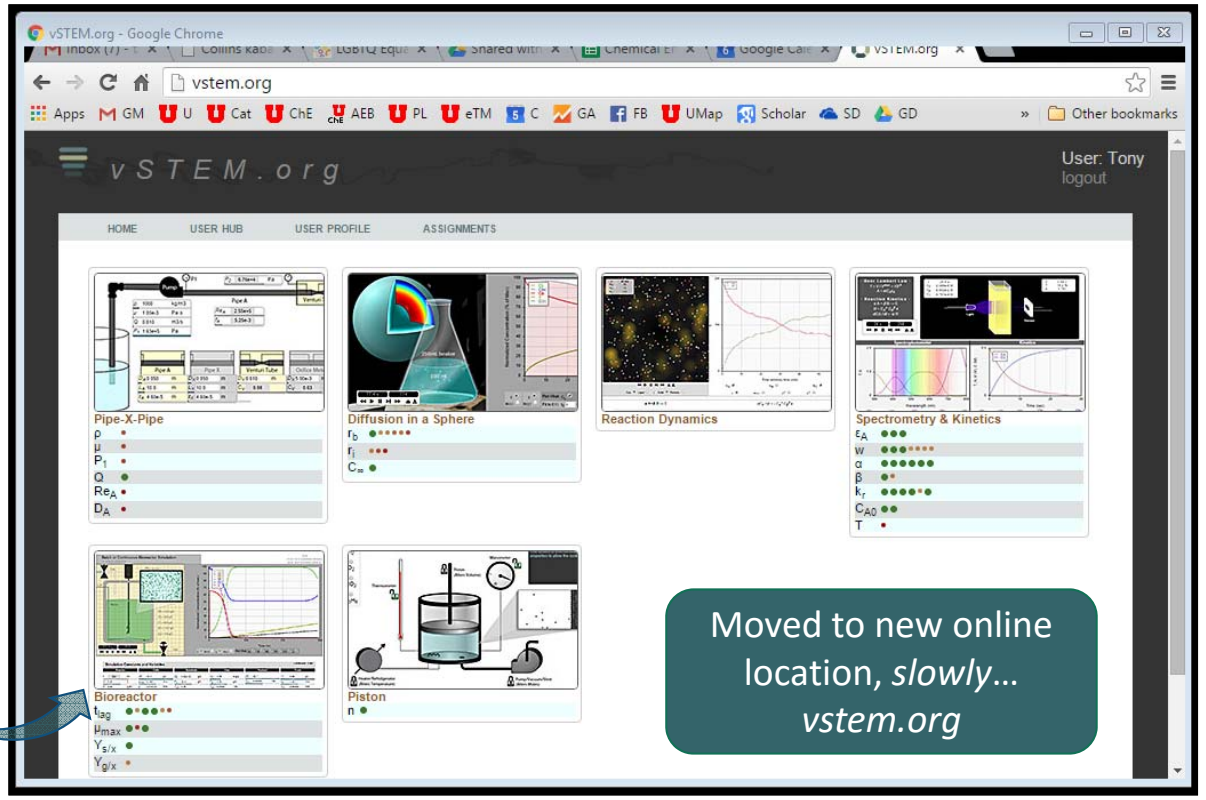
THE UNIVERSITY OF UTAH

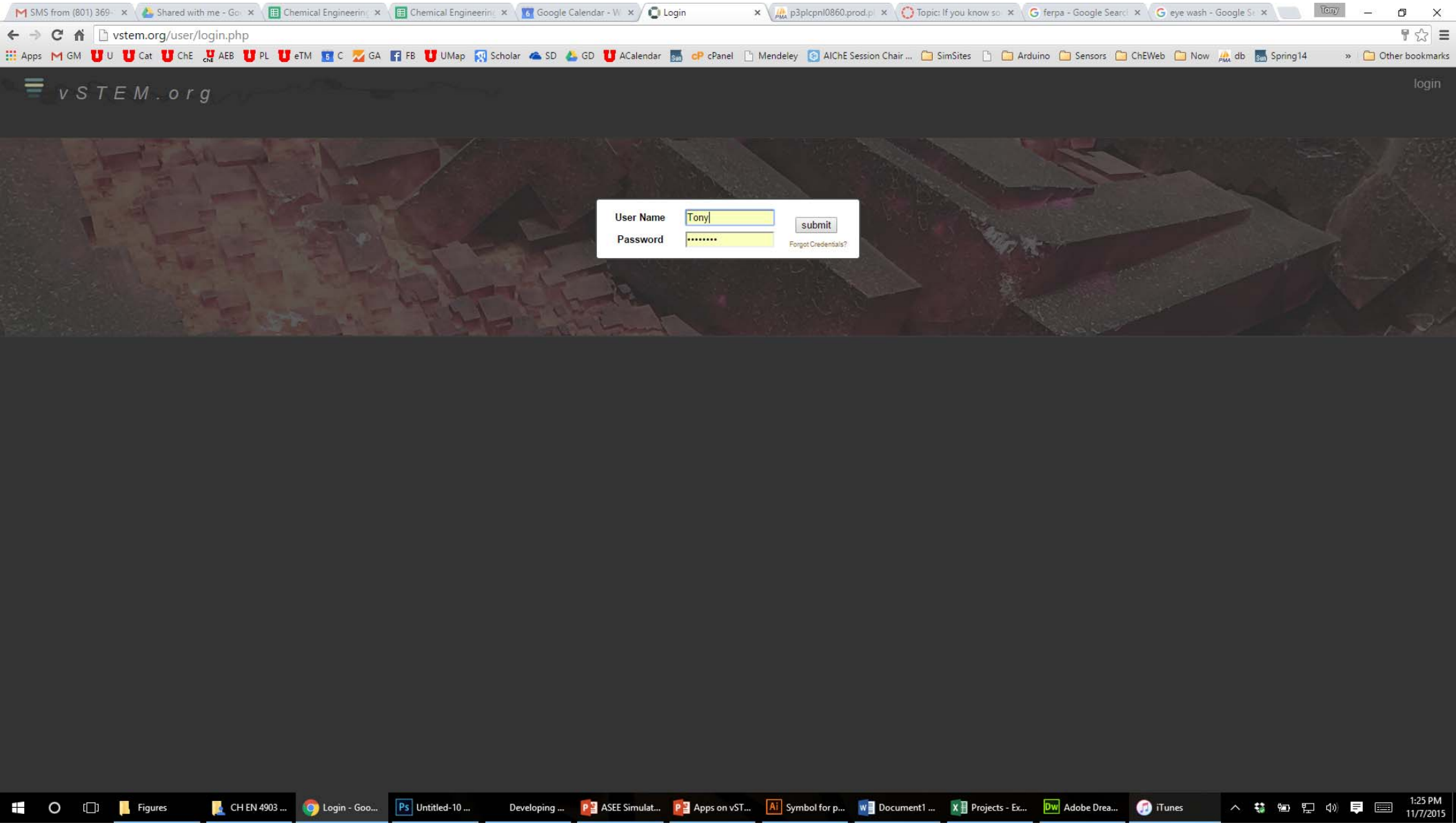
2010 AIChE Presentation



vSTEM.org
Collection of Chem E Applications & Simulations






vSTEM.org
login
User Name
Tony
Password
submit
Forgot Credentials?

A Collection of Virtual Experiments with Tracking of Student Interaction Data: *Motivation*

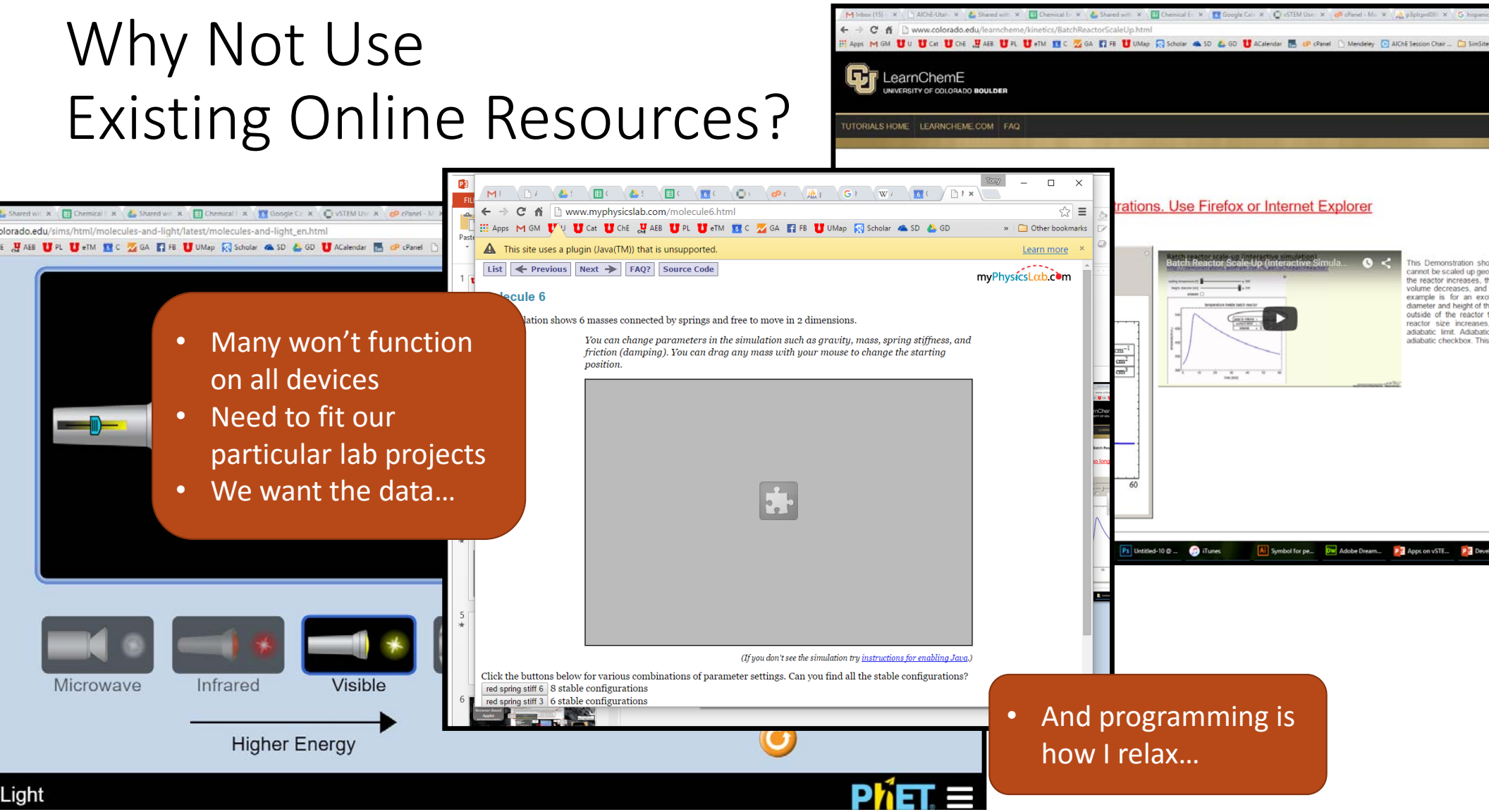
- Packing students into labs & classes.
  - Save lab resources.
  - Track students (and their retention) better.
    - Track students from year to year.
    - 50% transfer students.
  - More effectively track lab safety

https://commons.wikimedia.org/wiki/File:2006_sardines_can_open.jpg

- Better prepare individuals for team hands-on design projects.
  - General need for open-ended lab-like chemical engineering simulations.

- What can we learn about student learning from their interactions with simulated experiments?

Why Not Use Existing Online Resources?

