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A Catholic and Lasallian University

Triangulation of Student Outcomes from a CURE

Dr. Teresa J Bixby – Lewis University

IUPUI Assessment Institute

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Thank You

ELIPSS Enhancing Learning by Improving Process Skills in STEM

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GA Facilitators
Peer Research Mentors
Students

High Impact Practice

Undergraduate Research Experiences

”***Engaging students in authentic, real-world research*** in STEM fields not only socializes undergraduates into scientific thinking and practices, it may also play a significant role in students’ educational and career trajectories.”

“Many studies have demonstrated increased interest in and awareness of science careers, ***particularly among groups underrepresented in scientific fields***.”

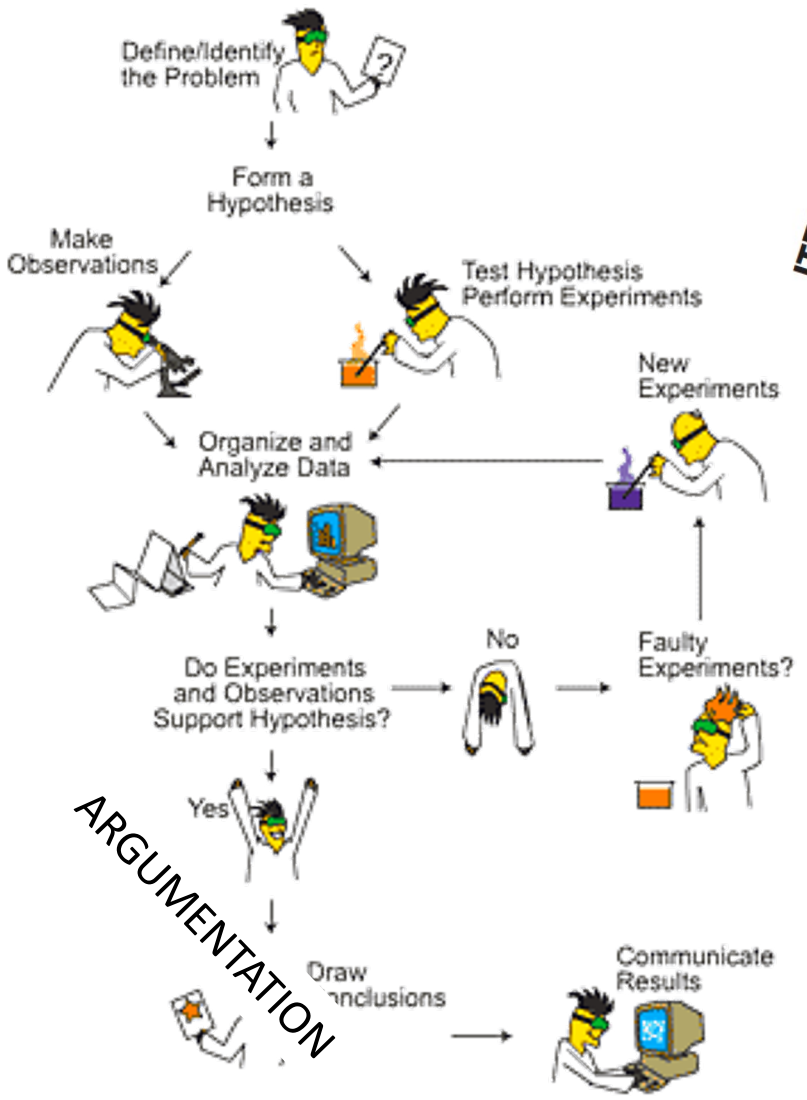
Thiry, Weston, Laursen, and Hunter, CBE-Life Sciences Education, **2012**, 11, 260

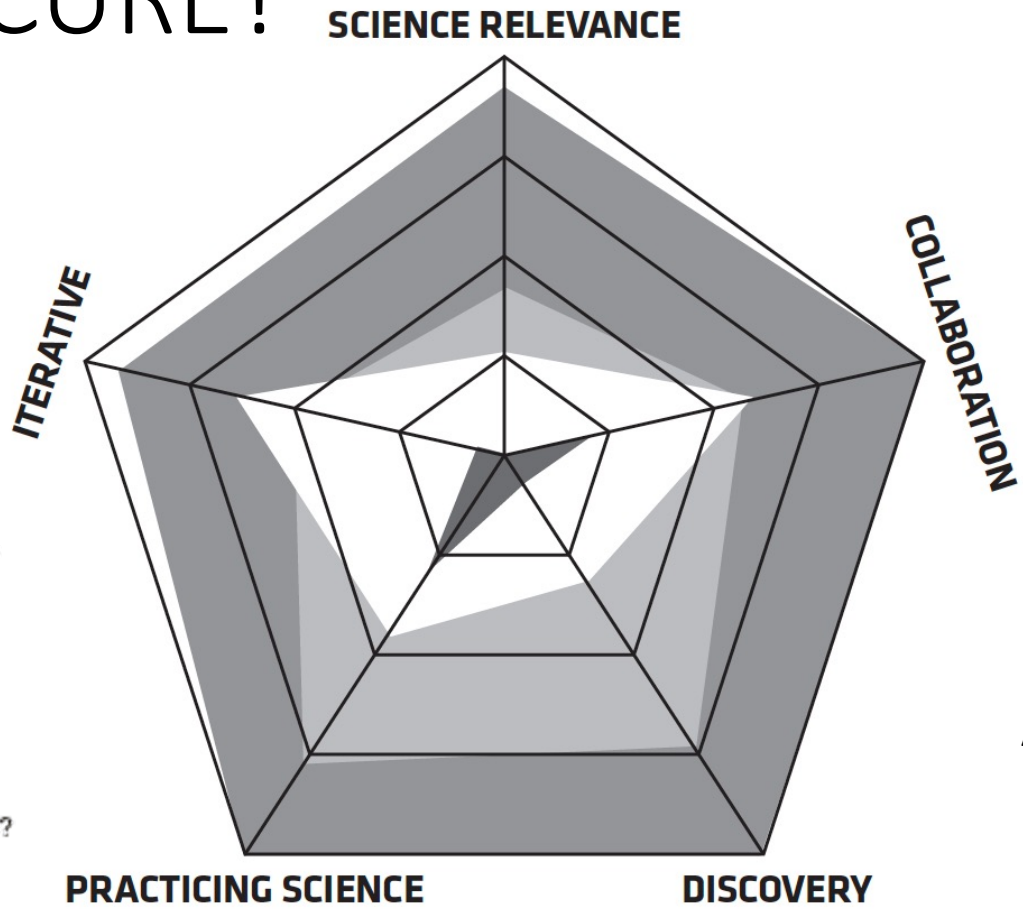
What's the Catch?

- Awareness of research opportunities
- Awareness of possible benefits of researcl
- Awareness of norms associated with scien
- Perceived barriers to interactions with faci
- Financial and Personal Barriers

Course-based Undergraduate Research Experience

What makes a CURE?





Cookbook Lab Worksheet
Course with CURE elements
Course with CURE elements
CURE course

Brownell and Kloser, 2015

Expanding the CURE Model, Ed. Waterman and Heemstra, 2018

Our Implementation

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GENERAL CHEMISTRY I LAB - Skills

LAB TECHNIQUES & EXPT PLANNING

WRITTEN COMMUNICATION

CHEM 11600.003

Introduction

A buffer is a solution that resists changes to its pH when an acid or base is added to it. Buffers are typically made using a weak acid or base and its conjugate base or acid. When solution that can change the pH of the buffer is added, initially, the buffer will resist the change by employing Le Chatelier's Principle, effectively removing hydrogen ions or hydroxide ions by adjusting its equilibrium in its aqueous environment. When too much of a solution is added, the buffer will eventually reach its buffering capacity, and a large change in pH is seen at this point.

$$HA_{(aq)} \leftrightarrow H^{+}_{(aq)} + A^{-}_{(aq)} \qquad Eq\ 1$$

The generic equilibrium reaction in Equation 1 will adjust to create more or less hydrogen ions in solution based on what is added. The equilibrium will adjust for added acid by causing the added hydrogen ions to turn back into HA, thus maintaining the pH. When base is added, more HA will dissociate to create hydrogen ions in solution, thus again maintaining the pH. The pH of a buffer can be determined by using the Henderson-Hasselbalch equation, seen in Equation 2.

$$pH = pKa + log\frac{[base]}{[acid]} \qquad Eq\ 2$$

DATA ANALYSIS and REPRESENTATION, STATISTICS

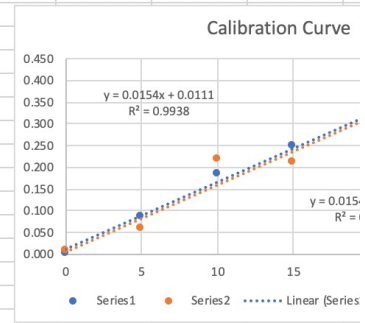
Home | Insert | Page Layout | Formulas | Data | Review | View

Cut | Copy | Calibri (Body) | 12

2	Calibration Curves and Linear Regression			1. Plot data
3				2. Add linear trendline and R
4				3. Execute LINEST for living s
5		Independent	Dependent	Dependent	4. Determine the concentrat
		Protein (mg)	Student A	Student B	
		0	0.000	0.008	
		5	0.086	0.059	
		10	0.183	0.215	
		15	0.246	0.211	
		20	0.326	0.27	
		25	0.384	0.422	

