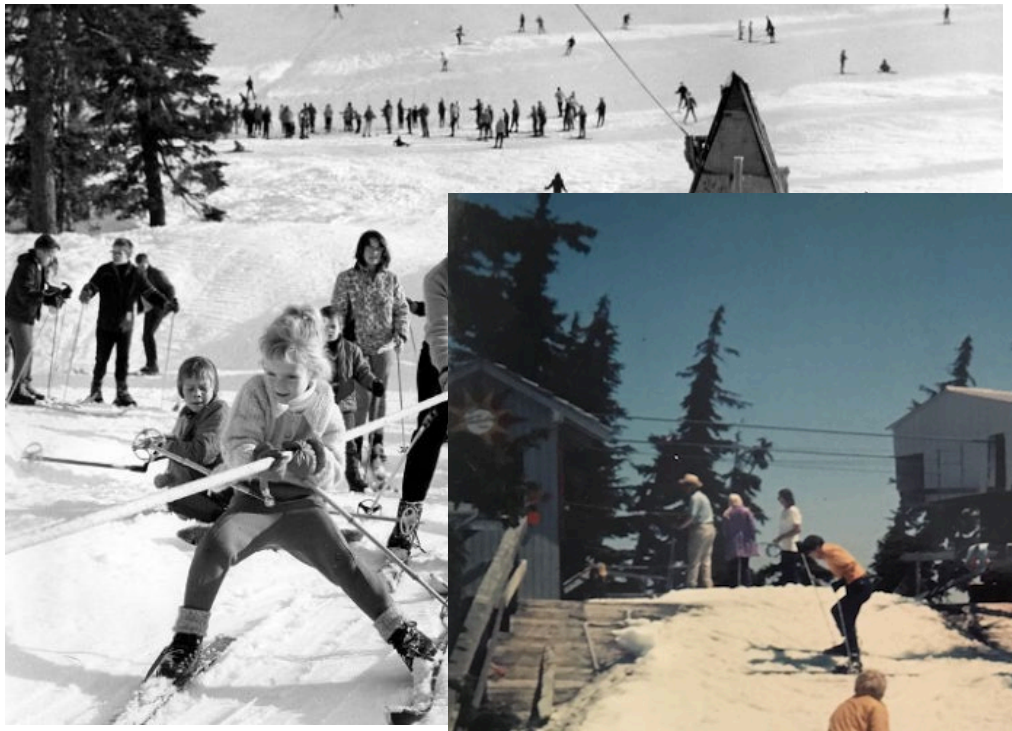
Driving forward learning in the laboratory with digital badges

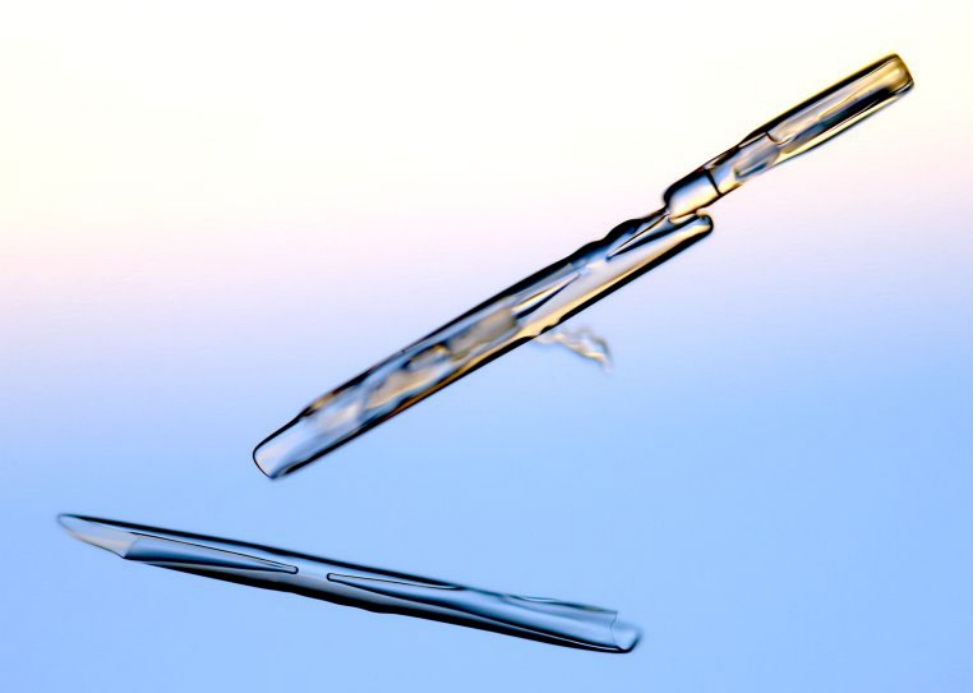
Marcy H. Towns, Bodner-Honig Professor of Chemistry
Purdue University