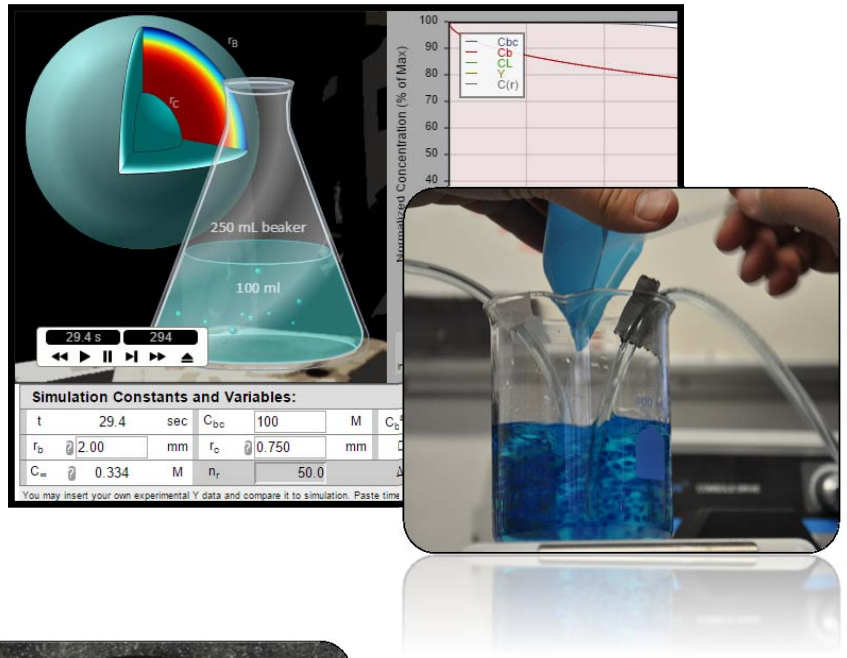


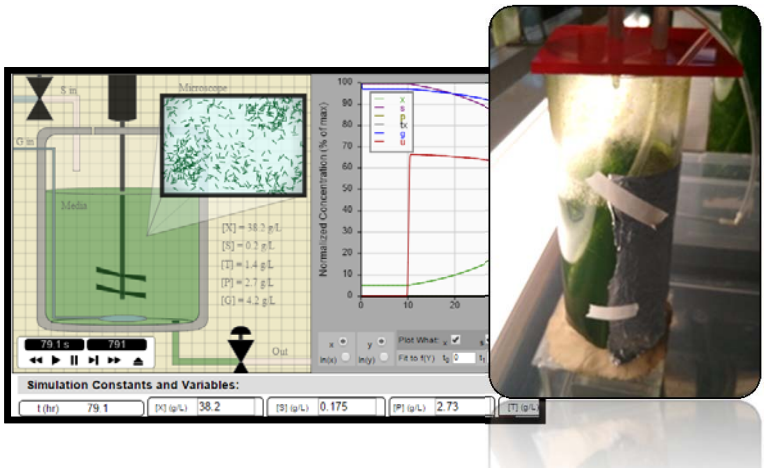
- Many won't function on all devices
- Need to fit our particular lab projects
- We want the data…

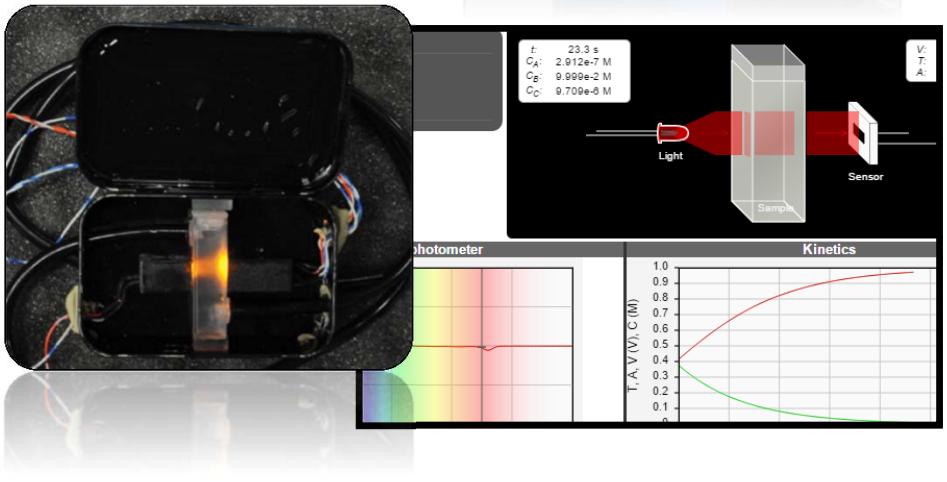
- And programming is how I relax…

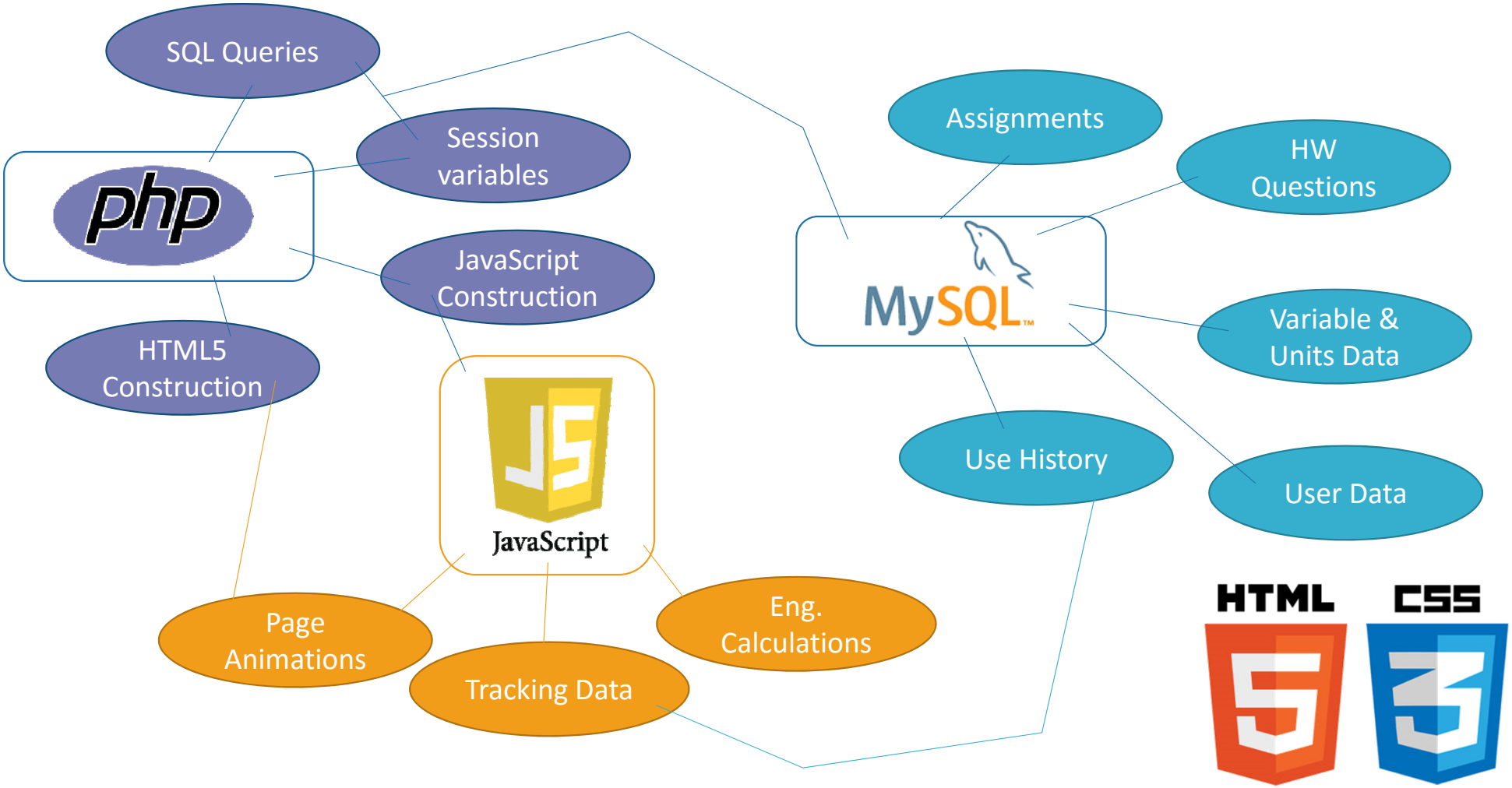
Our Simulations

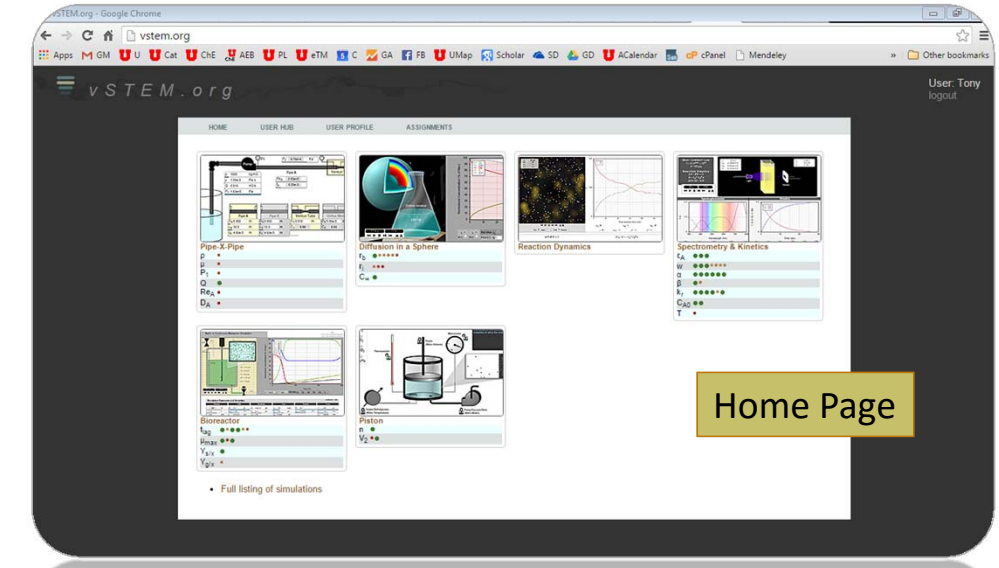
- Simulate lab experimentation
- Coupled with hands-on projects
  - Used in our freshman and senior laboratory courses
  - Soon to be implemented in our mid-curriculum courses

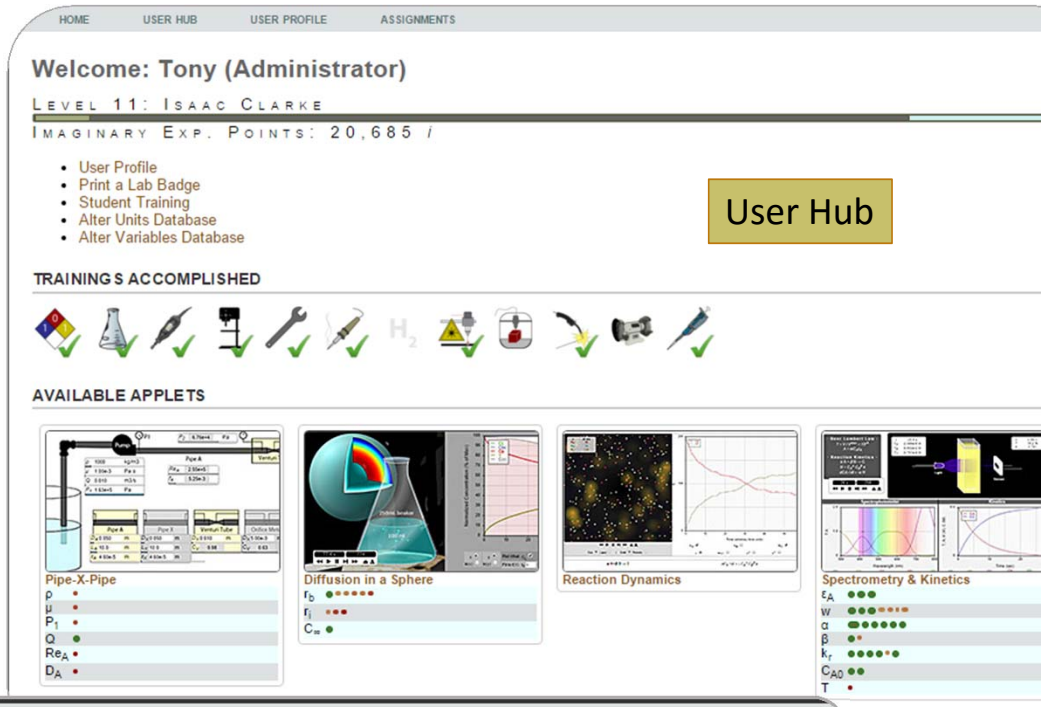


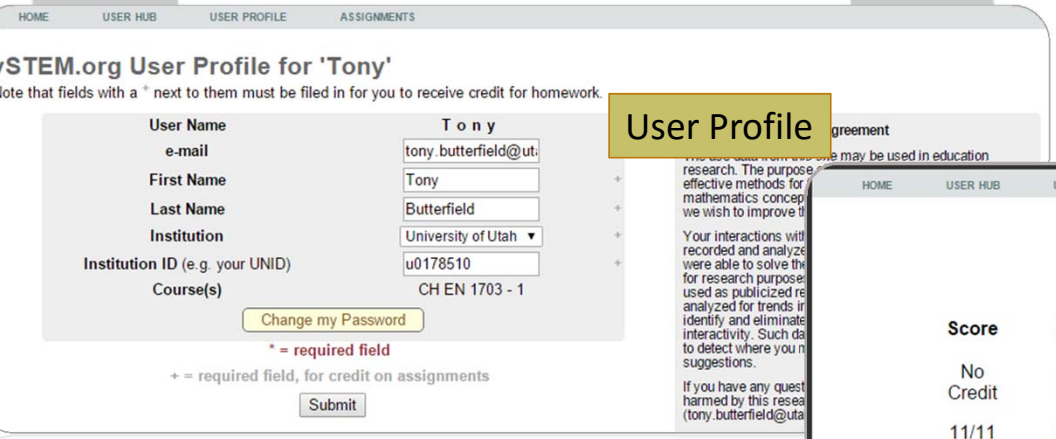


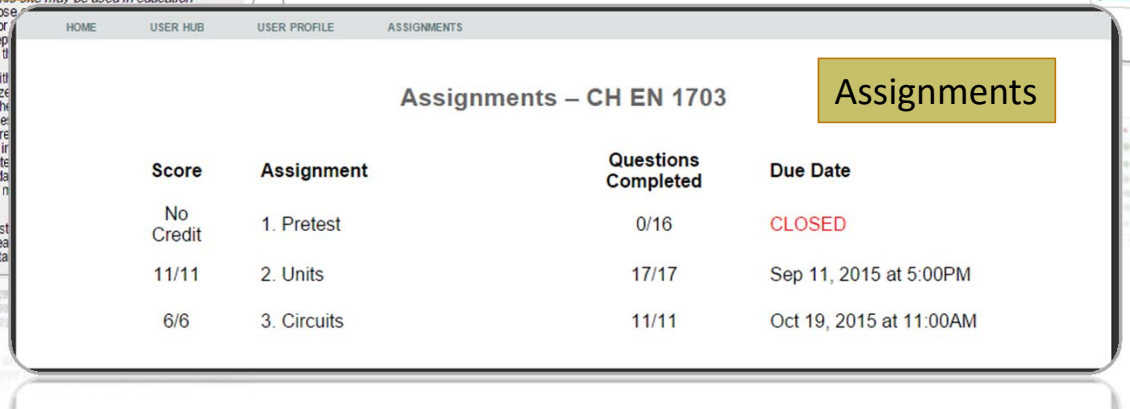



SQL Queries
Session variables
php
JavaScript Construction
HTML5 Construction
JavaScript
Page Animations
Tracking Data
Eng. Calculations
Assignments
HW Questions
MySQL
Variable & Units Data
Use History
User Data
HTML
CSS


vSTEM.org
User: Tony
logout
HOME
USER HUB
USER PROFILE
ASSIGNMENTS
Pipe-X-Pipe
Diffusion in a Sphere
Reaction Dynamics
Spectrometry & Kinetics
Bioreactor
Piston
Full listing of simulations
Home Page