LINEST

0.01544571	0.01109524	b
0.00061152	0.00925731	sb
0.99376915	0.01279081	sy



SOURCES of VARIATION in DATA

General Chemistry I - Skills

FLIPPED-Style Prelabs

PRE-LAB:
- Video tutorials
- Online Pre-lab Quiz
- Experimental Background and Prep

IN LAB:
- **Discussion**
- Prediction
- Execution

CONSENSUS PROCEDURE

POST-LAB:
- Critical Thinking Questions
- Lab Report
- Online Post-lab Quiz

Week 1	**Orientation** Logger Pro, Vernier equipment, Analytical Balance XLS basics	Week 7	**Peer Review** Deidentified, Team/Peer Assessment, Revise Draft
Week 2	**Glassware, what is it good for?** Accuracy & Precision, Statistical Tests, Extensive vs Intensive	Week 8	**Which is better, analog or digital?** Stoichiometry, Titrations with Indicators, with and without drop counters
Week 3	**What happened to the penny in 1982?** Histograms, Random and Systematic Errors	Weeks 9, 10	**What is the water hardness?** EDTA Titrations, Experimental Design
Week 4	**What's in your drink? Sugar** Solutions & Dilutions, Calibration Curves, LINEST	Weeks 11, 12	**How can you dissolve $CaCO_3$?** Thermochemistry, Calorimetry, Hess's Law
Week 5	**What's in your drink? Dyes** Absorption of Light & Beer's Law	Week 14	**Explain that demo!** Gas Laws

Distinctive Experience

Most CUREs are 2-4 week modules embedded in the lab curriculum.

This CURE was a semester-long experience.

Distinctive Experience

Projects in a CURE are typically related to or defined by faculty's primary research.

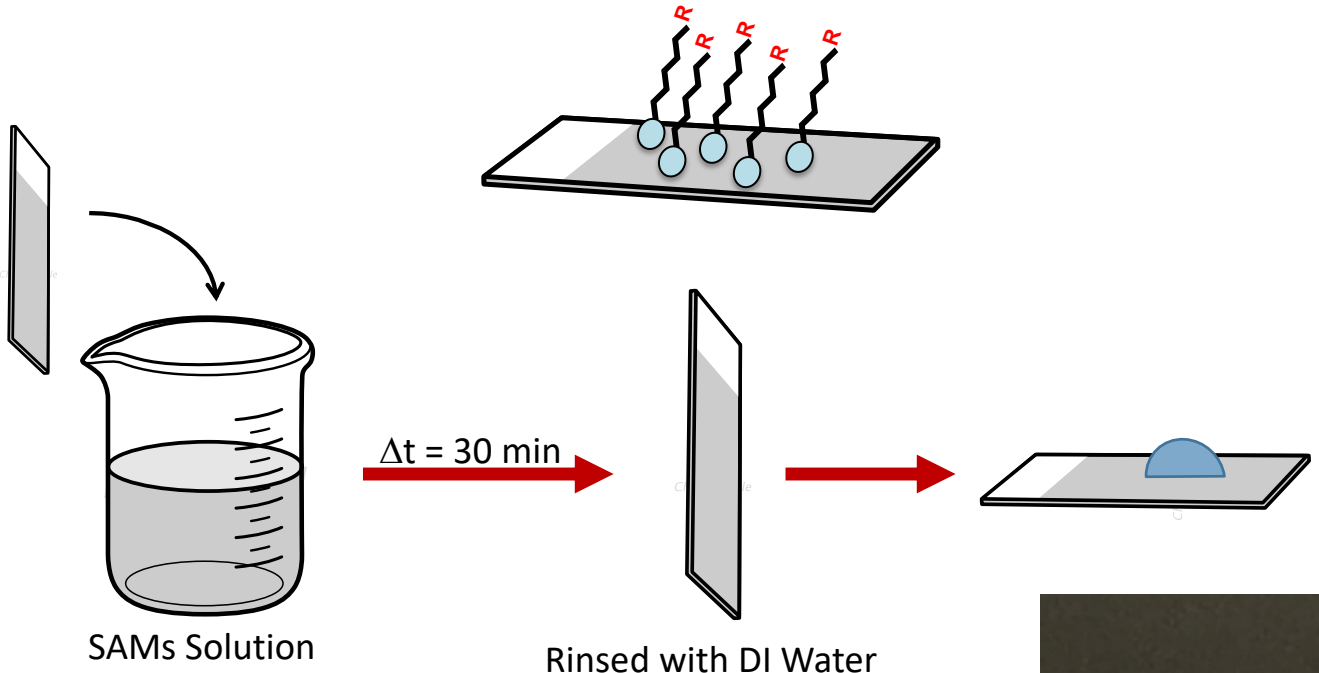
Here, student teams were asked to determine their own context, motivation, and researchable questions (within the scope of self-assembled monolayers).

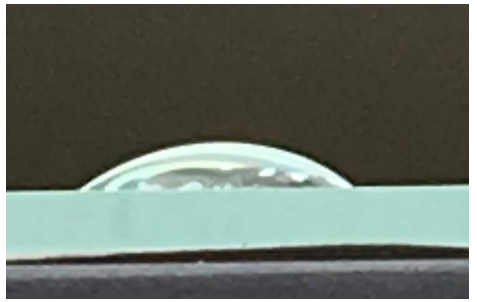
Self-Assembled Monolayers

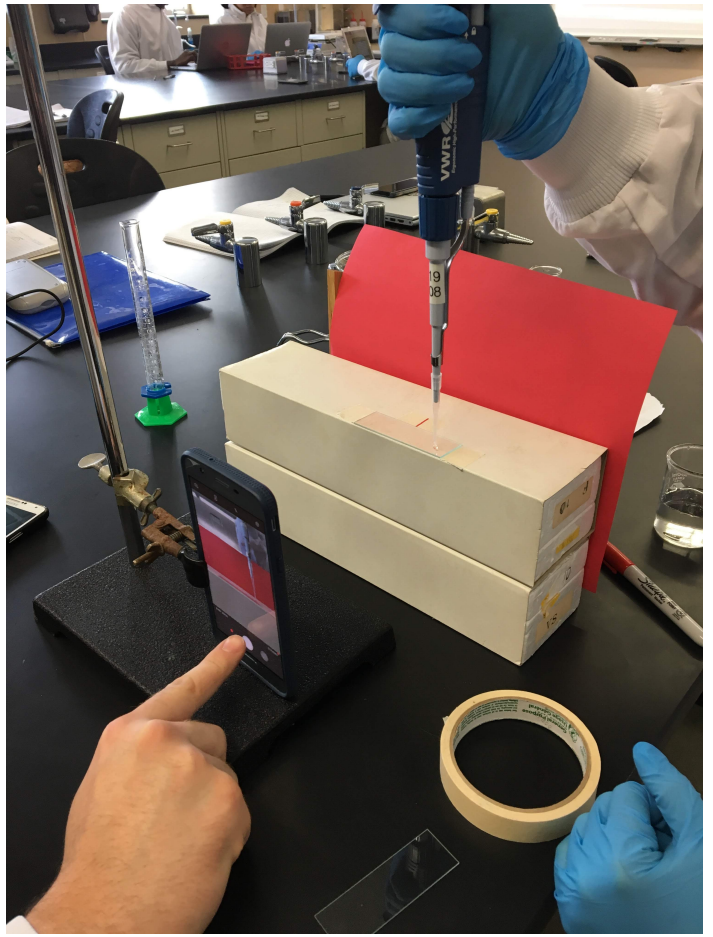
Chosen as a topic because:

- Related to traditional 2nd semester content
- Easy to make
- Easy to measure
- Wide variety of applications

Self-Assembled Monolayers







General Chemistry II - CURE

FLIPPED-Style Prelabs

PRE-LAB:
- Experimental Plan

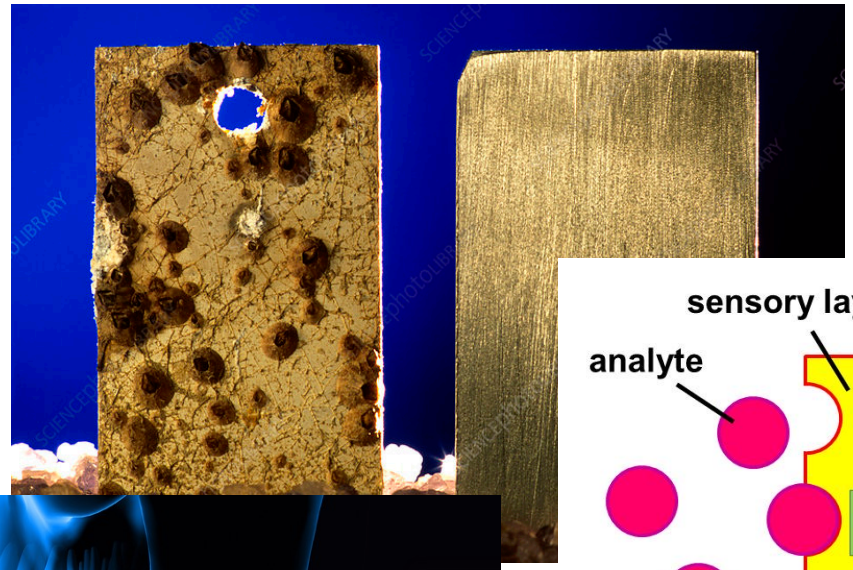
IN LAB:
- **Discussion**
- Prediction
- Execution
- ***Presentation***