Grateful to be the
Inaugural Dr. Steven Nils Ulosevich RISE Speaker
Celebrating Science Everywhere!
UNC Greensboro

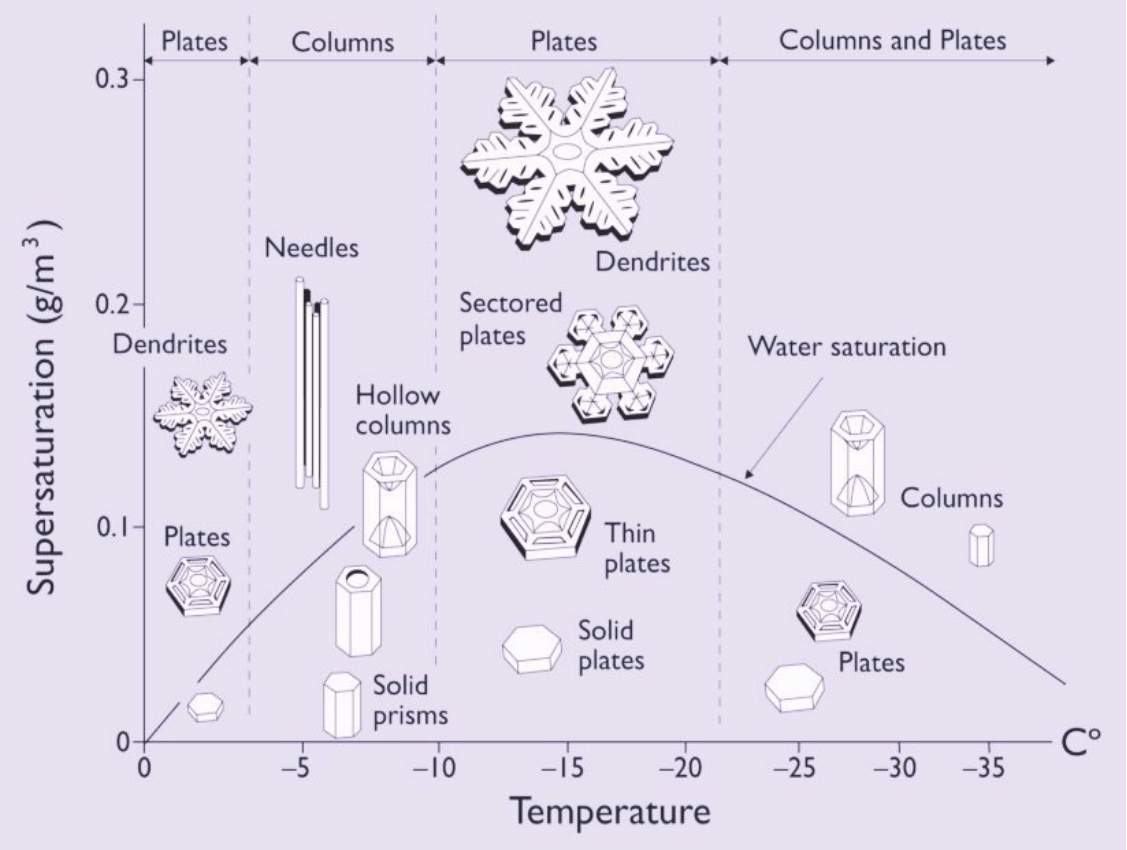


Marcy July 4, 1972 at Timberline Lodge,
Why am I wearing shorts?


Life is best experienced with a
sense of awe,
wonder and discovery.
Go about life with a child's curiosity.
Tom Gregory



Crystal shape depends on temperature and humidity in clouds



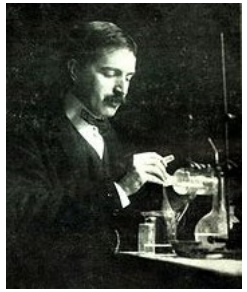
Why do these icicles point in toward the building?


LIVE


TRANQUILITY
BASE
LANDING SITE
OF THE FIRST MANNED
LUNAR LANDING

The Value of Lab: A Continuum

- Science is about the exploration of the physical world.
  - Lab has value because it engages students in activities that mimic scientists.
  - Strong unquestioned belief in the inherent value of laboratory work
    - Theodore Richards – Harvard, ACS President 1914
    - *"Value of lab experience is largely assumed"*
    - *"They spend lots of time there, don't they?*
      Time = Learning"
    - *"Learn with your hands", "writing, problem-solving critical thinking", "trouble shooting", "think it out", "GRIT building"*



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Unsettling questions

- *Notes science laboratory has a distinctive role in science education . . .* "research has failed to show simple relationships between experiences in the laboratory and student learning." *(Hofstein & Lunetta, 1982, 2004; Hofstein, 2007)*