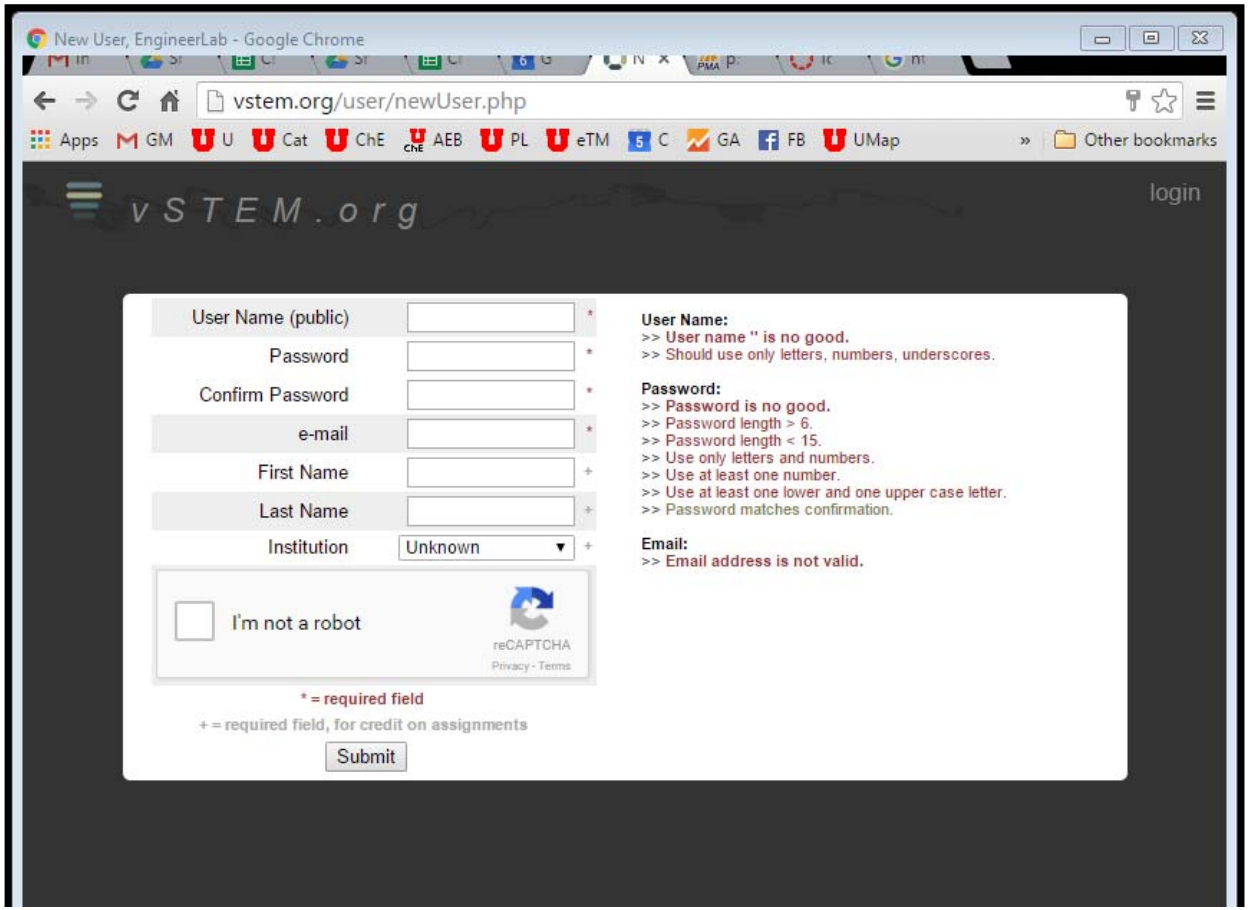

HOME
USER HUB
USER PROFILE
ASSIGNMENTS
Welcome: Tony (Administrator)
LEVEL 11: ISAAC CLARKE
IMAGINARY EXP. POINTS: 20,685
User Profile
Print a Lab Badge
Student Training
Alter Units Database
Alter Variables Database
User Hub
TRAINING S ACCOMPLISHED
AVAILABLE APPLETS
Pipe-X-Pipe
Diffusion in a Sphere
Reaction Dynamics
Spectrometry & Kinetics


HOME
USER HUB
USER PROFILE
ASSIGNMENTS
vSTEM.org User Profile for 'Tony'
lote that fields with a + next to them must be filed in for you to receive credit for homework.
User Name
Tony
e-mail
tony.butterfield@ut
First Name
Tony
Last Name
Butterfield
Institution
University of Utah
Institution ID (e.g. your UNID)
u0178510
Course(s)
CH EN 1703 - 1
Change my Password
* = required field
+ = required field, for credit on assignments
Submit
User Profile


HOME
USER HUB
USER PROFILE
ASSIGNMENTS
Assignments – CH EN 1703
Assignments
Score
Assignment
Questions Completed
Due Date
No Credit
1. Pretest
0/16
CLOSED
11/11
2. Units
17/17
Sep 11, 2015 at 5:00PM
6/6
3. Circuits
11/11
Oct 19, 2015 at 11:00AM

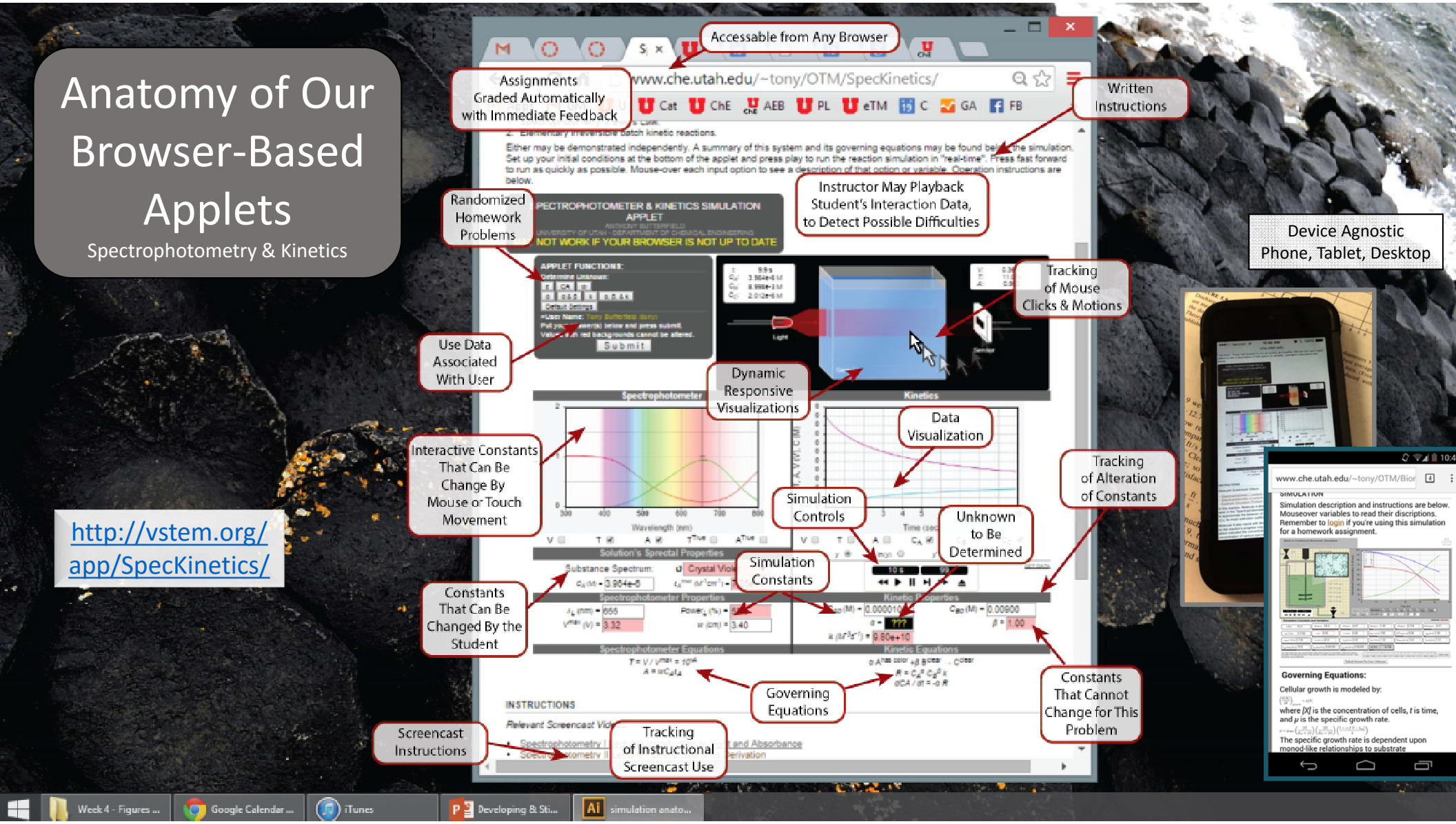
User Data Management & FERPA Fears

- How to link score to names *and* ensure privacy is maintained?
  - Data PW protected.
  - PW encrypted.
- Lost passwords…
- Compromising usernames…
- Demographic data.



Anatomy of Our Browser-Based Applets

Spectrophotometry & Kinetics



Immediate Feedback

HOME USER HUB USER PROFILE ASSIGNMENTS

Ideal Gas in a Piston

This app simulates an ideal gas within a piston. Place your mouse over the system variables below to see a detailed descriptions of each.

To make sure the system is not over or under defined, two of the locks on the system must be in place. For example, the system can be adiabatic and isomolar (not heat flux, and constant moles), but it could not also be isothermal (constant temperature) and change from one state to another. Click on locks to lock or unlock properties, and click and drag to move various properties or the piston. Click on a variable symbol to solve for an unknown value of that variable.

RESULTS		
Your Volume 2	=	7
Correct Volume 2	=	0.792
Percent Error	=	783.84%
Total Error	=	**783.8%**
Max Error	=	**5.0%**

Not Near Enough. Try Again?

Results for Tony successfully recorded in the database.
Check the Database · Restart the Simulation

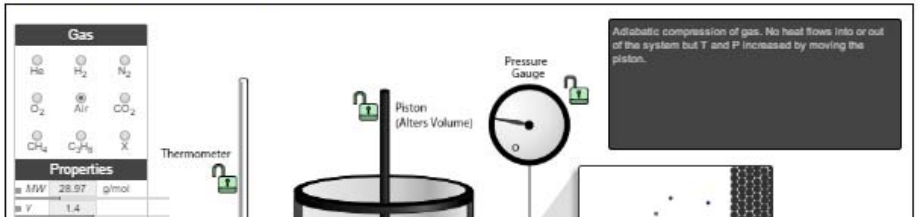
CONSTANTS																	
MW	=	2.897e+1	g/mol	γ	=	1.400e+0	-	n	=	3.620e-1	-	S_0	=	1.991e+2	J/mol·K
V_{max}	=	2.000e+0	L	P_1	=	1.080e+1	atm	V_1	=	1.078e+0	L	T_1	=	3.270e+2	K
n_1	=	4.259e-1	mol	m_1	=	1.234e+1	g	V_{m1}	=	2.531e-3	m^3/mol	ρ_1	=	1.144e+1	kg/m^3
$C_{P,1}$	=	2.920e+1	J/mol·K	$C_{V,1}$	=	2.088e+1	J/mol·K	U_1	=	6.829e+3	J/mol	H_1	=	9.548e+3	J/mol
S_1	=	1.482e+2	J/mol·K	v_1	=	5.306e+2	m/s	W	=	3.799e+2	J	Q	=	0.000e+0	J
P_2	=	1.632e+1	atm	V_2	=	7.920e-1	L	T_2	=	3.699e+2	K	n_2	=	4.259e-1	mol
m_2	=	1.234e+1	g	V_{m2}	=	1.860e-3	m^3/mol	ρ_2	=	1.558e+1	kg/m^3	$C_{P,2}$	=	2.940e+1	J/mol·K
$C_{V,2}$	=	2.108e+1	J/mol·K	U_2	=	7.798e+3	J/mol	H_2	=	1.087e+4	J/mol	S_2	=	5.270e+1	J/mol·K
v_2	=	5.644e+2	m/s												

Piston Containing an Ideal Gas

13.7
(133, 271)
(-413, -483)

University of Utah - Department of Chemical Engineering
by Anthony Butterfield

May Not Work if Your Browser Is not Up to Date



Spectrophotometry & Kinetics

SIMULATION

This simulation is meant to demonstrate aspects of:

1. Spectrophotometry & Beers Law.
2. Elementary irreversible batch kinetic reactions.

her may be demonstrated independently. A summary of this system and its governing equations may be found below the simulation. Set up r initial conditions at the bottom of the applet and press play to run the reaction simulation in "real-time". Press fast forward to run as ckly as possible. Mouse-over each input option to see a description of that option or variable. Operation instructions are below.