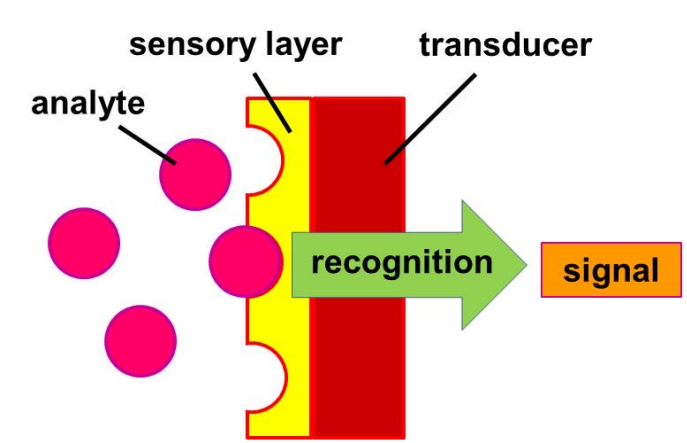
CONSENSUS PROCEDURE

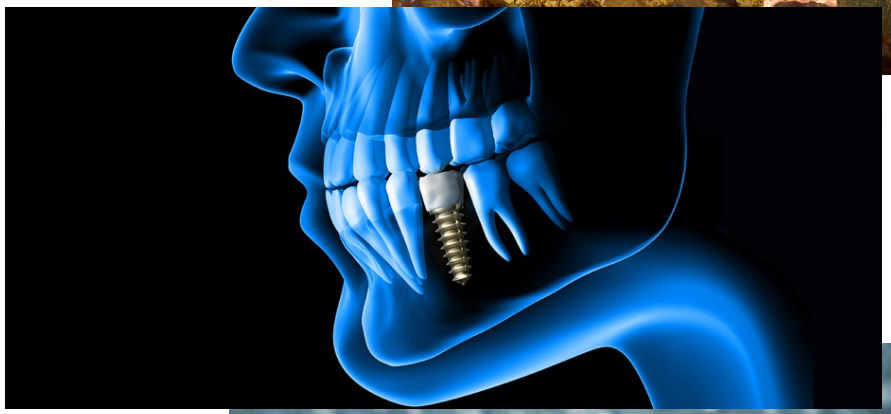
POST-LAB:
- Executive Summary

Week 1	**M1: Orientation and Scientific Literature** Overview of Research, Introduction to SAMs, Team Assembly Reference Librarian – Searching for Relevant Literature Literature Review and Researchable Questions	Week 8	**Research Proposal**
Week 2		Week 10	**M4: CV Degradation on a SAMs Surface** Experimental Design and Molecular Modelling
Week 3	**M2: SAMs and Contact Angle** Construct Apparatus and Investigate Surfaces Modify Surfaces with SAMs and Explore IMFs	Week 11	
Week 4		Week 12	**Research** Execution
Week 5	**Foundational Investigations** Replicate Prior Research or Start Foundational Studies	Week 13	
Week 6	**M3: Kinetics** Determine the Rate Law of CV + OH- Determine the Activation Energy of CV + OH-	Week 14	**Team Research Presentations** Wrap Up Experiments
Week 7		Week 15	Research Paper Due