- *"The most important issue in the context of laboratory classes is whether there needs to be a laboratory program at all."*
  - *Tertiary Science Education in the 21st Century, Rice, Thomas, & O'Toole, 2009.*

- *"Laboratories are one of the characteristic features of education in the sciences at all levels. It would be rare to find any science course in any institution of education without a substantial component of laboratory activity. However, very little justification is normally given for their presence today. It is assumed to be necessary and important.*
  - *(Reid & Shah, 2007).*

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Evidence for the Importance of Laboratory Courses

- "What evidence does your department have that the significant investment of space, time, personnel, and resources is essential for your students to learn chemistry? What arguments and data would your department amass to defend laboratory instruction if your university administration decided that virtual laboratories and simulations would be a far less expensive pedagogy that does not compromise student learning? Chemists can no longer afford to believe that the importance of teaching laboratories is a truth we hold to be self-evident. As scientists we must support our research claims with evidence. Our claims about student learning require this same standard."

- Bretz, S.L. "Evidence for the Importance of Laboratory Courses," *Journal of Chemical Education*, **2019**, 96(2), 193–195.

Dinr

Faculty Goals. Student Goals. Correspondence? Learn meaningfully?

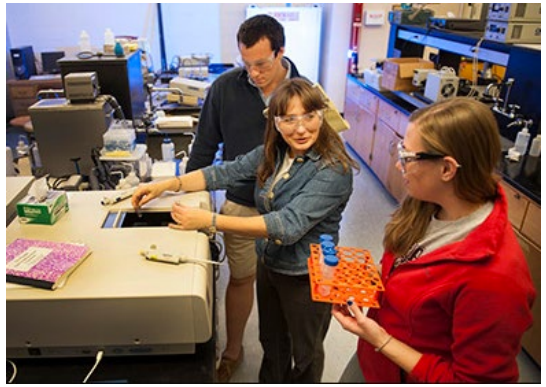
Lets write an NSF grant to do all of this, for $150,000.

We got $130,000 and were told, just do the faculty piece.

Faculty Goals for Chemistry Laboratory

- Lab skills & techniques
- Critical thinking skills

- Research experiences and real world chemistry
  - Usefulness of specific techniques
- Writing
- Error analysis
  - Data collection and analysis



M. E. Fay, N. P. Grove, M. H. Towns, S. L. Bretz. *Chem. Educ. Res. Pract.*, **2007**, *8(2),* 212-219.
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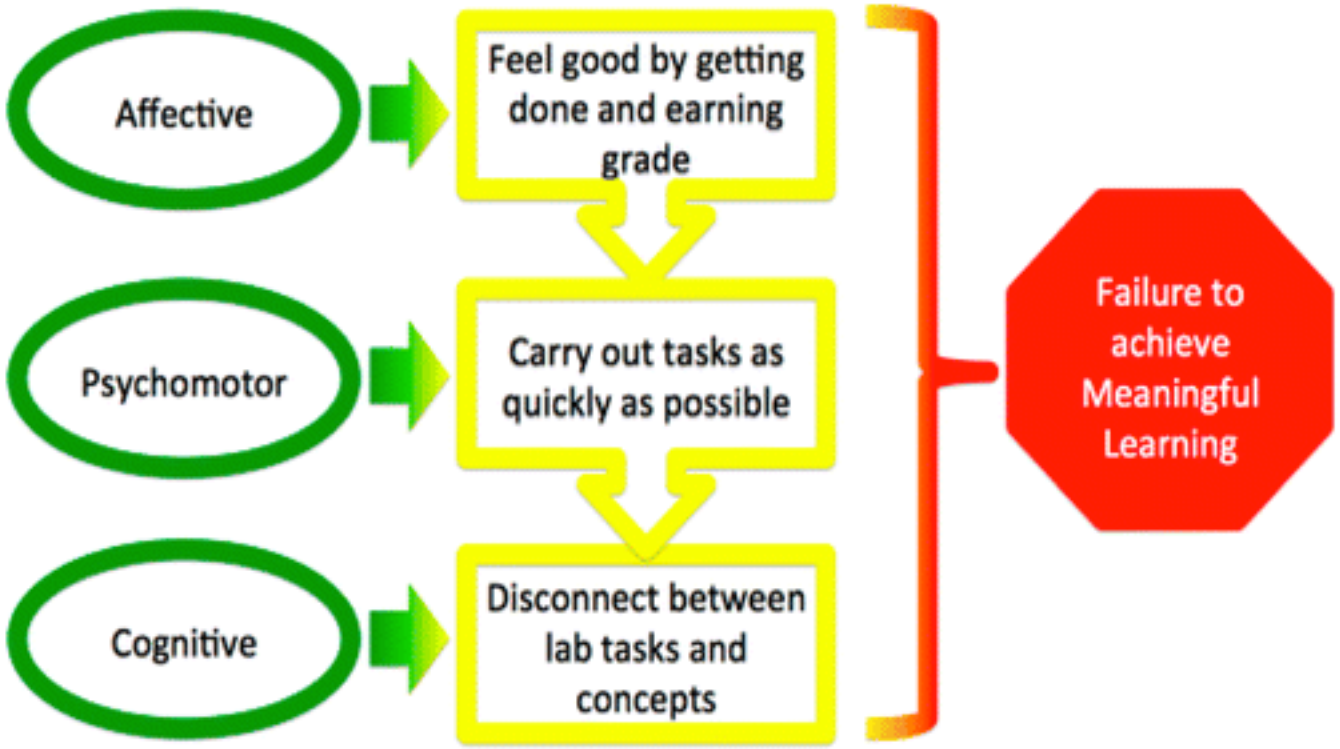
L. B. Bruck, M. Towns, S. L. Bretz, *J.Chem. Educ.*, **2010**, 87(12), 1416-1424.
S. L. Bretz, M. Fay, L. Bruck, M. Towns, *J. Chem. Educ.* **2013**, 90, 281-288.
A. Bruck, M. H. Towns, *J. Chem. Educ.,* **2013**, *90(6)*, 685-693