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%**

Within Error. Good Job!

Results for Tony successfully recorded in the database.
Check the Database · Restart the Simulation

CONSTANTS																	
w	=	2.587e+0	cm	λ	=	5.792e+2	nm	P_L	=	2.080e+1	%	V_{max}	=	3.076e+0	V
V	=	5.460e-3	V	T	=	1.775e-1	%	A	=	2.754e+0	-	C_{A0}	=	4.767e-5	M
C_A	=	4.767e-5	M	C_{B0}	=	7.406e-4	M	C_B	=	7.406e-4	M	C_C	=	0.000e+0	M
ε_A	=	4.741e+4	$M^{-1}cm^{-1}$	α	=	2.000e+0	-	β	=	1.000e+0	-	k_r	=	1.190e+0	-
t	=	0.000e+0	s												

action Within a Spectrophotometer

50300.6
(28, 419)
(-186, -368)

ersity of Utah - Department of Chemical Engineering
nthony Butterfield

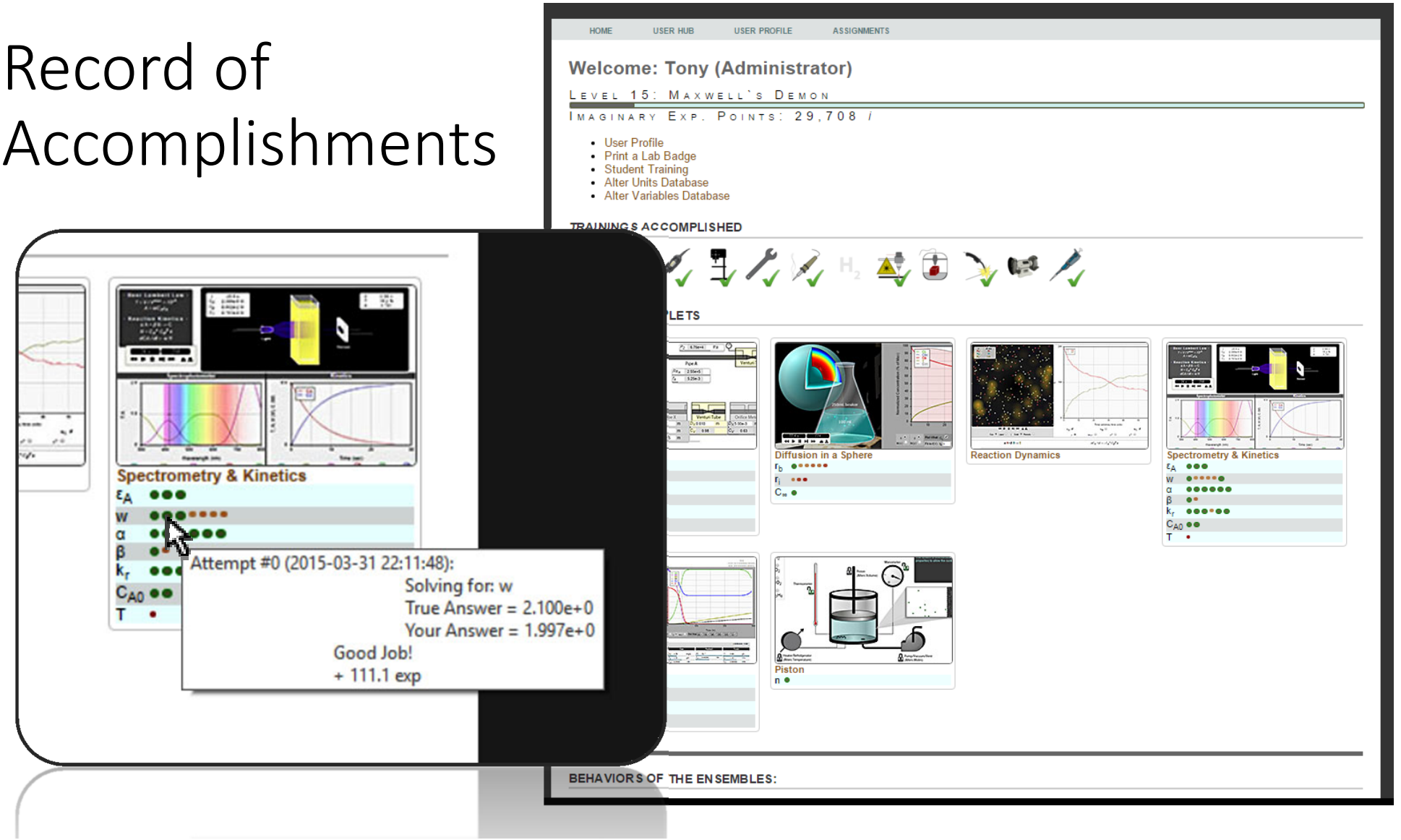
y Not Work if Your Browser Is not Up to Date

· Beer Lambert Law ·

t: 0 s

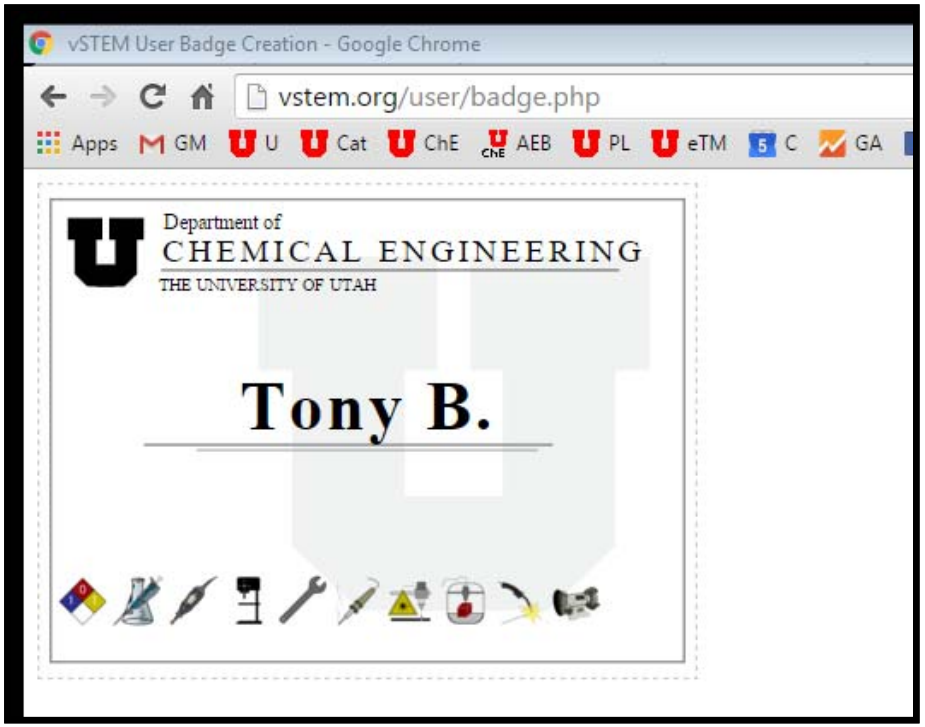
V: 0.31 V

Record of Accomplishments



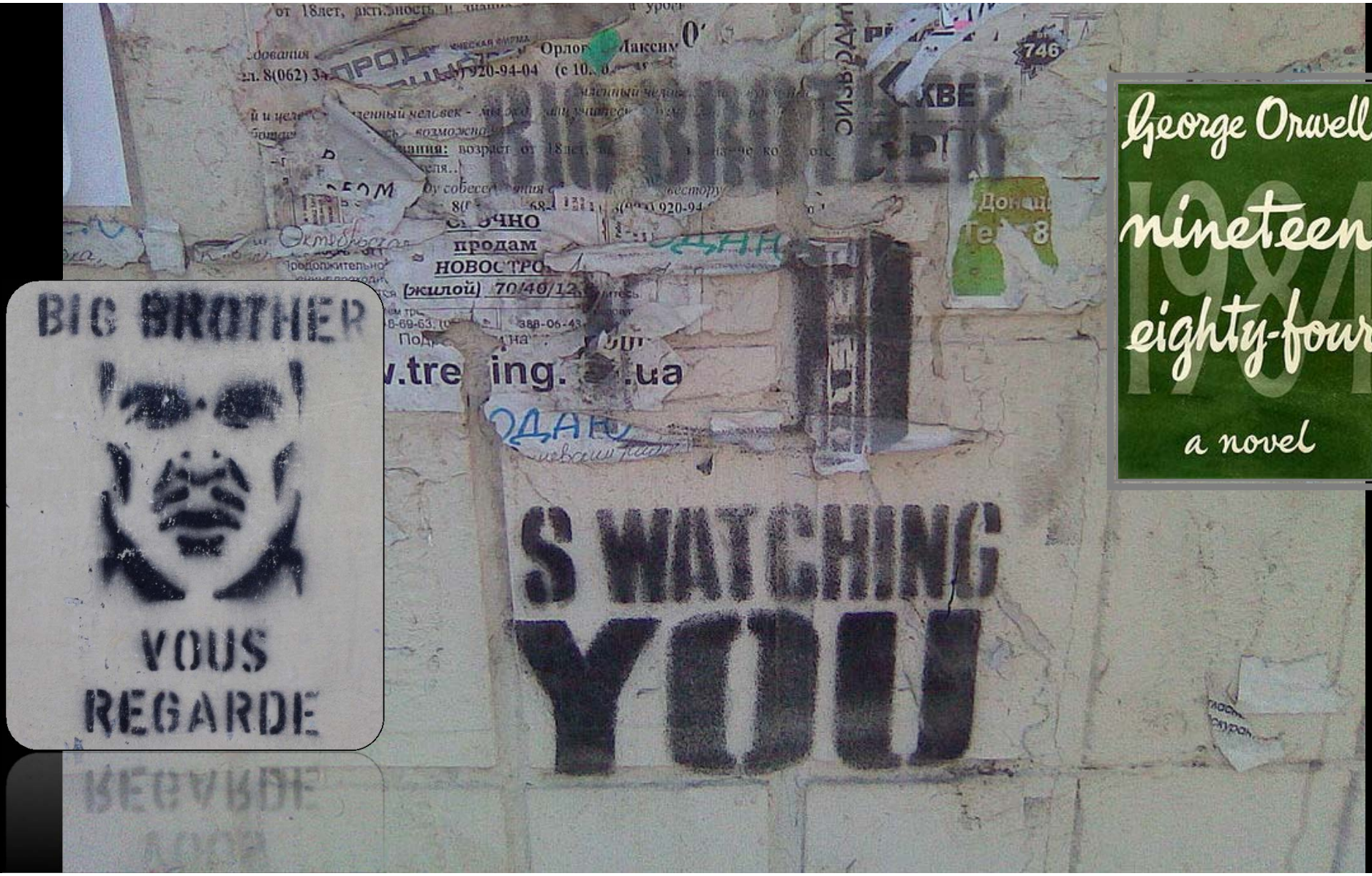
Tracking of Lab Training

- Needed to use a new piece of lab equipment.
- Quick indication of authorization.
- To obtain badge icon:
  - Study SOP.
  - Pass online safety test.
  - Properly operate equipment under instructor supervision.