Topics

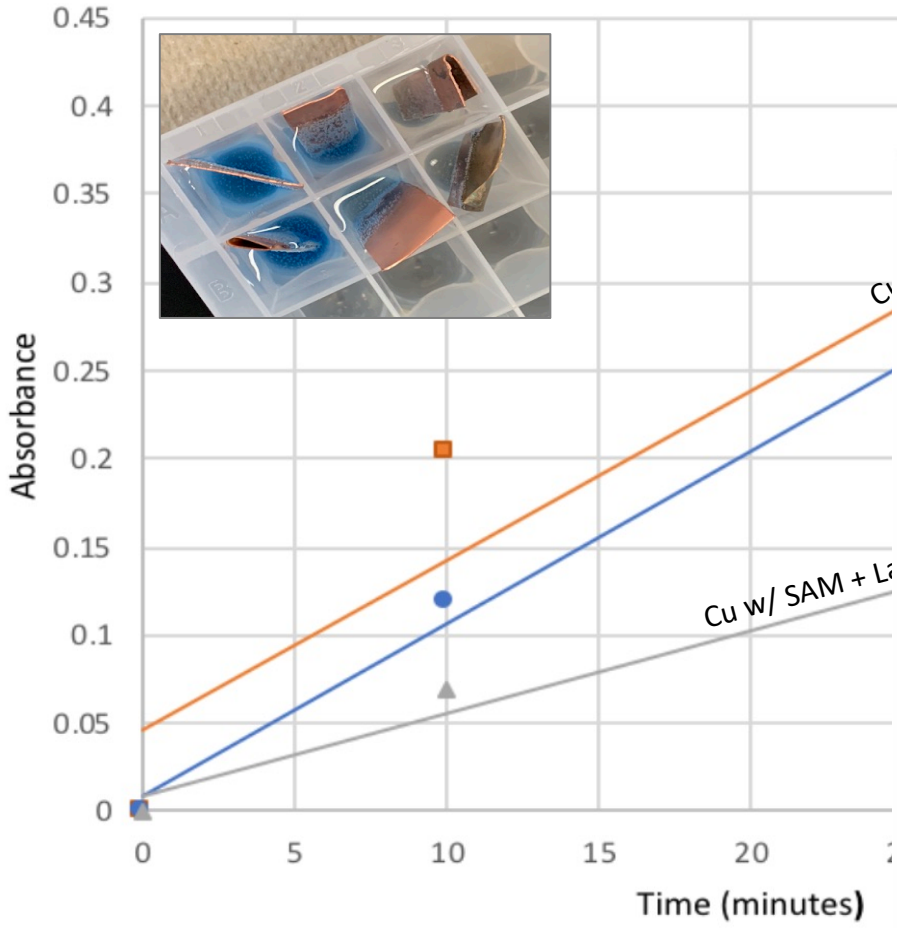


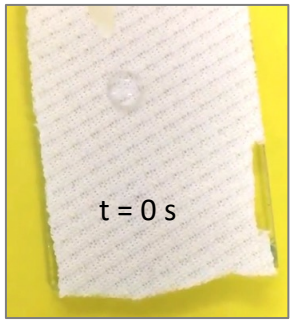


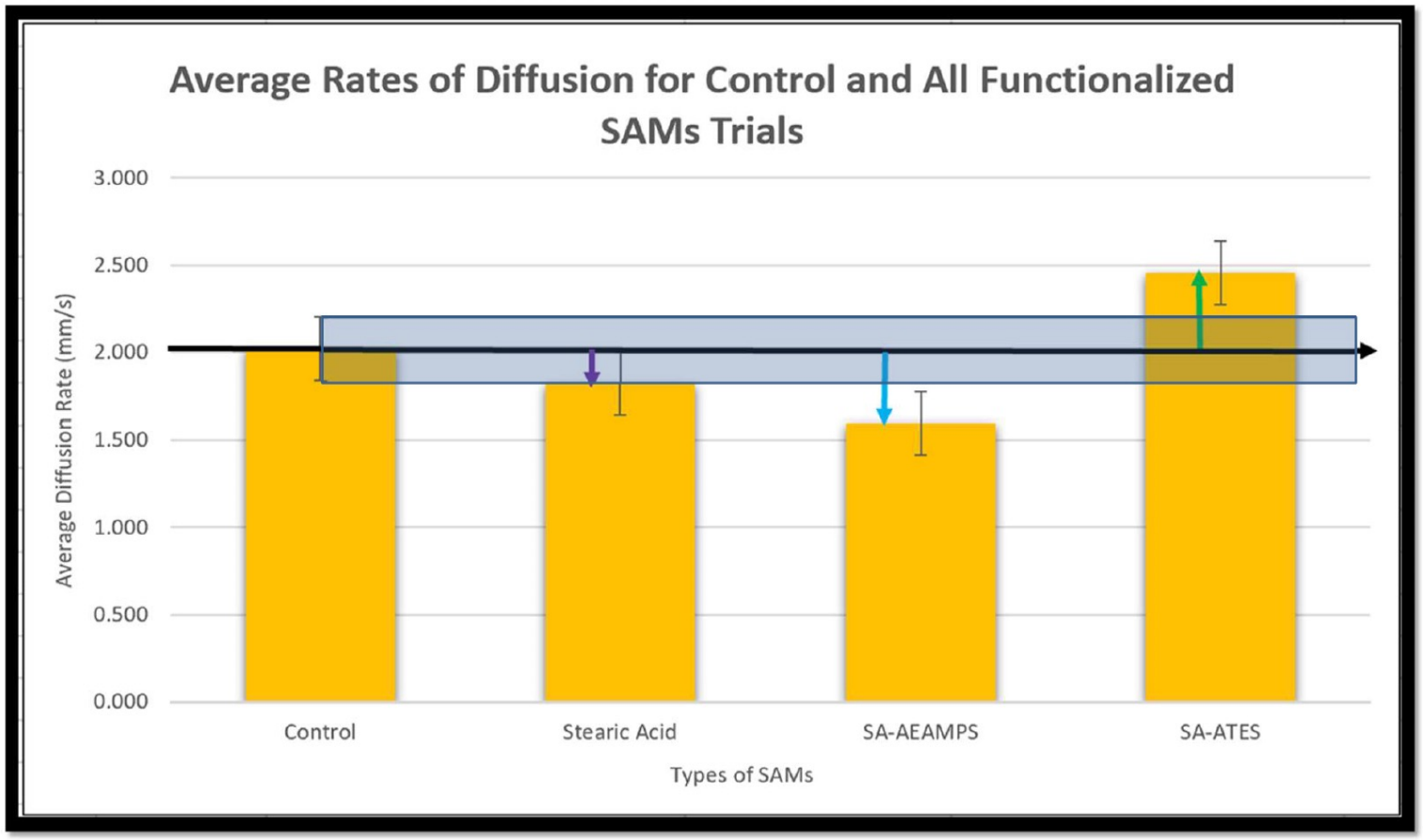


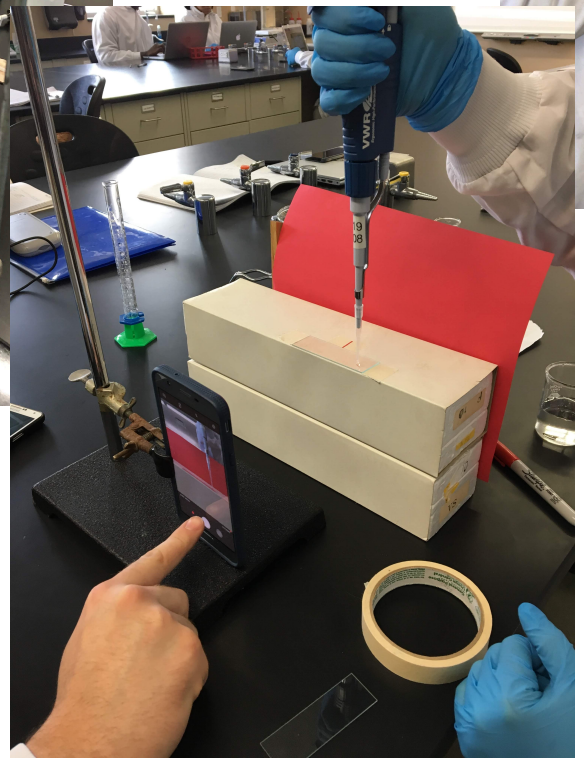
- Drug delivery
- Anti-corrosion
- Waterproof fabrics
- Prevent/modify ice
- Dental/medical implants
- Biosensors

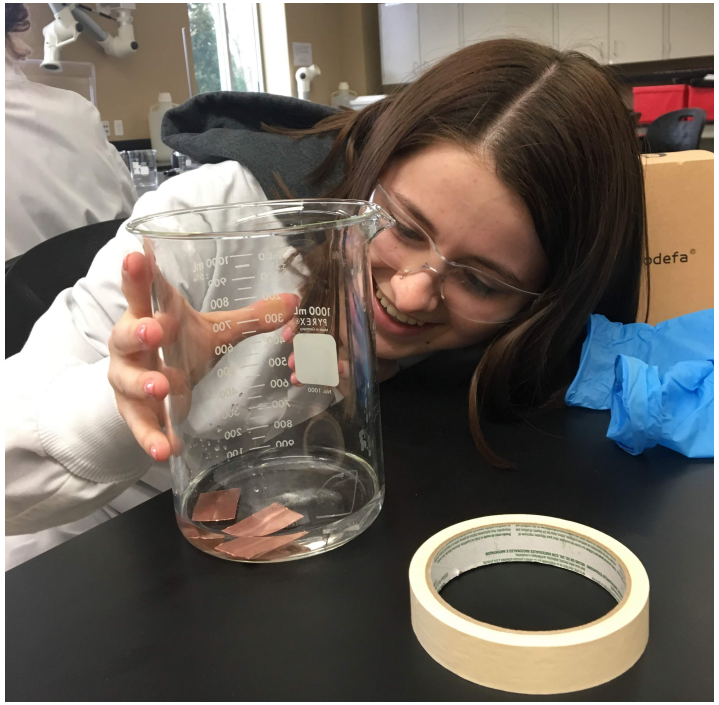
Cu/Glycine Complex Detected Over Time

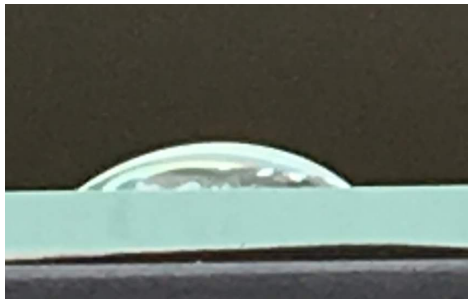


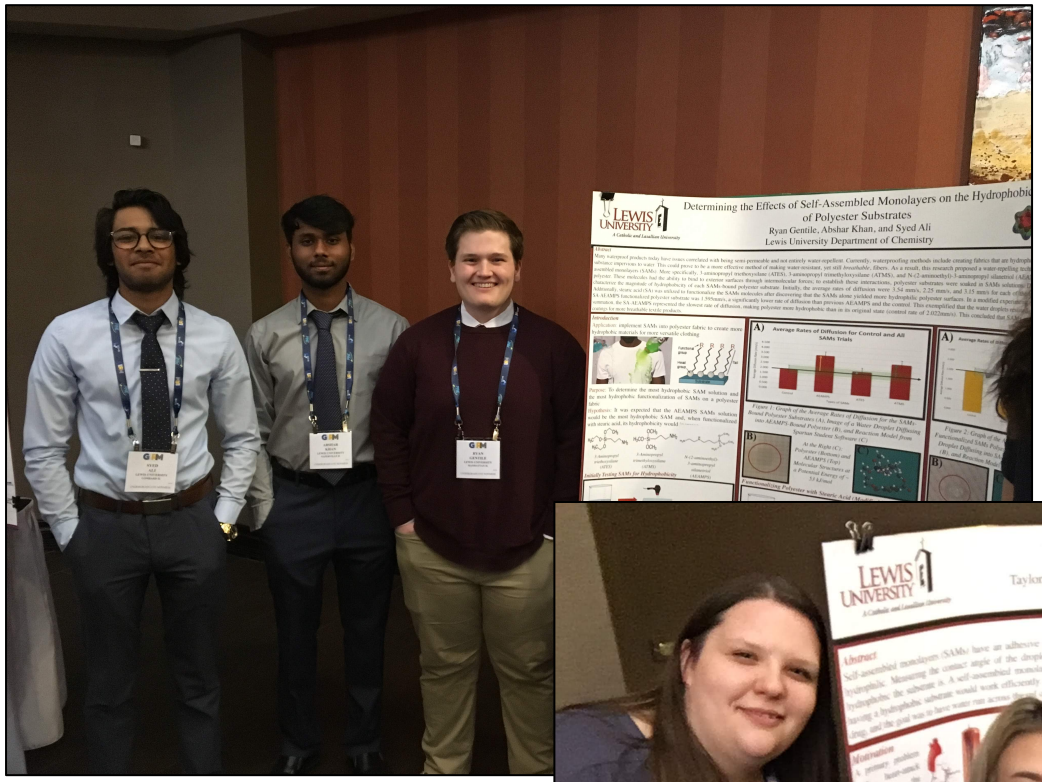








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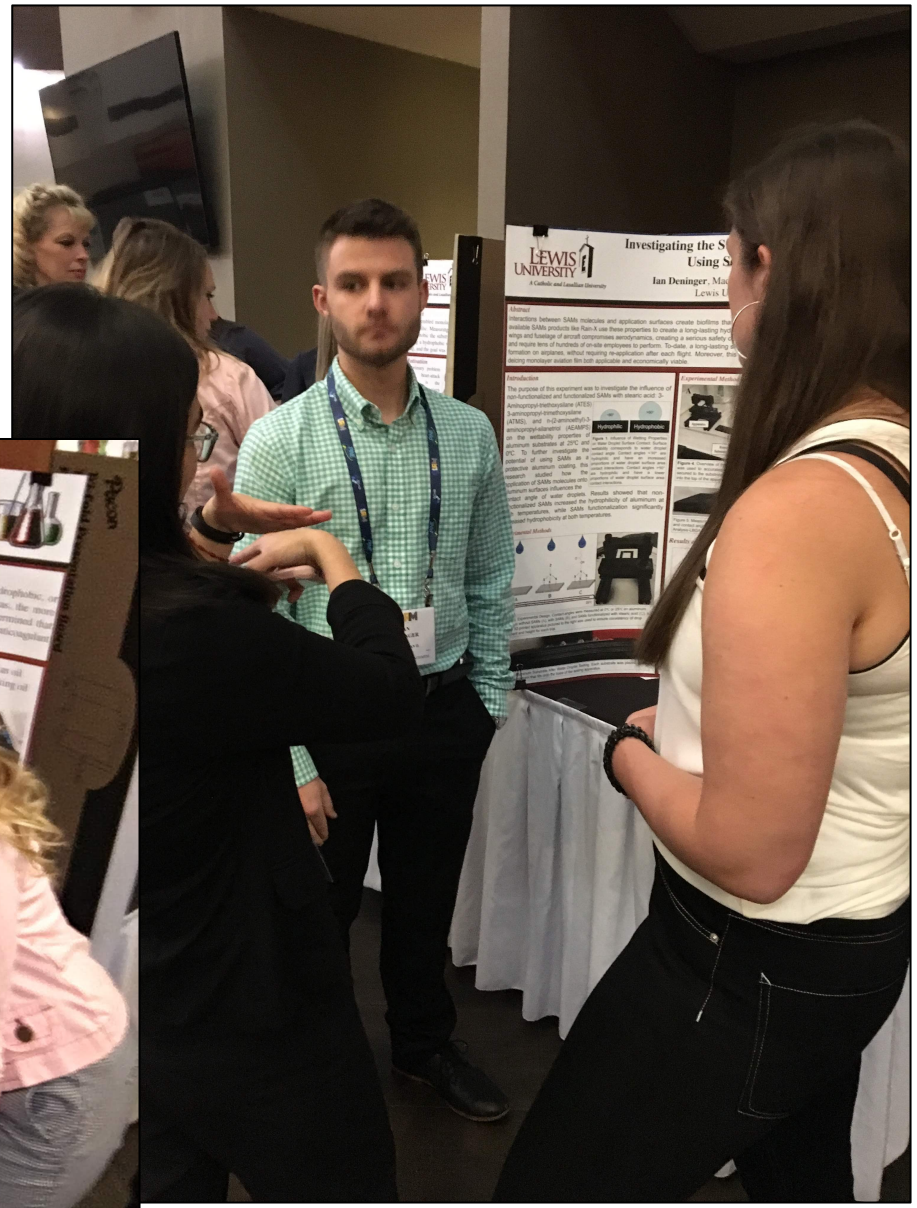
Determining the Effects of Self-Assembled Monolayers on the Hydrophobic
of Polyester Substrates
Ryan Gentile, Abshar Khan, and Syed Ali
Lewis University Department of Chemistry