Student goals for laboratory



DeKorver & Towns, *J. Chem. Educ.*, **2015**, *92* (12), pp 2031–2037

Comparison of Upper Level and First Year Students

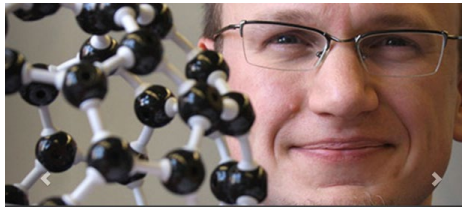
- Exhibit similar goals
  - Get a good grade
  - Finish the lab quickly
  - Avoid learning new techniques
  - Disconnect between concepts and experiments
- Poor retention of earlier lab experiences

Freshmen

Seniors

DeKorver & Towns, *J. Chem. Educ.*, **2015**, *92* (12), pp 2031–2037
DeKorver & Towns, *J. Res. Sci. Teach.*, ***2016***, *53(8), 1198-1215.*

Comparison of Goals



- Faculty
  - Lab skills & techniques
  - Critical thinking skills
  - Research experiences and real-world chemistry
    - Usefulness of specific techniques
  - Writing
  - Error analysis
    - Data collection and analysis

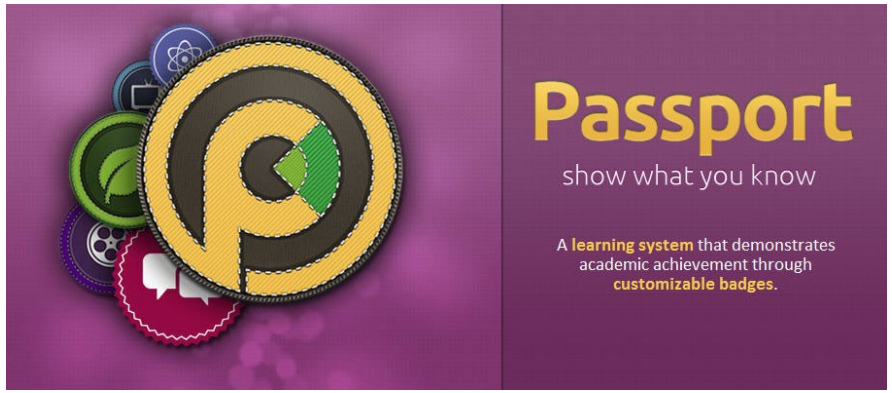
- Students
  - Avoid unfamiliar tasks
    - Learn new techniques?
    - Why are they useful?
  - Conceptual learning is not a priority
  - Focus on assessment

Students, Course, Need

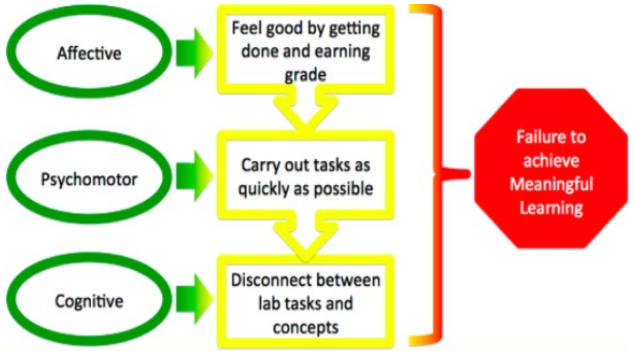
- Non-majors general chemistry
- Predominantly College of Ag and HHS
  - About 1000-1100 students

- Survey 2012 and 2021
  - 30% of students have completed 5 or fewer chemistry lab labs in high school.