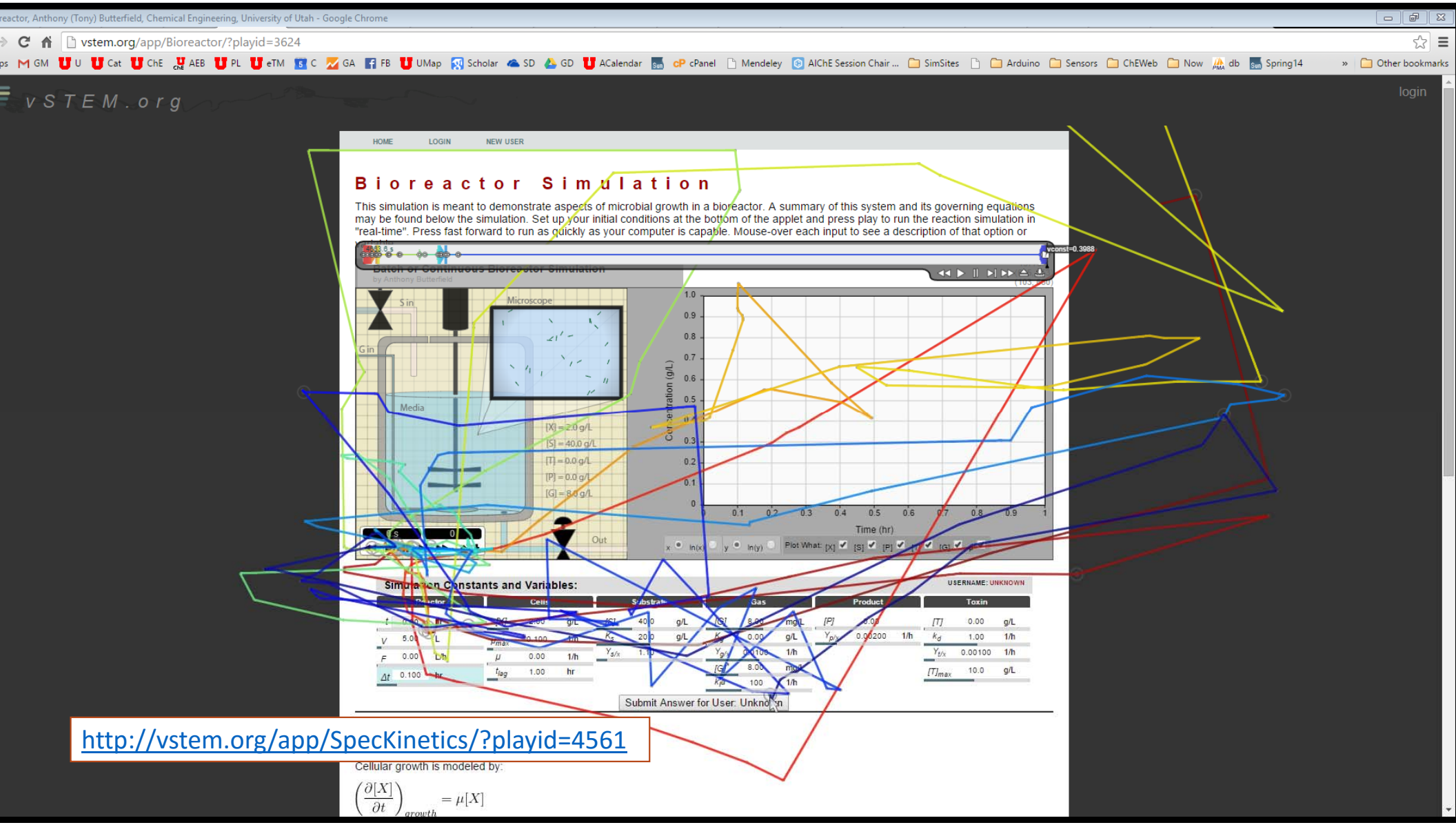


Data on the Periphery of the Right & Wrong Answer

- Time of use
- User:
  - IP address
    - At university or at home?
    - Unknown user?
  - Operating system
  - Browser
- Total time of use
- Time while interacting
- Every mouse move, and click.
- Every touchpad touch & click.
- Every form change and keystroke.
- Number of
  - Mouse clicks
  - Mouse moves
  - Touchscreen touches
  - Keystrokes
  - Form changes
  - App controls



https://en.wikipedia.org/wiki/Nineteen_Eighty-Four#/media/File:BigBrother.jpg

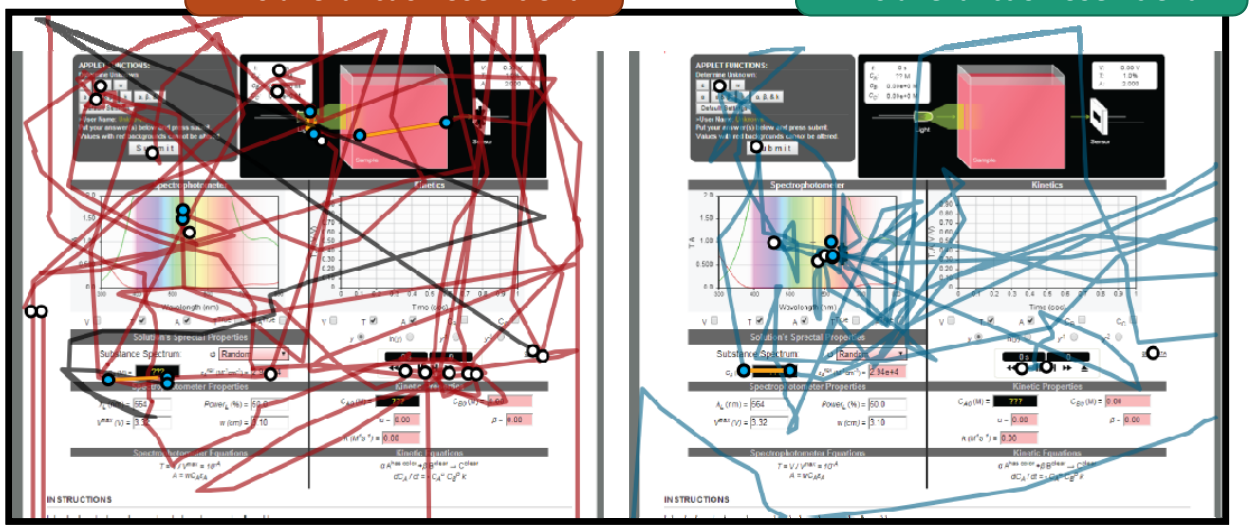

reactor, Anthony (Tony) Butterfield, Chemical Engineering, University of Utah - Google Chrome
vstem.org/app/Bioreactor/?playid=3624
vSTEM.org
login
HOME
LOGIN
NEW USER
Bioreactor Simulation
This simulation is meant to demonstrate aspects of microbial growth in a bioreactor. A summary of this system and its governing equations may be found below the simulation. Set up your initial conditions at the bottom of the applet and press play to run the reaction simulation in "real-time". Press fast forward to run as quickly as your computer is capable. Mouse-over each input to see a description of that option or
Batch or Continuous Bioreactor Simulation
by Anthony Butterfield
Microscope
Media
Out
Concentration (g/L)
Time (hr)
Simulation Constants and Variables:
USERNAME: UNKNOWN
Submit Answer for User: Unknown
http://vstem.org/app/SpecKinetics/?playid=4561
Cellular growth is modeled by:

What Can We Learn from Each Scribble?

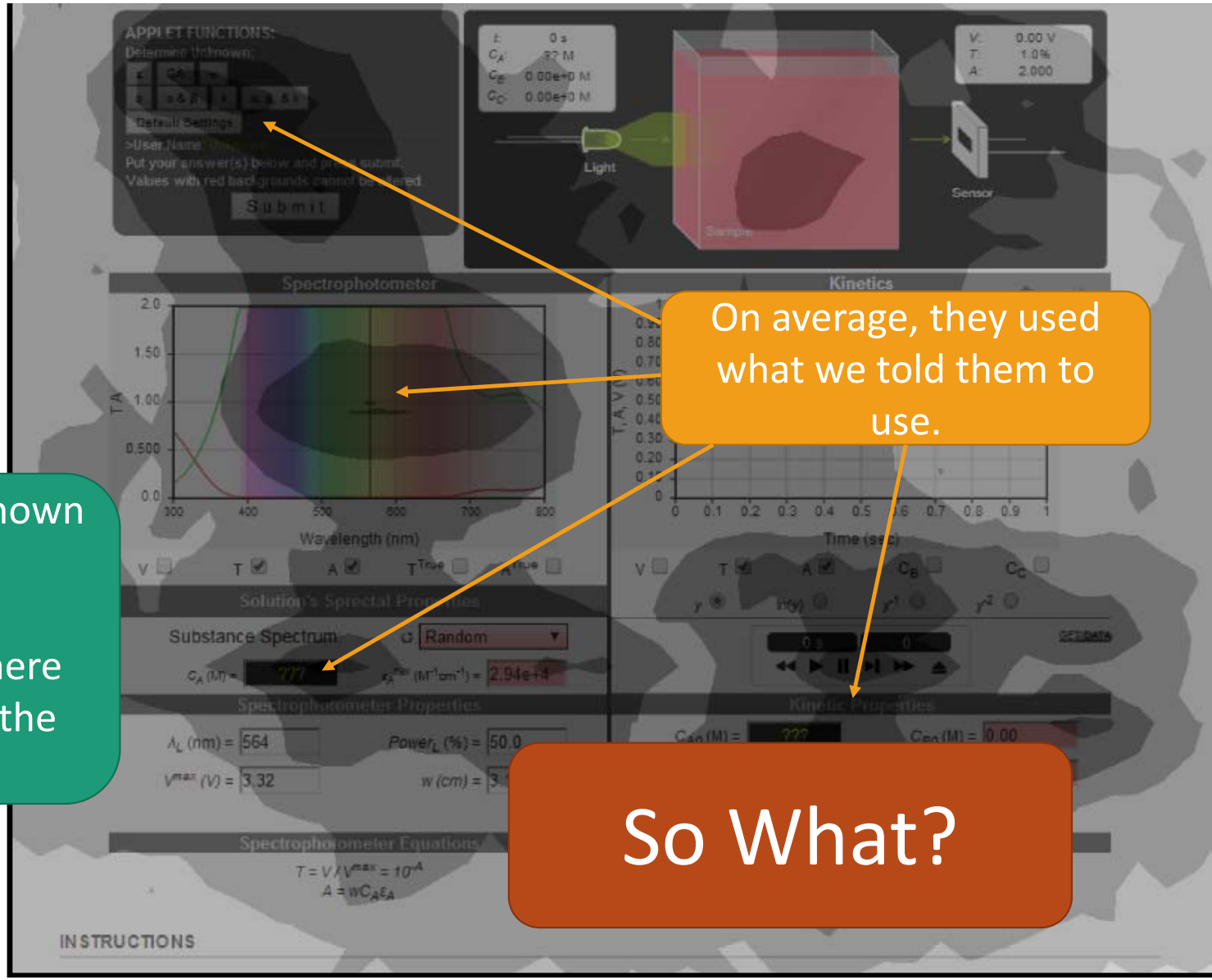
- Most motions tell us very little…
- Some, though, are very telling
  - Attempts to interact with app in a way that is not part of the coding.
    - Improve intuitiveness of interface.
  - Necessary steps are skipped?
    - Insights into student misunderstandings.

Failed attempt to determine molar extinction Coefficient

Successful attempt to determine molar extinction Coefficient



Average Mouse Locations



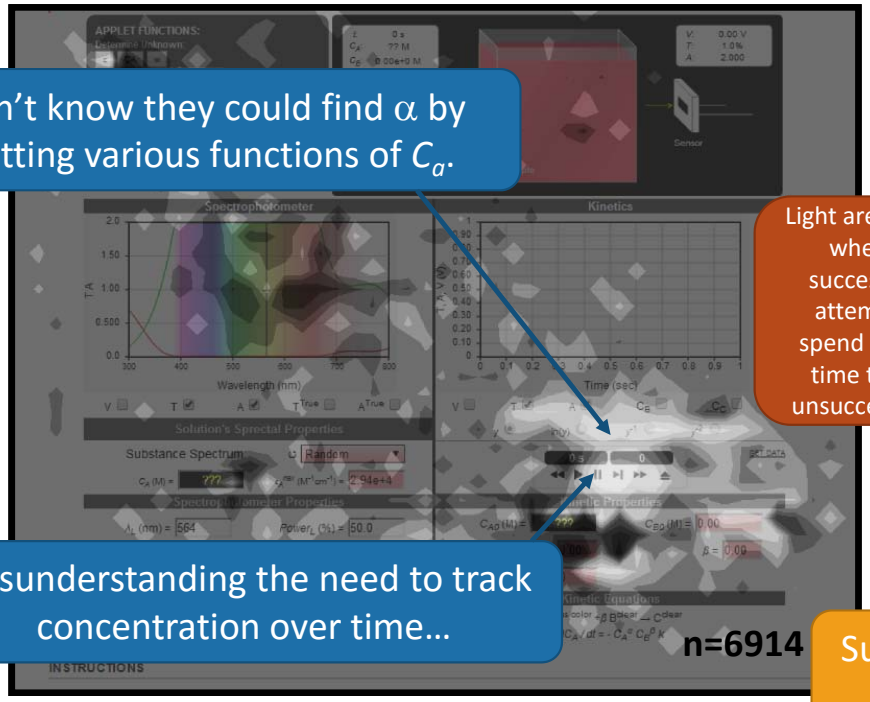
Calculating an unknown concentration.

Dark areas are where the mouse spent the most time.

What Can We Learn from Averaged Scribbles?