LEWIS UNIVERSITY
Application of Self-Assembled Monolayers in
Nanomedical Drug Delivery
Taylor Kenny, Caitlyn Scott, Madison Smith, and Dr. Teresa Bixby
Lewis University Department of Chemistry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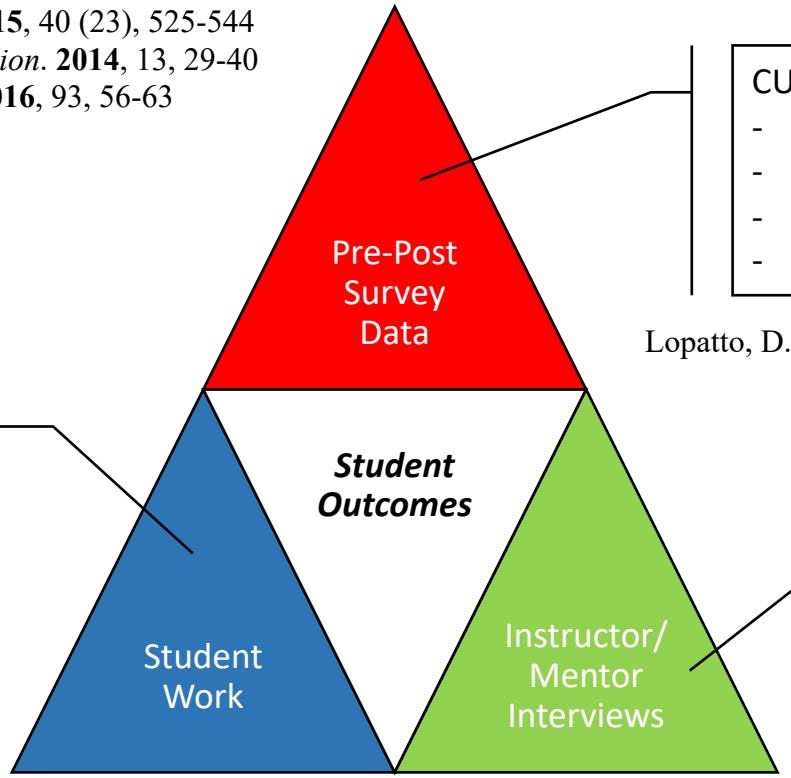
Investigating the S
Using S

Assessment Plan

IRB

Curriculum Outcomes: *What opportunities does the curriculum provide for students to engage in research practices?*

Brownell and Kloser. *Studies in Higher Ed*. **2015**, 40 (23), 525-544
Auchincloss et. al. *CBE – Life Sciences Education*. **2014**, 13, 29-40
Clark et. al. *Journal of Chemical Education*. **2016**, 93, 56-63



CURE Survey:
- Course Elements
- Benefits
- Attitudes
- Overall

Lopatto, D., et al. *Bioscience*. **2013**, 63 (9), 754–762

Lab Reports:
- Written
- Poster
- PowerPoint
- (all evaluated with ~90% similar rubric)

ELIPSS Project, elipss.com

Semi-Structured Interviews:
- Graduate Assistants
- Instructors
- Peer Research Mentors (former students)

Shortlidge, E. E., et. al. *Bioscience* **2016**, *66* (1), 54–62.

Curriculum Assessment

Inquiry classification scheme. Classification by the presence or absence of student independence in scientific practices in General Chemistry I (blue) and General Chemistry II (yellow) Labs. Green indicates both GCI and GCII Labs.

Student independence is limited in Theoretical Background and Methods due to the inexperience of students at this level.

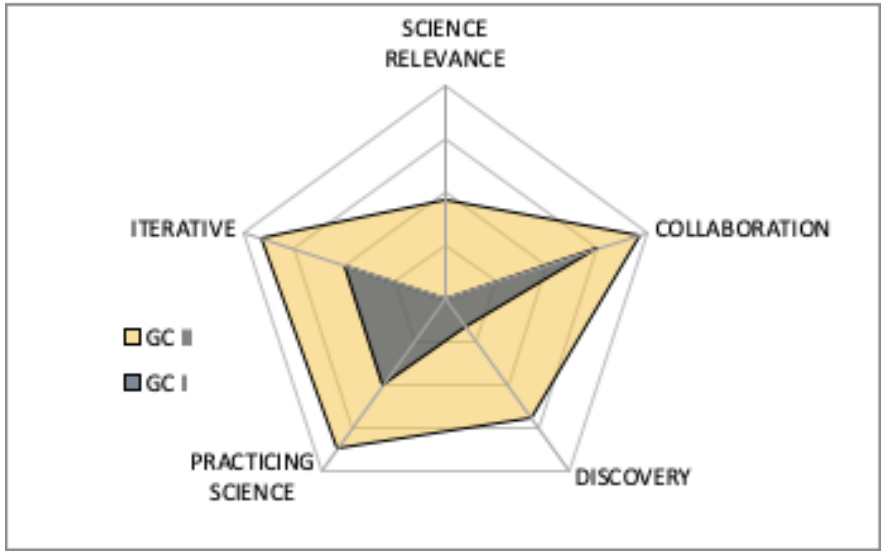
Presence or absence of student independence by scientific practice								
	Inquiry lab type	Research question	Theoretical Background	Methods	Analysis	Conclusions	Communication of Results	Known Answer
Cookbook	Confirmation	NO	NO	NO	NO	YES	YES	YES
CUREs	Structured	NO	NO	NO	YES	YES	YES	YES
CUREs	Guided	NO	NO	YES	YES	YES	YES	YES
CUREs	Open	NO	YES	YES	YES	YES	YES	NO
CUREs	Authentic	YES	YES	YES	YES	YES	YES	NO

Brownell and Kloser. *Studies in Higher Ed*. **2015**, 40 (23), 525-544

Curriculum Assessment

Each characteristic of authentic research experiences is rated from 1-5. A rating of 1 would be in the center of the radar plot and a rating of 5 is the outer edge of the plot.

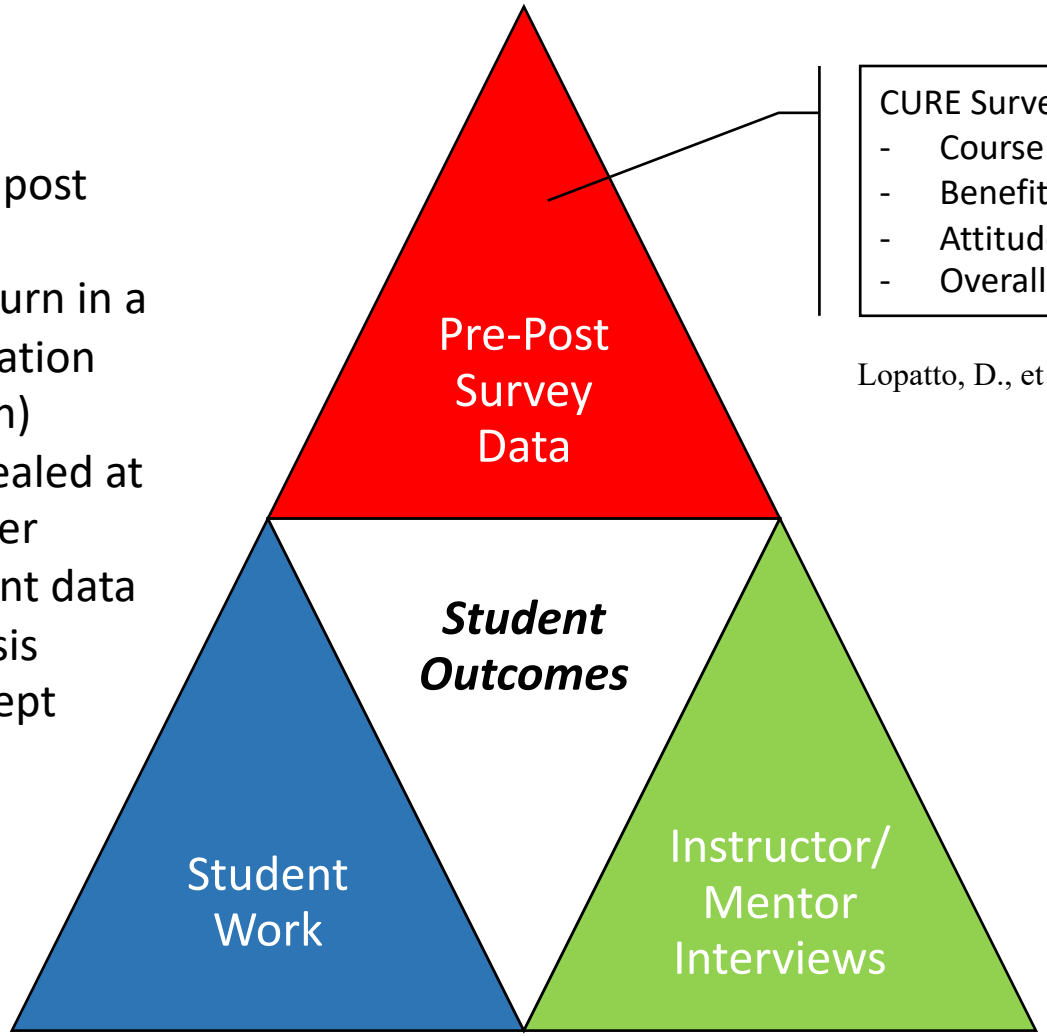
Science Relevance is limited, research projects are NOT related to faculty research.