- Pipetting is a fundamental lab skill
  - 6 of 11 labs use Pipets
- Replacing 200-250 pipet bulbs each semester at a cost of $14 per bulb



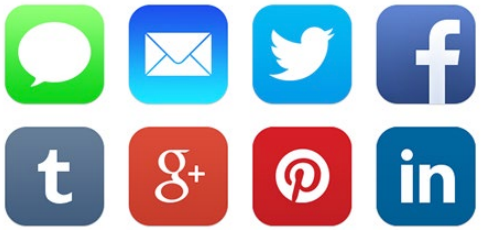
$2800-$3500 per semester



DeKorver and Towns, J. Chem. Educ., 2015, 92, 2031-2037.

Digital Badges

- Electronic credential or micro-credential
  - Learners “learn it, earn it, share it”
  - Digital representation of accomplishments with a verifiable description of knowledge and skills required to earn it. *Evidence is crucial.*
- Value
  - Sharable online: LinkedIn, website, etc.



Evidence Centered Design

- To make evidence-based claims about student knowledge you must design your assessment such that you have the correct evidence.
  - Method for designing educational assessments
- Based upon domain analysis (years of research), what tasks could we ask students to do that would provide evidence about their knowledge or skills?
  - Analysis? Interpretation? Inference?

Mislevy, R. J., Almond, R. G., & Lukas, J. F. (2003). A brief introduction to evidence-centered design (CRESST Technical Paper Series). Los Angeles: Center for Research on Evaluation, Standards, and Student Testing.

Mislevy, R. J., Risconscente, M. M. Evidence Centered Assessment Design: Layers, Structure, and Terminology http://padi.sri.com/downloads/TR9_ECD.pdf


PIPETTING

What evidence do you need?

Pipet Video Instructions (remember to narrate, tell us what you are doing):

1. State your name at the beginning of the video.
2. State Laboratory Section number.
3. Your face and hands must be shown in the video at the beginning.
4. Collapse pipet bulb properly (not attached to pipet)
5. Connect bulb to pipet properly (tell us how).
6. Draw liquid into the pipet above mark, but not into the bulb.
7. Do a close up shot showing the meniscus at calibration mark.
8. Remove drops of liquid from the end of pipet if needed by tapping on side of beaker.
9. Dispense liquid into flask.
10. Do a close up shot showing the bottom 2-3 inches of pipet. There should still be liquid in the bottom.

This is shared and discussed with students.

Rubric to Evaluate Videos

Pipet Video Rubric

	Performance description and score		
Criteria	2	1	0
Connect pipet and bulb properly	Hold pipet close to the top. Gently twist bulb on 1-2cm.	Hold pipet at the wide part of the pipet. Collapse bulb after putting it on the pipet.	Hold pipet lower than the wide part of the pipet. Push bulb on too far. Attach pipet upside down.
Draw liquid into a pipet	Smoothly draw liquid in a constant flow past the calibration line, but not into the bulb.	Draw liquid just to the calibration line without going above it	Air bubbles remain in pipet prior to dispensing that impact the volume.
Get liquid to the proper level	Shows that the meniscus of the liquid is at the calibration line on the pipet.	Meniscus slightly above/below calibration line – must mention calibration line in video. Makes some obvious attempt to get it to calibration line, but the line is not visible in the video.	No recognition of calibration line.
Dispense liquid	Uses the valve to release the liquid, being careful not to push all the liquid out. Students should show a close up with a few drops left in the pipet tip	Doesn't show tip of pipet at end of video but appears to have dispensed liquid properly.	Makes obvious effort to force or push all liquid out. Sucks liquid back into the bulb.

Harwood, C. J.; Hewett, S.; Towns, M. H. Rubrics for assessing hands-on laboratory skills, *J. Chem. Educ.*, 2020, 97(7), 2033-2035.

Gra

Back to scorecard

Ryan F

on 3/5/2017, 9

Pipet Video Su

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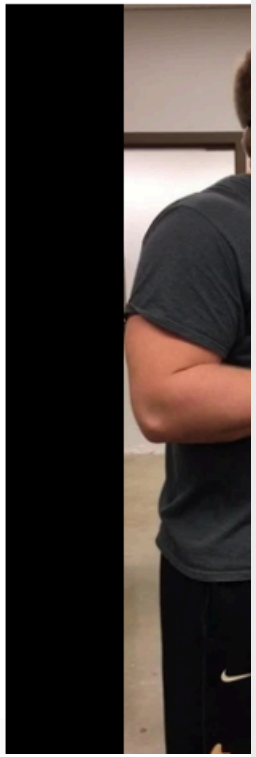
Open Text