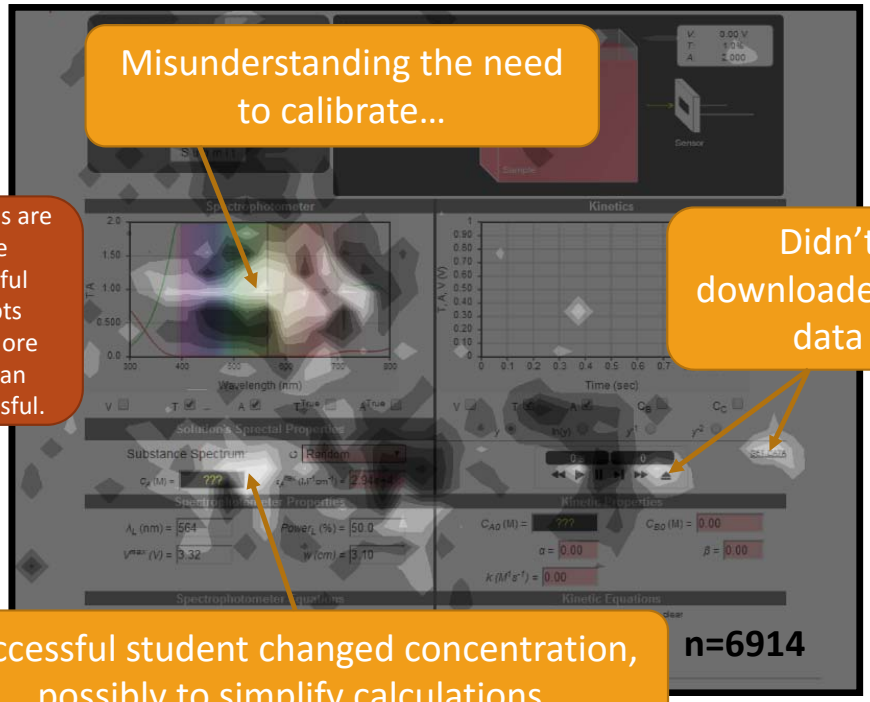
Stoichiometric Coefficient

α



Maximum Molar Extinction Coefficient

ε_{max}

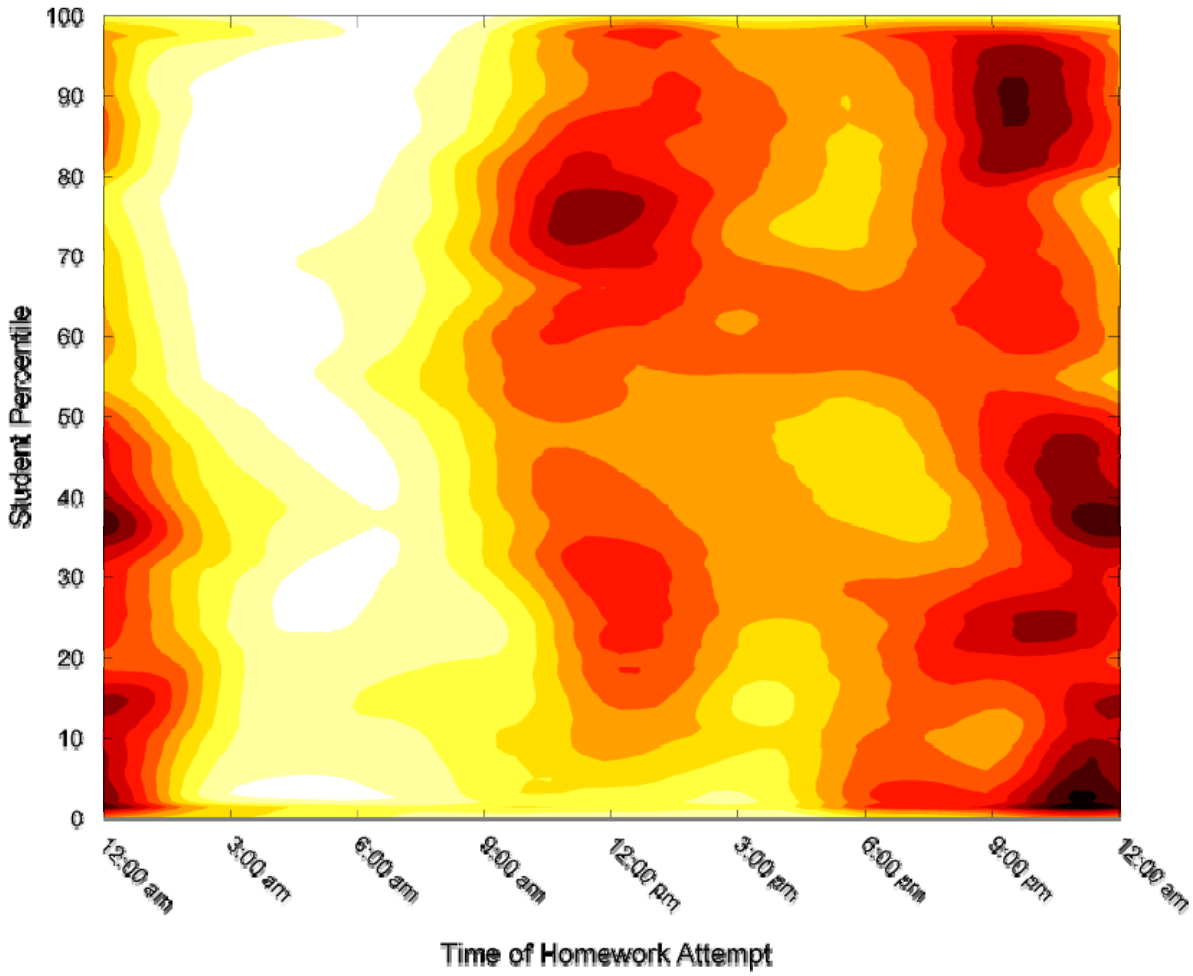


Light areas are where successful attempts spend more time than unsuccessful.

Promote Healthier Work Habits

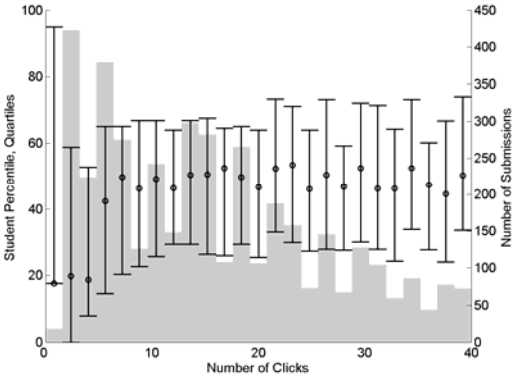
- **When Do Successful Students Do Homework?**

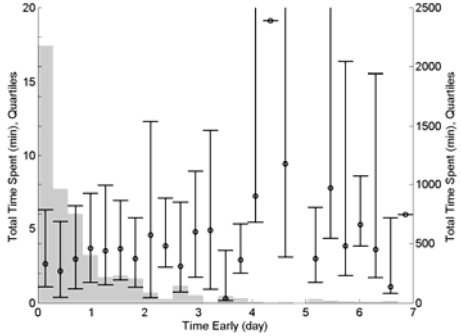
  Data shows higher performing students do homework about an hour earlier than their peers.

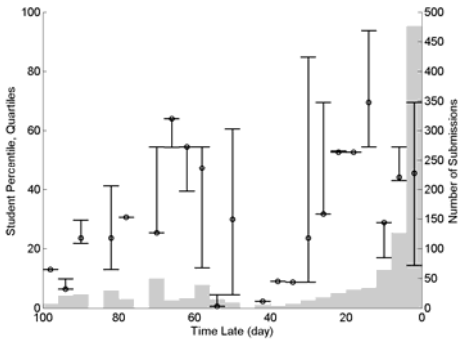


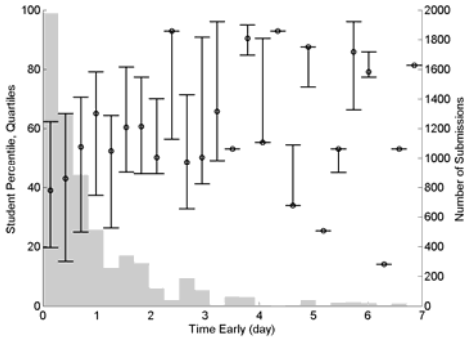
Other Early Findings

- Higher performing students.
  - Do their homework early.
  - Take more time with the simulations.
  - More time between clicks.
    - More deliberation?
- Lower performing students.
  - Turn their homework in late…
  - Do their homework last minute.
  - Use fewer clicks and less time.