Auchincloss et. al. *CBE – Life Sciences Education*. **2014**, 13, 29-40
Clark et. al. *Journal of Chemical Education*. **2016**, 93, 56-63
Waterman and Heemstra. *ACS Symposium Series Educational and Outreach Projects from the Cottrell Scholars Collaborative Undergraduate and Graduate Education.* Volume 1 **2017**, 33–63

Assessment Plan – Student Outcomes

- Administered pre and post course
- Students required to turn in a screenshot of confirmation page (5 pts completion)
- Informed consent revealed at the end of the semester
- Non-consenting student data deleted prior to analysis
- Deidentified, no key kept



CURE Survey:
- Course Elements
- Benefits
- Attitudes
- Overall

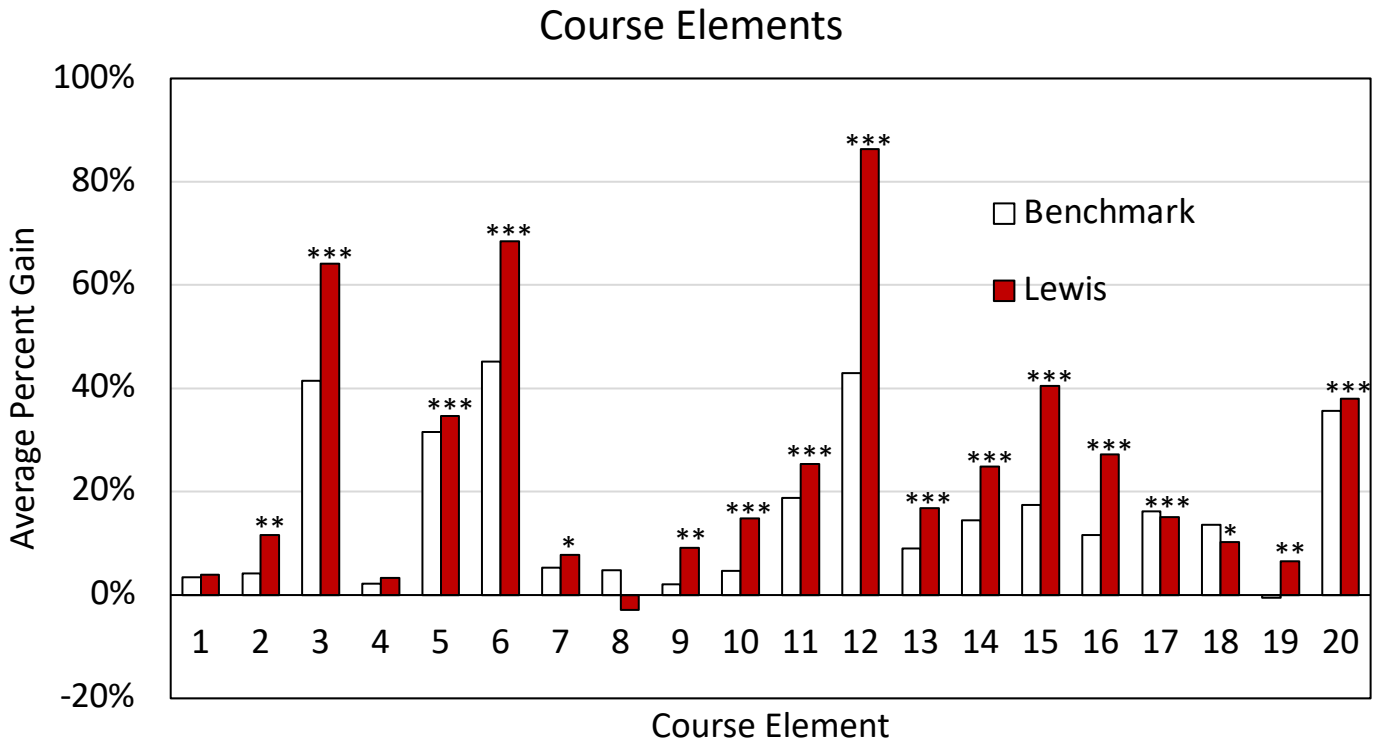
Lopatto, D., et al. *Bioscience*. **2013**, 63 (9), 754–762

CURE Survey – Course Elements

Pre/Post Comparison

Students reported significant gains ($p < 0.05$) on 17/20 items with medium to large effect size on 11/20 items.

Largest (black bars) and smallest (white bars) percent gains are shown with corresponding Cohen's d values.



Percent gains are calculated as the average gain for the item divided by the average pre-course score.
Asterisks indicate the significance level:

** $p < 0.05$ (5/20 items) ** $p < 0.001$ (1/20 items) *** $p < 0.000$ (11/20 items)*

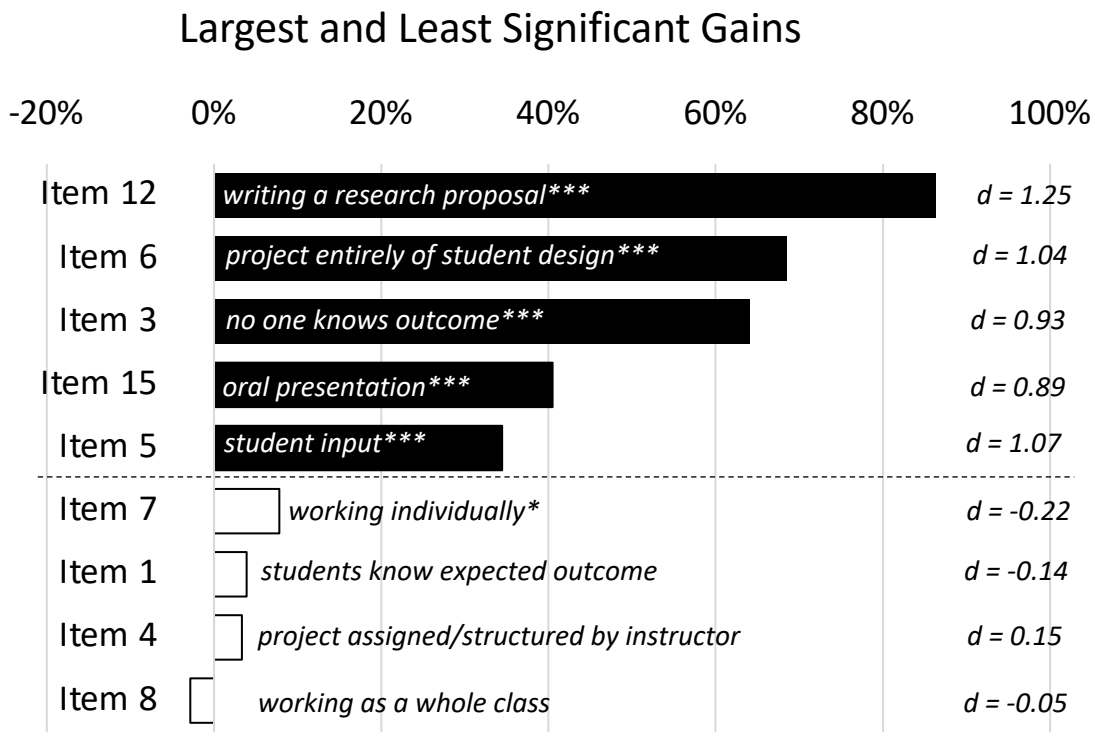
CURE Survey – Course Elements

Pre/Post Comparison

Students reported significant gains ($p < 0.05$) on 17/20 items with medium to large effect size on 11/20 items.

Largest (black bars) and smallest (white bars) percent gains are shown with corresponding Cohen's d values.