No text available

Attachments *



Get liquid to the proper level	No recognition of calibration line 0 points	Meniscus slightly above/below calibration line – must mention calibration line in video Makes some obvious attempt to get it to calibration line, but the line is not visible in the video 0.5 points	**Shows that the meniscus of the liquid is at the calibration line on the pipet.** 1 point
Dispense liquid	Makes obvious effort to push all liquid out Sucks liquid back into the bulb 0 points	Doesn't show tip of pipet at end of video but appears to have dispensed liquid properly 0.5 points	**Uses the valve to release the liquid, being careful not to push all the liquid out** **Students should show a close up with a few drops left in the pipet tip** 1 point

Instructor Comments *(Optional)*

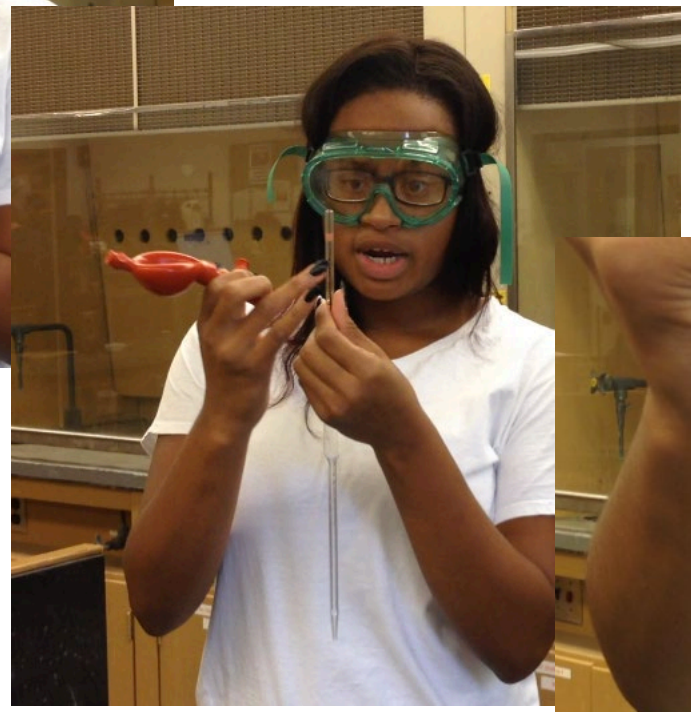
Deny & Allow Resubmission

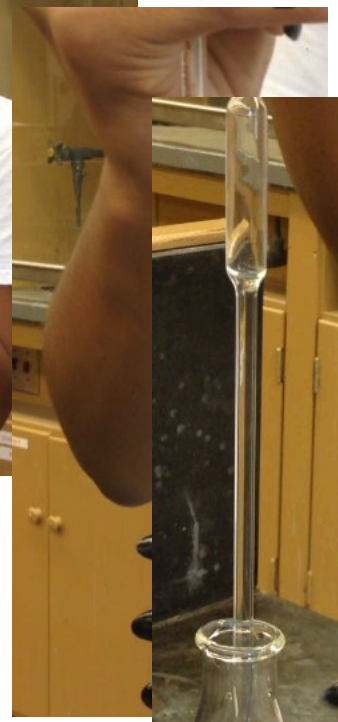
Deny

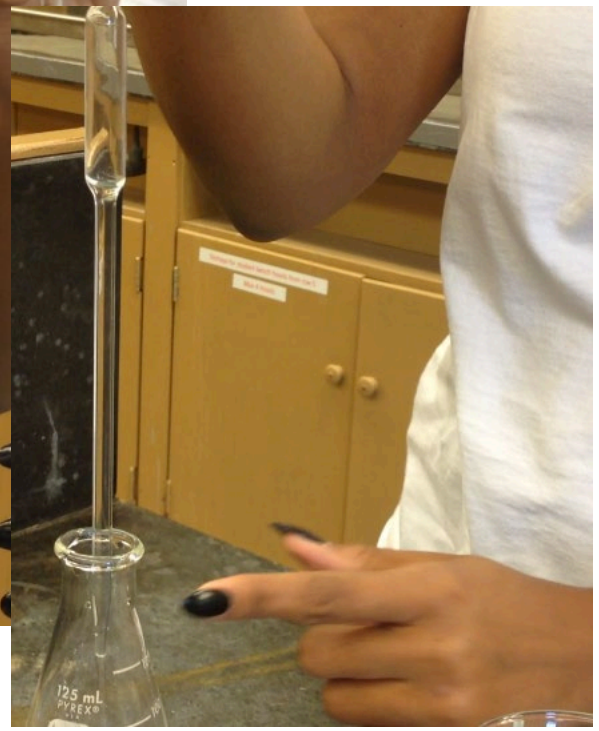
Submit Grade

nto 4 parts. You will give the parts according to

	Performance Level
e	**Hold pipet close to the top** **Gently twist bulb on 1-2cm** 1 point
ter	
to ne bove	**Smoothly draw liquid in a constant flow past the calibration line but not into the bulb** 1 point
y	**Shows that the meniscus of the liquid is at the**