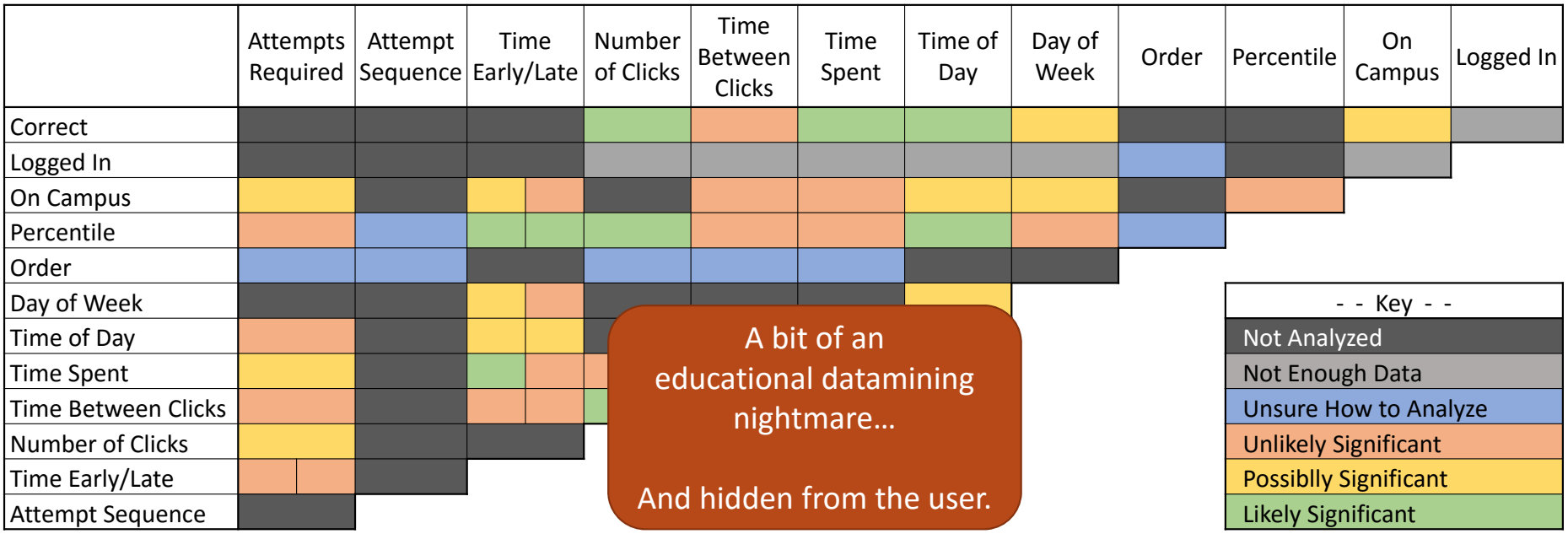






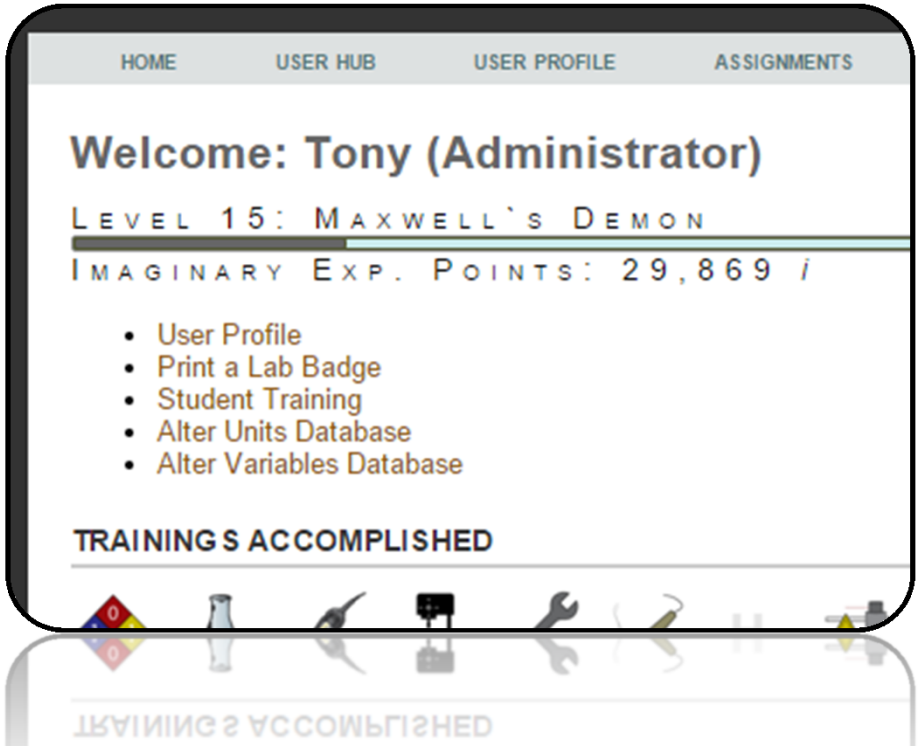


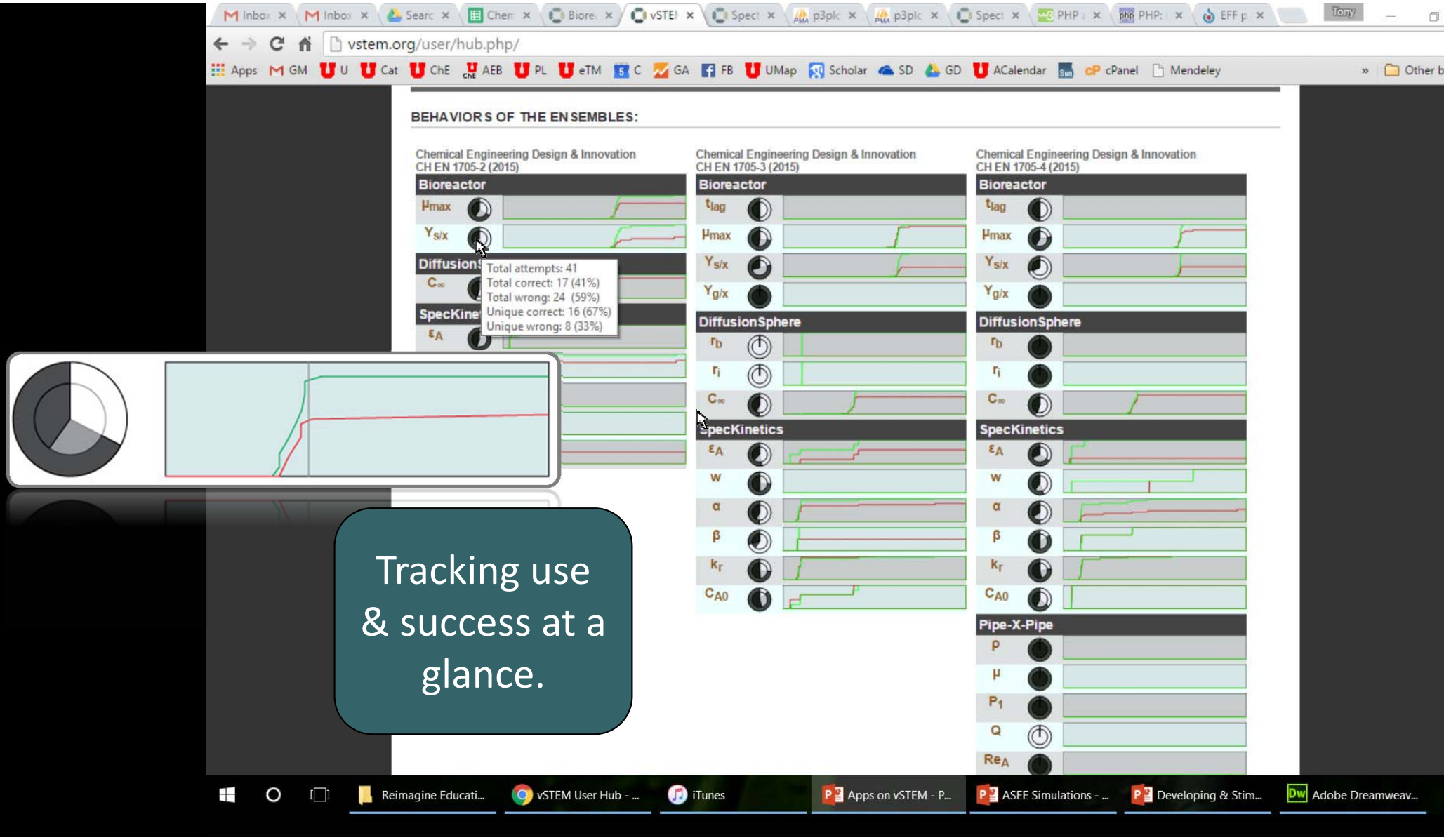
Preliminary Analysis: Pairwise Relationships



Instructor Interface…

- Moving educational data mining analysis online.
  - Average mouse locations
  - Tests for correlations
    - On any pair of measurements
  - Automated detection of cheating
  - Others.




vstem.org/user/hub.php/
BEHAVIORS OF THE ENSEMBLES:
Chemical Engineering Design & Innovation
CH EN 1705-2 (2015)
Bioreactor
μmax
Ys/x
Total attempts: 41
Total correct: 17 (41%)
Total wrong: 24 (59%)
Unique correct: 16 (67%)
Unique wrong: 8 (33%)
Chemical Engineering Design & Innovation
CH EN 1705-3 (2015)
Bioreactor
tlag
μmax
Ys/x
Yg/x
DiffusionSphere
rb
ri
C∞
SpecKinetics
εA
w
α
β
kr
CA0
Chemical Engineering Design & Innovation
CH EN 1705-4 (2015)
Bioreactor
tlag
μmax
Ys/x
Yg/x
DiffusionSphere
rb
ri
C∞
SpecKinetics
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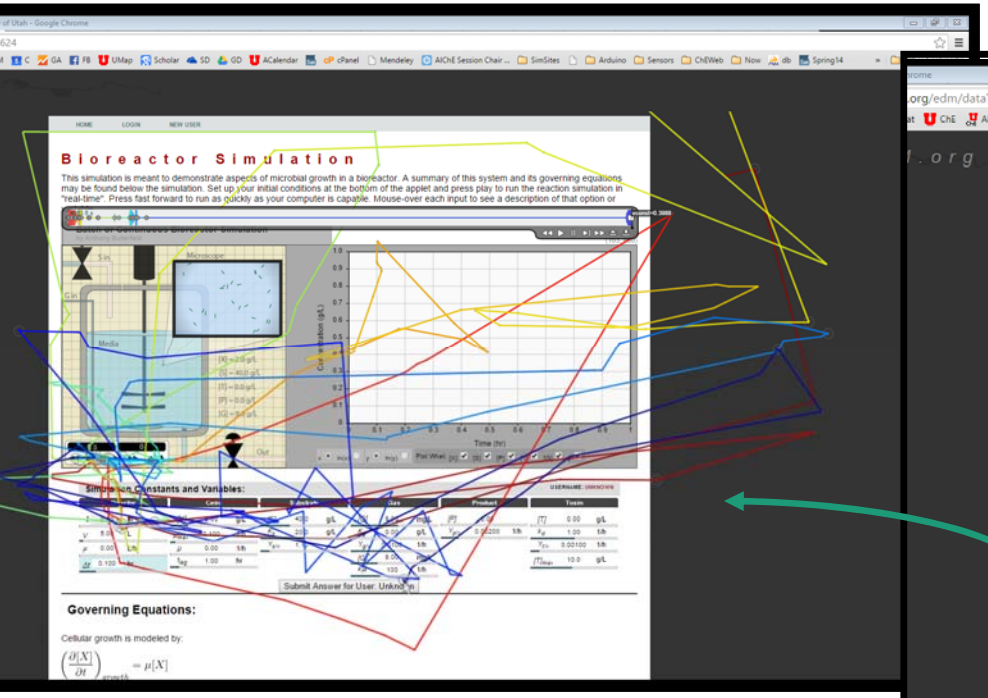
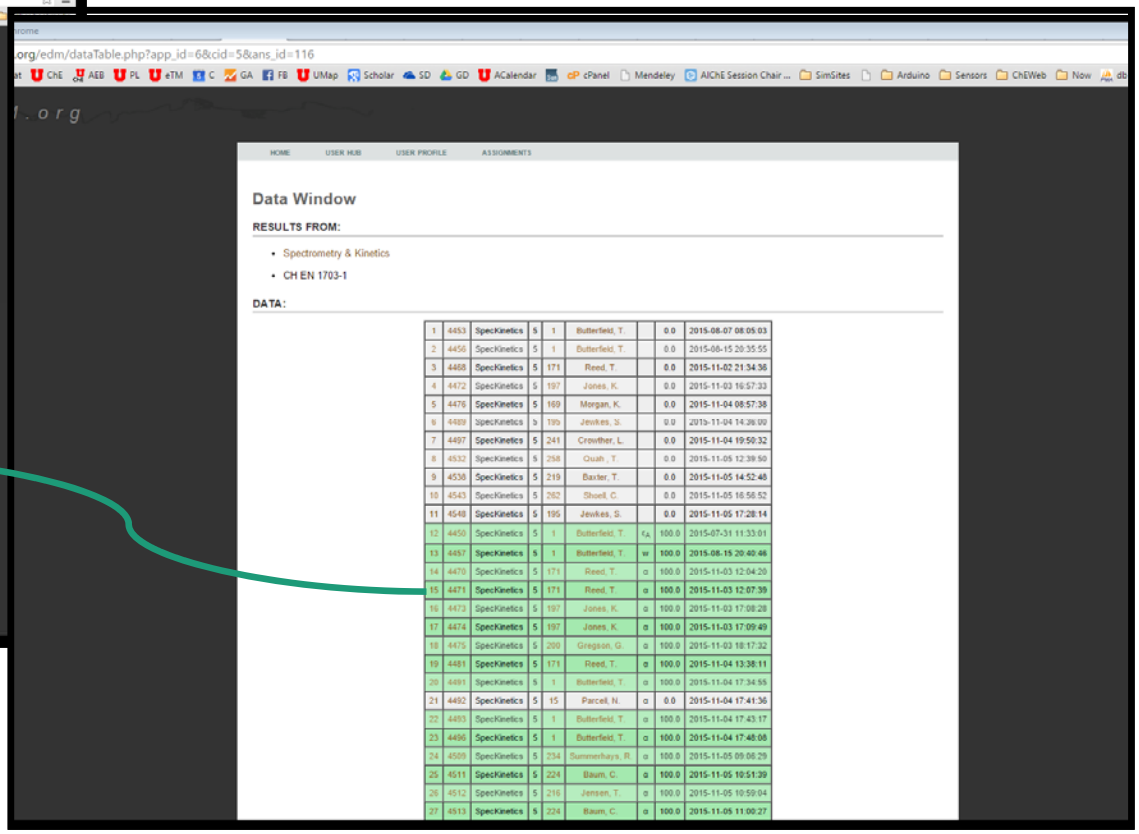
CA0
Pipe-X-Pipe
ρ
μ
P1
Q
ReA
Tracking use & success at a glance.
Reimagine Educati...
vSTEM User Hub - ...
iTunes
Apps on vSTEM - P...
ASEE Simulations - ...
Developing & Stim...
Adobe Dreamweav...