COMMUNICATION/WRITING
PROCESS of RESEARCH
TEAMWORK
DATA COLLECTION/ANALYSIS
PRIMARY LITERATURE



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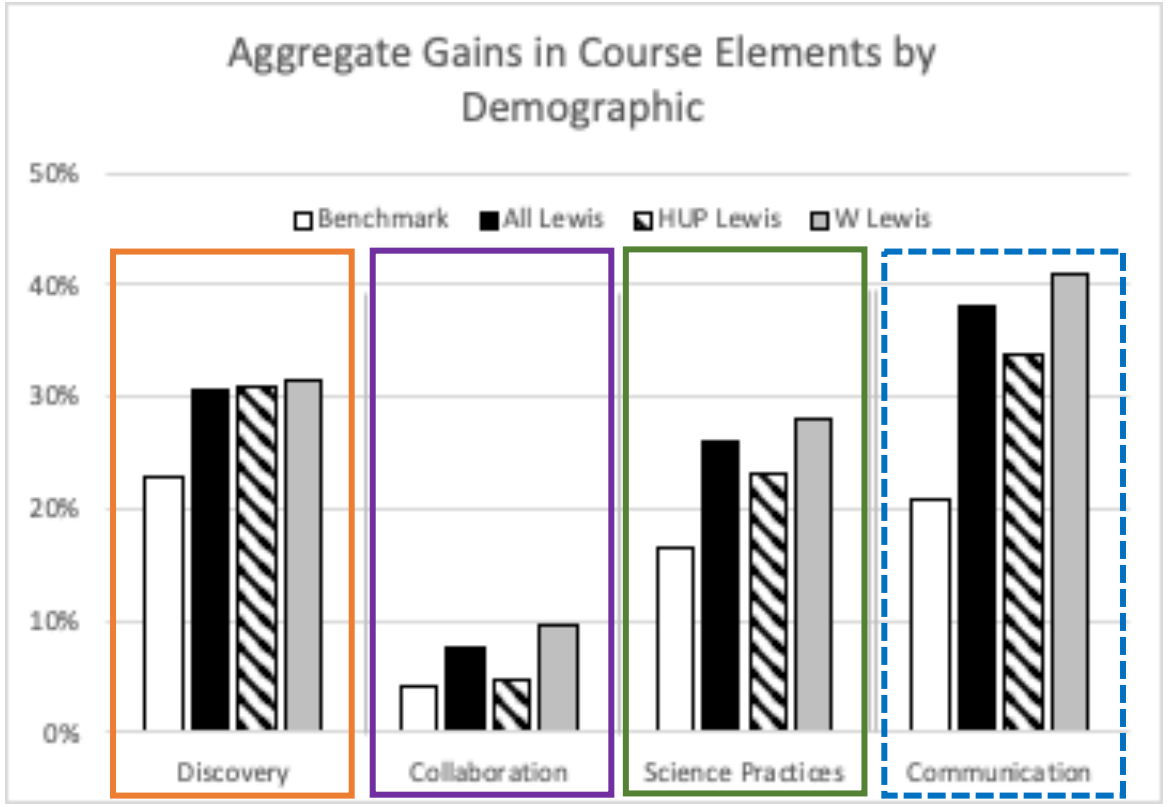
** $p < 0.05$ (5/20 items) ** $p < 0.001$ (1/20 items) *** $p < 0.000$ (11/20 items)*

CURE Survey – Course Elements

Nineteen of the 20 items were also aggregated into scale factors along 3 of the 5 critical components of research experiences; ***discovery***, ***collaboration***, and ***practicing science***. Further, a subset of the practicing science items can be categorized as ***communication***.

The racially disaggregated gains in the scale factors reveal that the gains for students from historically underrepresented populations are lower than those for white students. However, nearly half of individual items (9/20) reveal larger gains for students in HUPs.



When aggregated, the negative items were reverse coded. These scale factors were calculated as the sum of item gains for the category divided by the sum of item scores from the pre-course survey. Benchmark CURE data, N ≤ 17680.

CURE Survey – Benefits

Item	Lewis	Benchmark SURE	p-value	Hedge's g
1: Clarification of career path.	2.51	3.26	0.000	-0.68
9: Understand that scientific assertions require supporting evidence.	4.14	3.50	0.000	0.56
10: Ability to analyze data and other information.	4.13	3.66	0.000	0.46
11: Understand science.	3.90	3.49	0.001	0.38
12: Learning laboratory techniques.	4.14	3.66	0.001	0.38
15: Skill in science writing.	3.81	3.14	0.000	0.57

No significant differences by demographic are found in the student-reported benefits.

In the post-course CURE survey students were asked to report how much they feel they gained on 18 items.

Lopatto reports no statistically-significant differences between benchmark CURE and SURE responses.

For most items Lewis-reported gains are statistically similar to both benchmark CURE and SURE gains. However, there are ***six items with statistically-significant differences between Lewis and benchmark SURE responses*** ($N \leq 3281$).

WRITING
PROCESS of RESEARCH
DATA ANALYSIS

CURE Survey - Attitudes

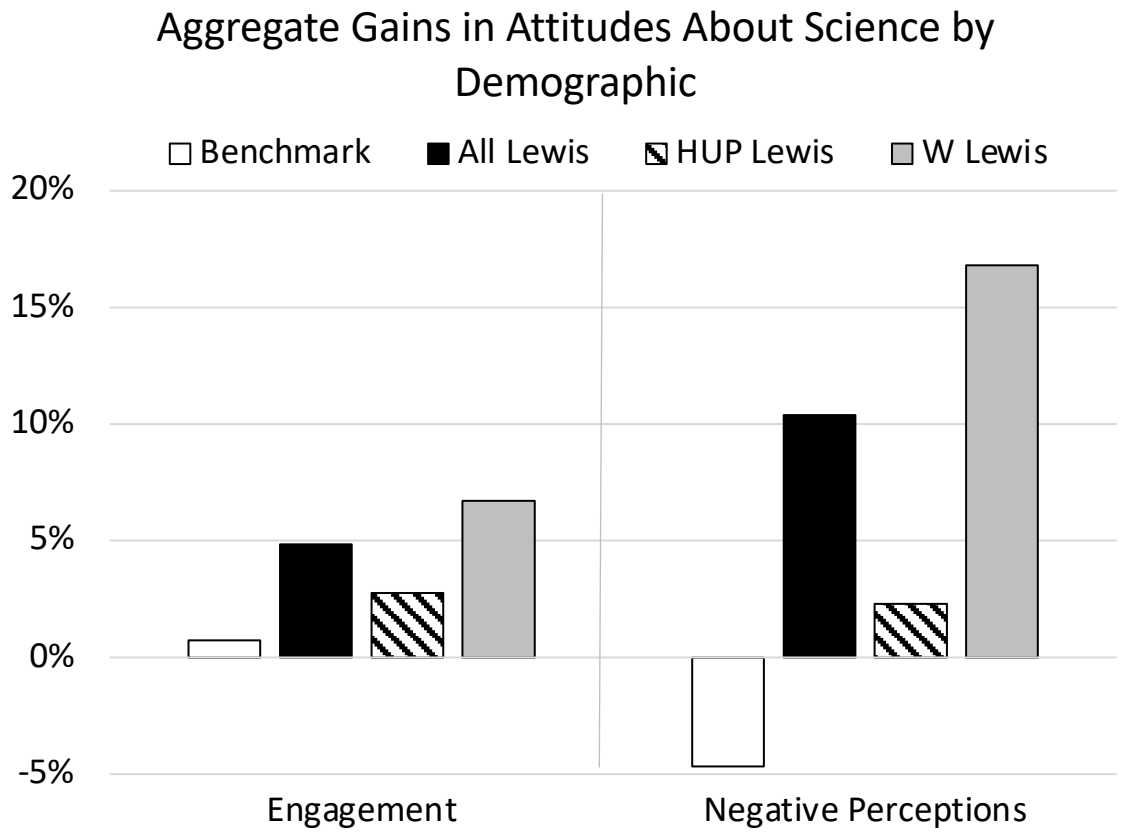
Pre/Post Comparison

Students were asked to rate their agreement with 15 items related to positive and negative attitudes about science.

From benchmark data, there are 2 scale factors:

- “Engagement”, 5 items
- “Negative Attitudes”, 6 items

Lopatto reports no large gains in attitudes in the benchmark data.



The negative attitudes have been reverse coded so that a decrease in agreement with a negative attitude appears as a positive gain.