125 mL
PYREX

Survey about student perceptions

- Participant Perception Indicator
  - Lee, Kerner, & Berger (NARST meeting 1998)
  - Based on Bandura's self-efficacy
  - Based on Ross's 2006 review of student self assessment
- Knowledge, confidence, and experience
  - Cognitive, affective, psychomotor

Lee, Y., Kerner, N., & Berger, C. Student perceptions of collaborative laboratory inquiry. Paper presented at the National Association for Research in Science Teaching meeting, San Diego, CA, 1998.
Bandura, A. Self-efficacy: Toward a unifying theory of behavioral change. *Psychol. Rev.* **1977**, *84*, 191-215.
Ross, J. A. The reliability, validity, and utility of self-assessment. *Pract. Assess. Res. Eval*. **2006**, *11(10),* 1-13.

Student Perceptions

Participant Perception Indicator, Pipet Badge

Table 1: Seven statements to measure students' knowledge, experience, and confidence pipetting. 35 is the maximum score for each subscale.

	Statement	Knowledge Low				High	Experience Low				High	Confidence Low				High
Identification	1. Identify a pipet from among pieces of glassware.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Identification	2. Identify a pipet bulb from among pieces of equipment.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Process	3. Use a pipet and pipet bulb to deliver a sample of liquid to a flask.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Process	4. Connect a pipet and pipet bulb properly.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Process	5. Draw liquid into a pipet.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Process	6. Get liquid to the proper level in the pipet.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Process	7. Dispense liquid from the pipet.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

- Administered as a retrospective-pre and post survey, "then – now" design.
- Statistically analyze.

Lee, Y., Kerner, N., & Berger, C. Student perceptions of collaborative laboratory inquiry. Paper presented at the National Association for Research in Science Teaching meeting, San Diego, CA, 1998

Towns, Harwood, Robertshaw, Fish, O'Shea, *Journal of Chemical Education*, 2015, 92, 2038-2044.

Findings

- Statistically significant differences on survey.
  - Largest gain: How to connect a pipet and pipet bulb properly.

- Based on student survey their knowledge, confidence, and ex of identifying equipment ar how to use it improves

- Exam quest of lear ition al)

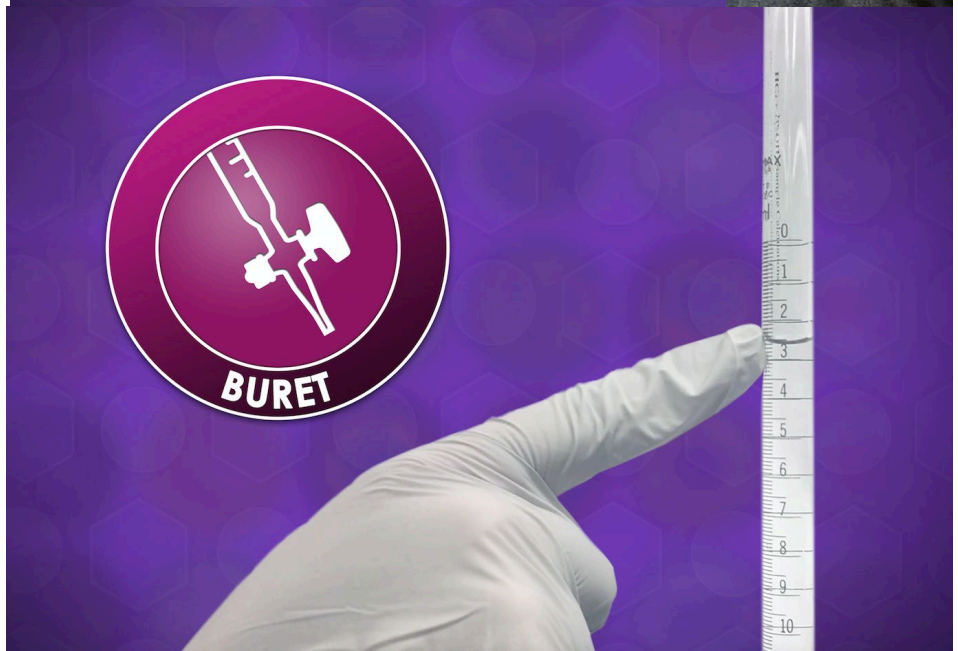
- Towns, H Robertshaw, Fish, O'Shea, *Jo al of Chemical Education*, 2015, 92, 2038-2044.