Running Tally of Each Attempt

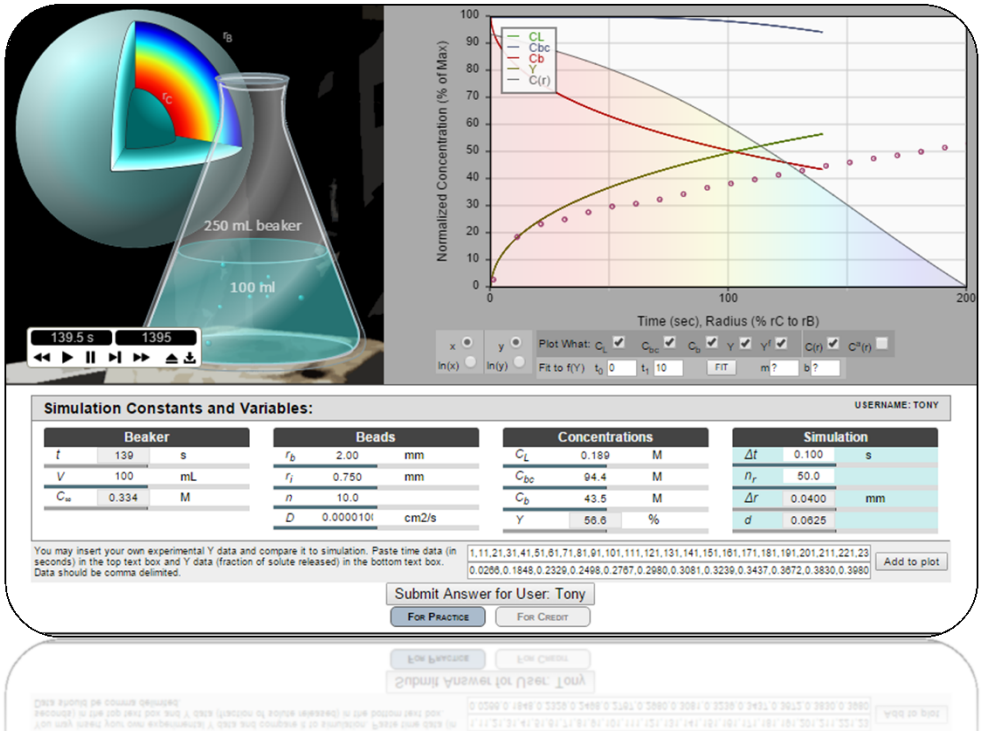


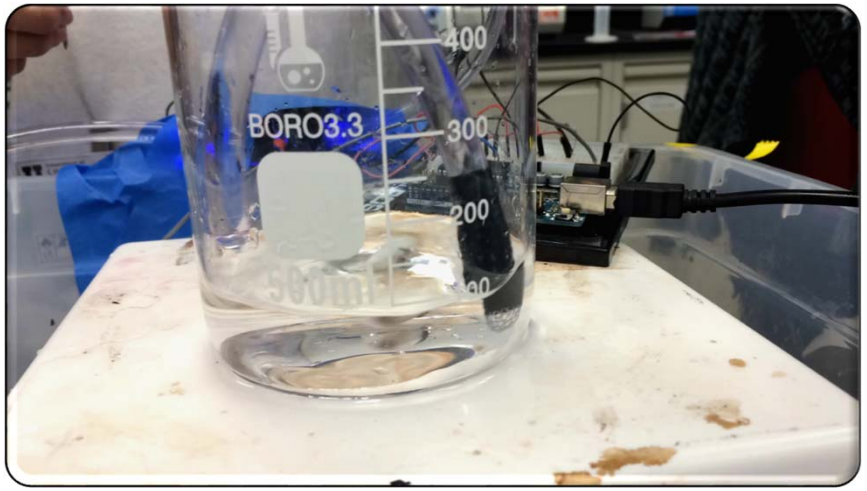


http://vstem.org/app/SpecKinetics/?playid=4561

Interaction With Data from the Real World

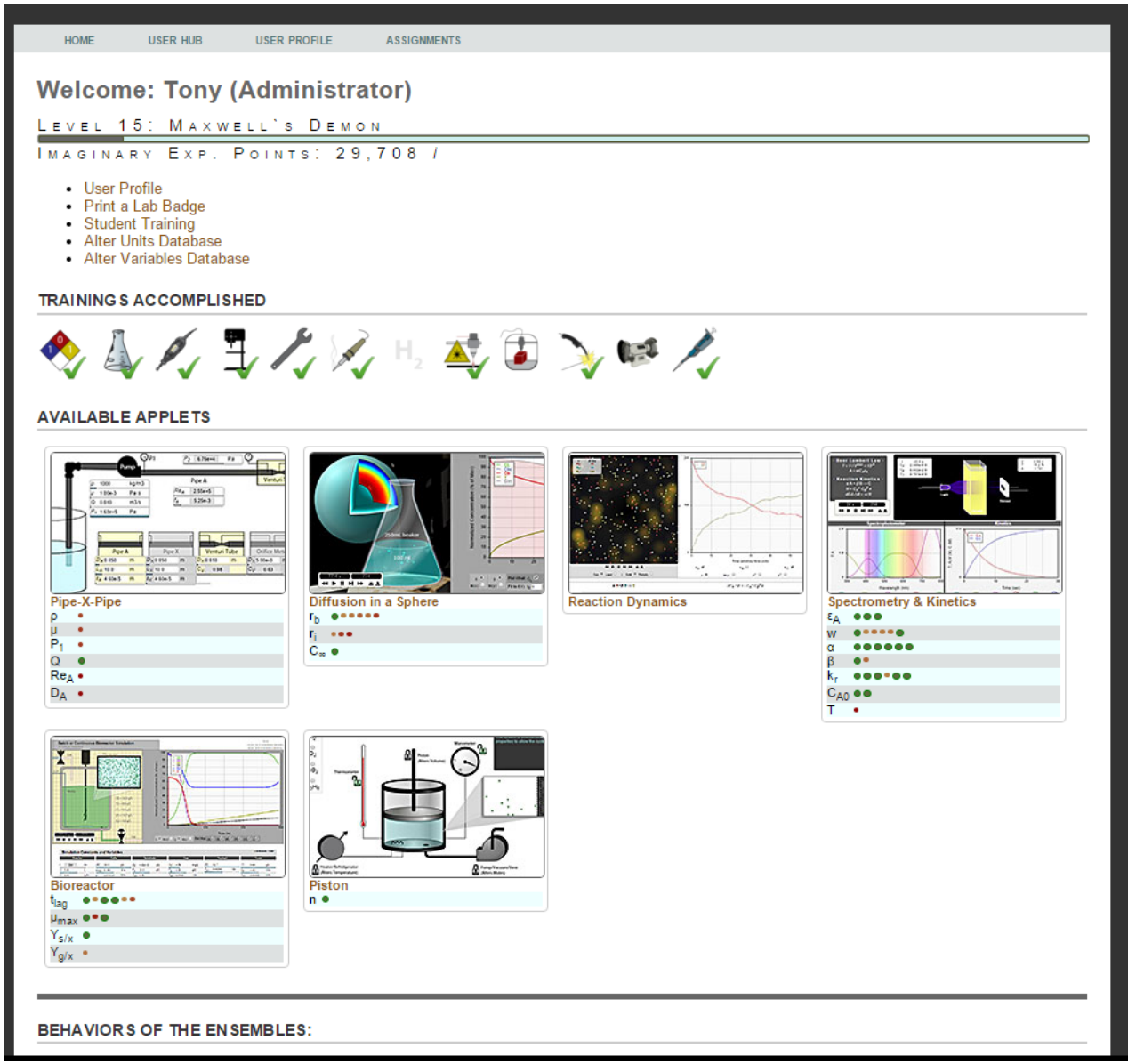
- http://vstem.org/app/DiffusionSphere/





Gamification

- Imaginary experience points.
  - Solving simulation problems.
  - Hands-on equipment training.
- Levels.
- Evidence of extra work.
- Future:
  - Avatars.
  - Leaderboards.



Student Feedback Comments

- Vast majority were positive.
- Students specifically liked:
  - 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 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."

"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."

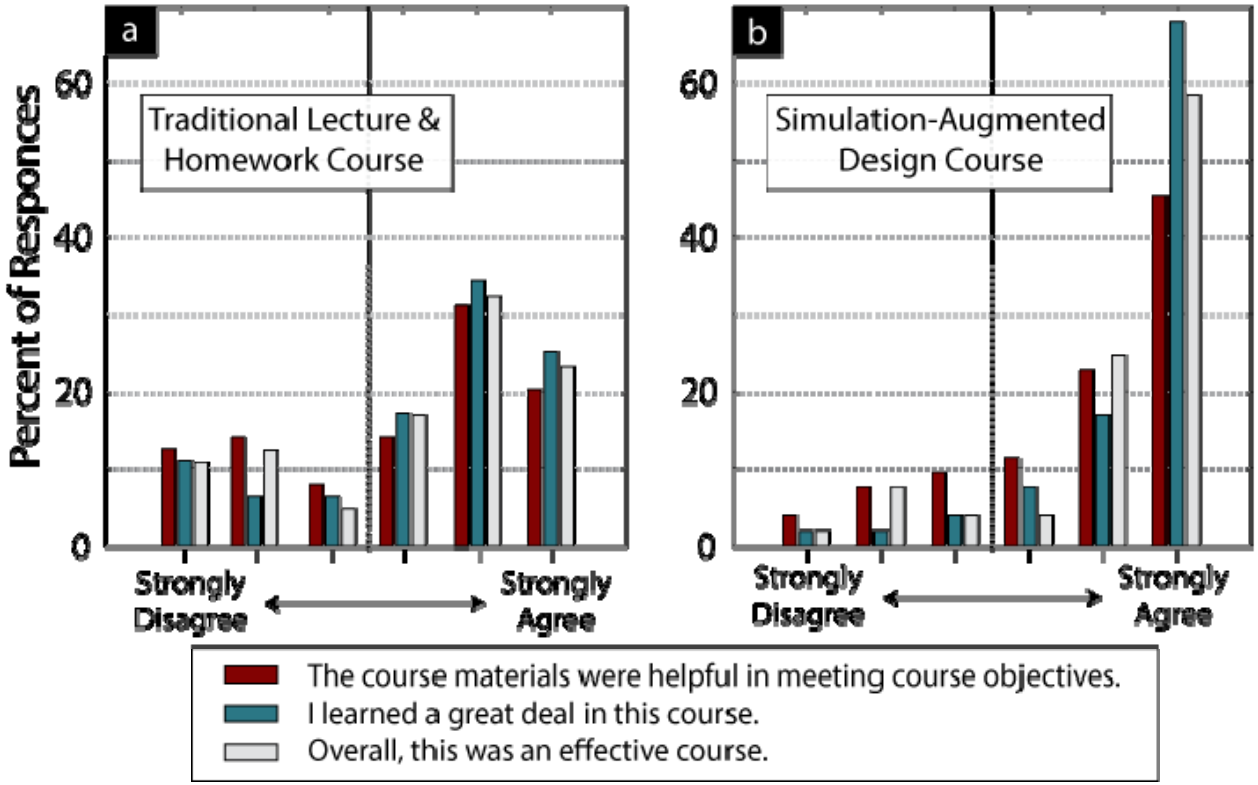
"I thought the hands-on design and prototyping aspects of this course were awesome. The online simulations we did for individual homework were also generally helpful."

"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



- Students took a traditional lecture and textbook introduction to chemical engineering the semester before taking the course developed in this work.
- On official university evaluations, the same cohort was far more enthusiastic about the new course.

Positive Reception by ABET

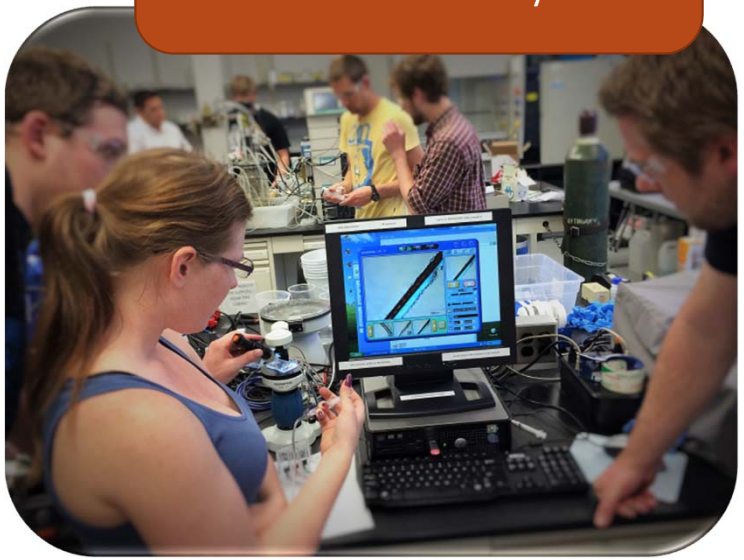
- Just passed our review unblemished.
- Reviewer made special note of our lab courses which are coupled to vSTEM.org.

https://commons.wikimedia.org/wiki/File:Sydney_harbour_fireworks_new_years_eve_2008.JPG

Retention & Underrepresented Groups

- Historically:
  - Freshmen to sophomore ≅ 60% retention.
  - Freshmen to graduation ≅ 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.

Can now track students and underrepresented status from freshmen to senior years.

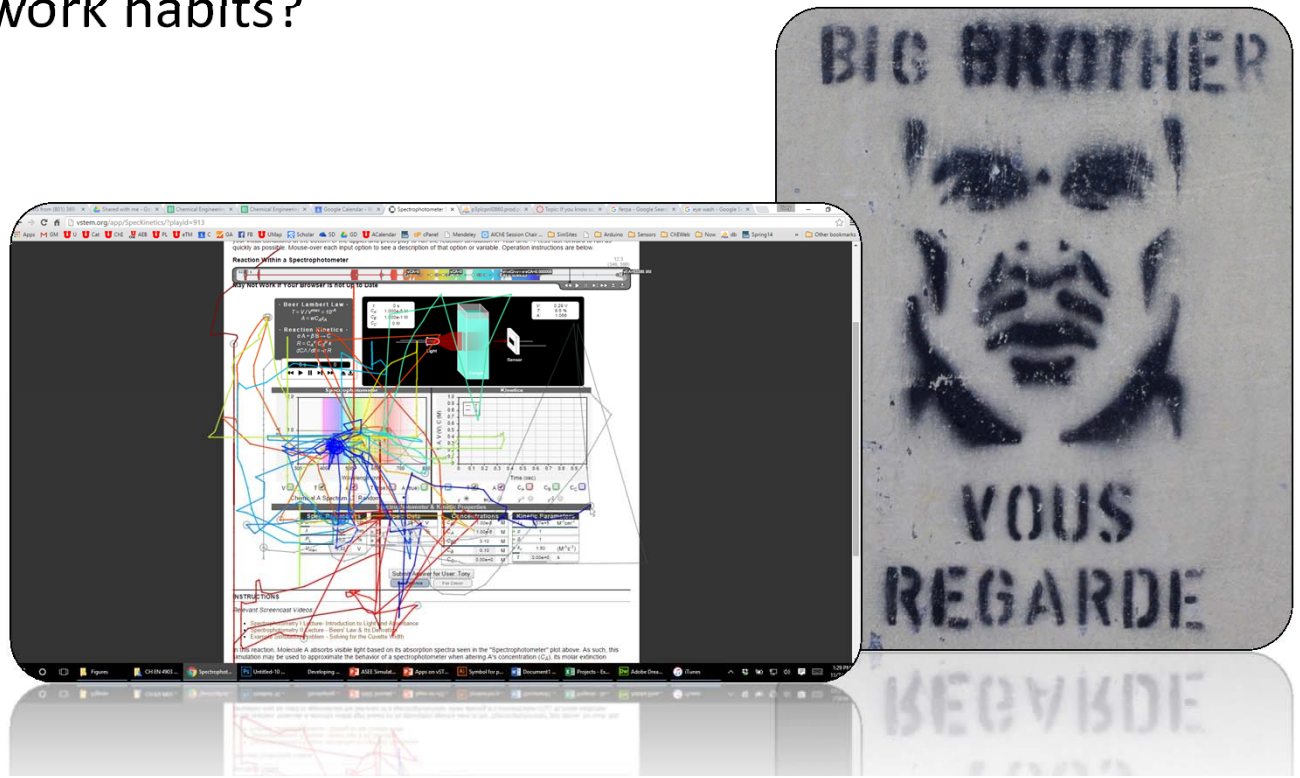


Real Virtual Hurdles…

- It’s just me an my grad student…
- We code until it works seamlessly… for our courses.
  - Want to extend reach.
  - Working now to make use seamless for anyone.
    - Have only moved beyond our department on accident.
    - Use as classroom examples should be easily transferable.

Future Work:
Letting Students Know What Big Brother Knows

- How can knowledge of peer behavior be used to encourage better work habits?
  - % started homework
  - % successful
  - Time it took
  - Leaderboards
- Peer worked examples.



Department of
CHEMICAL ENGINEERING
THE UNIVERSITY OF UTAH

A Collection of Virtual Experiments with Tracking of Student Interaction Data

Anthony Butterfield
Kyle Branch

November 11, 2015
Best Practices of Online Courses and Virtual Environments

15AIChE
Annual Meeting, Salt Lake City, UT