Saved >$20,000 USD

Improving and Assessing Student Hands-on Laboratory Skills through Digital Badging, J. Chem. Educ., 2016, 93(11), 1847-1854.

<u>Very similar implementation</u>
PPIs tailored to task
Required video

<u>Analyzed PPI</u>
Statistically significant gains with large effect sizes



Badging references

- Pipet
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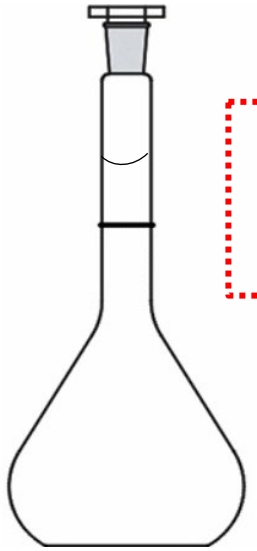
- Buret and Volumetric flask
  - Improving and Assessing Student Hands-on Laboratory Skills through Digital Badging, J. Chem. Educ., 2016, 93(11), 1847-1854.
- Grading Rubrics
  - Rubrics for assessing hands-on laboratory skills, J. Chem. Educ., 2020, 97(7), 2033-2035.

Implementation

- Majors course
  - Beginning of the course
- Non-majors course
  - As needed for laboratory activities
  - Two weeks to complete
    - If badge is “rejected”, performance in video is not adequate, they have time to do it again and submit new video.

Advanced badges

- How long does a badge certification last?
  - More than one semester.
- Created advanced badges for the pipet, volumetric flask, and buret.
  - Scenario based, free response.



Did not appear in badge

Unlimited tries

Challenges

Solution 1

You are diluting a 5.0M HCl solution to 1.0 M in a volumetric flask. When you finish adding the water to the flask, you notice that the level of the liquid is below the calibration line.

1.) How does this impact the concentration of the solution in the flask? Is it greater than, less than, or equal to 1.0M?

2.) Explain your answer from question 1.

3.) What would you do next?

Solution 2

You are diluting a 5.0M HCl solution in a volumetric flask to a concentration of 1.0 M. While you are adding the water to the flask you accidentally fill it above the calibration line.

1) How does this impact the concentration of the solution in the flask? Will it be greater than, less than, or equal to 1.0 M?

2)Explain your answer to question 1.

3) What would you do next?

Sample correct response

1. The solution concentration will be less than 1.0M.

2. In this case, the solution was over diluted because too much water was added. The more dilute a solution is, the smaller its concentration is.

3. Pouring out or removing any solution from the flask would change the solution's concentration. The solution would have to be disposed of, and I would need to start over again.

Sample incorrect response

"If you add too much water and the level of the liquid is above the calibration line, that means that the solution is more dilute than you want it to be, causing the concentration of the solution to be less than 1.0 M. Next, I would remove water until the level of the liquid was at the calibration line so then it would result in a proper dilution and a solution that equals 1.0 M."

- *Although not in DeKorver's published papers, in her data collection she watched students do this!*
- *Feedback is important.*
  - *"If you removed the water and it had a little bit of the solute in it, would the concentration be 1.0M even if the meniscus was at the calibration mark?"*

Badging and Advanced Badges

- Evidence of student abilities.
  - Improve knowledge, experience, confidence
  - Improved lab outcomes, saved $.

- Advanced badges - focus on common errors.
  - Ask students what do you do next and/or provide reasoning.
  - Targeted feedback is important to shape their reasoning.
  - Improve practices

- Grateful and honored to be the inaugural Dr. Steven Nils Ulosevich RISE Speaker
- Thank you to Chris Rhea and Maia Popova!
- Thank you for your gracious hospitality in hosting me.
- Continue to ask questions, to be open to awe and wonder!

Acknowledgements

Digital badging project
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& Dr. Cynthia J. Harwood Purdue
Collaborators (Purdue):
Jason Fish, Kevin O'Shea (Teaching & Learning Tech)

Past group members on this project (Faculty and student goals for laboratory)
Laura Bruck, Aaron Bruck, Taylor Owings, Brittland DeKorver,

Collaborators at Miami University
Dr. Stacey Lowery Bretz, Kelli Galloway
Michael Fay

Collaborator at University of Northern Iowa
Dr. Dawn Del Carlo

Collaborator now at Oregon State University
Dr. M. Brooke Robertshaw

Purdue University Provost's Office

Purdue University
College of Science

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- Hensiek, S., DeKorver, B. K., Harwood, C. J., Fish, J., O'Shea, K., Towns, M., *J. Chem. Educ.,* **2016,** 93(11), 1847-1854.
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- Towns M.H., Harwood, C., Robertshaw, M.B., Fish, J., O'Shea, K., *J. Chem. Educ.*, **2015**, 92, 2038-2044.
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