WRITING
CRITICAL THINKING

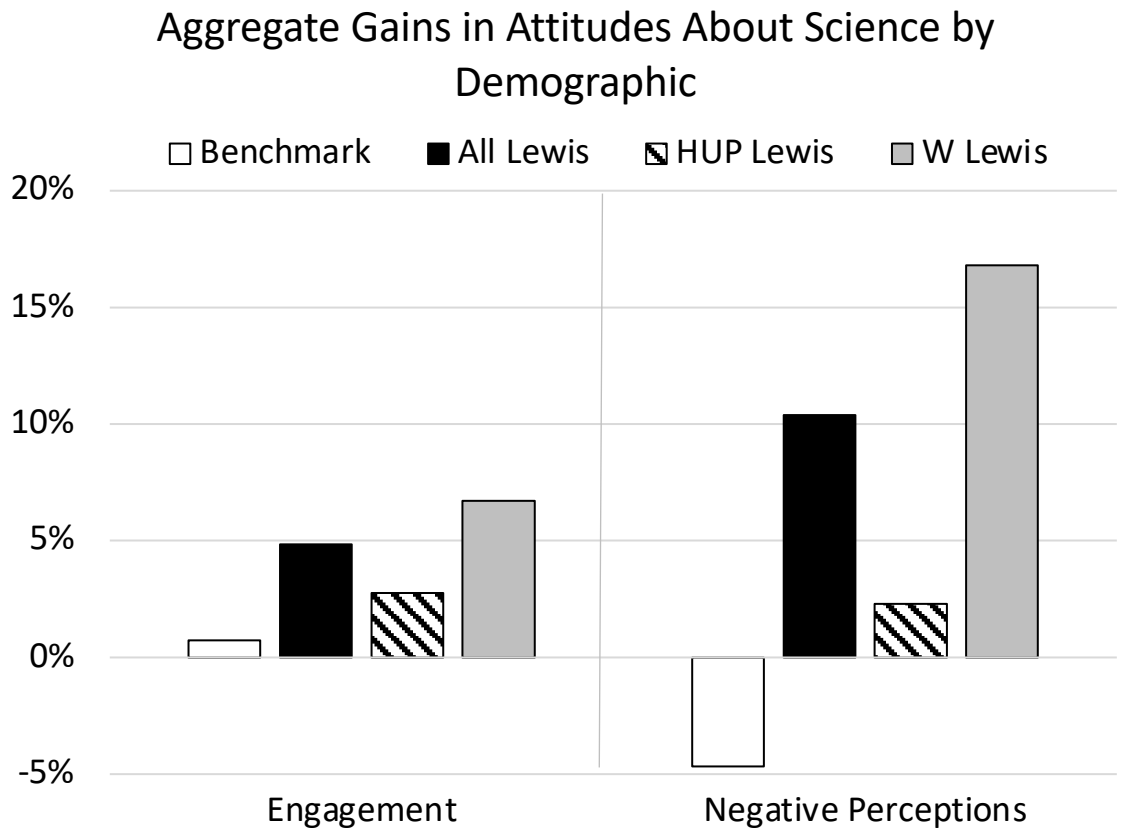
CURE Survey - Attitudes

Disparities in Negative Attitudes driven by:

"Science is not connected to non-science fields such as history, literature, economics, or art."
(loss for HUP, gain for W)

"There is too much emphasis in science classes on figuring things out for yourself."
(no change for HUP, gain for W)

"Only scientific experts are qualified to make judgements on scientific issues."
(loss for HUP, gain for W)



The negative attitudes have been reverse coded so that a decrease in agreement with a negative attitude appears as a positive gain.

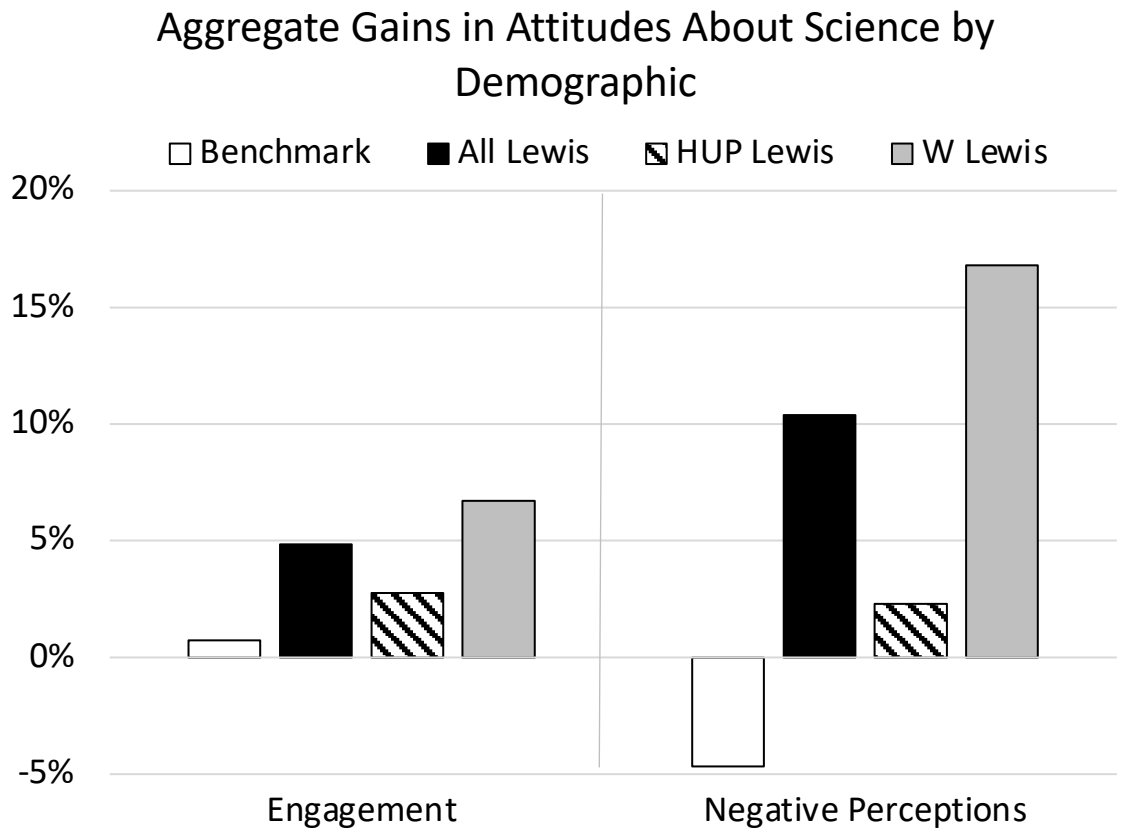
WRITING
CRITICAL THINKING

CURE Survey - Attitudes

Gains Across The Board:

"Even if I forget the facts, I'll still be able to use the thinking skills I learn in science."

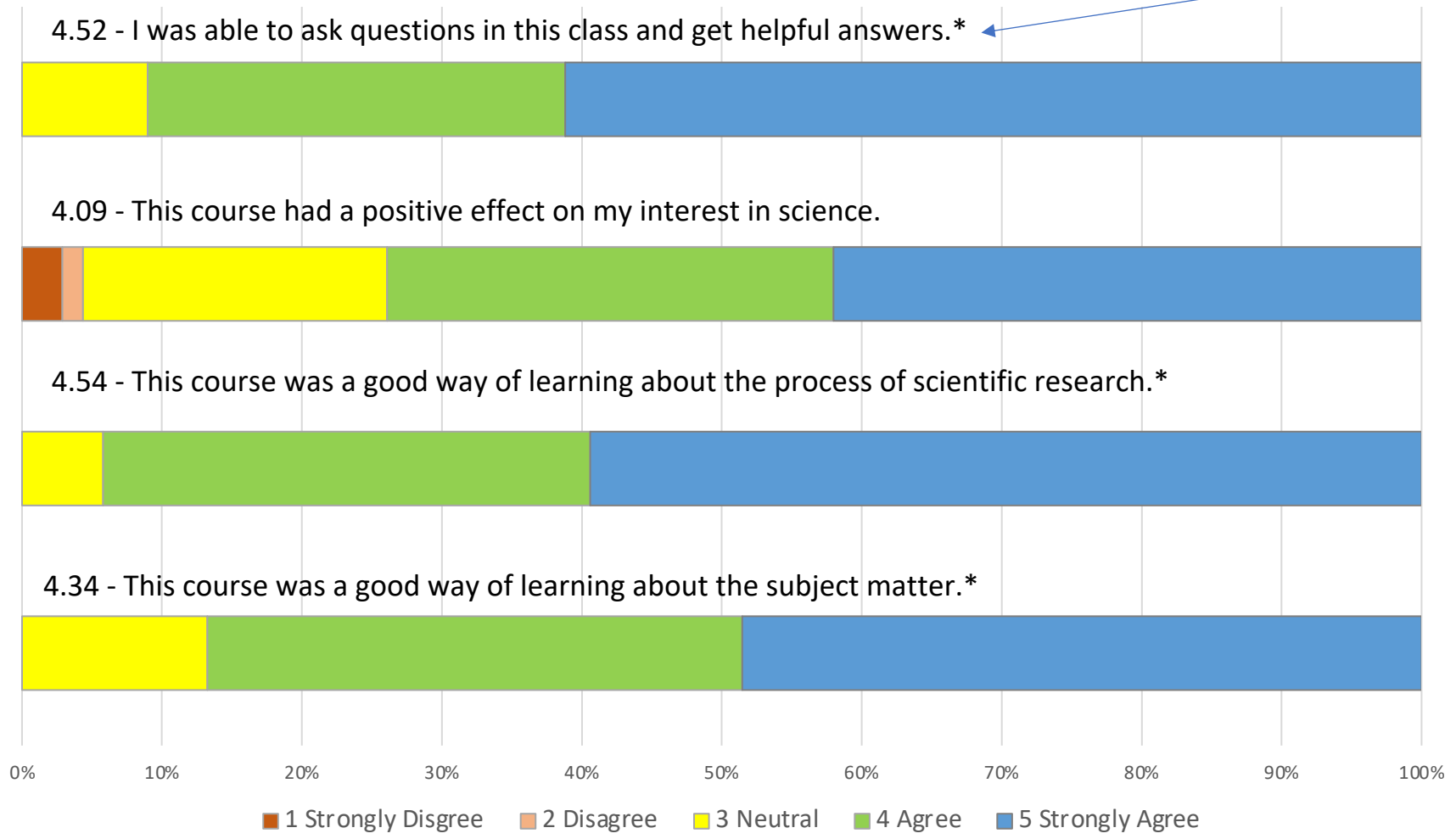
"The process of writing is helpful for understanding scientific ideas."



The negative attitudes have been reverse coded so that a decrease in agreement with a negative attitude appears as a positive gain.

WRITING
CRITICAL THINKING

CURE Survey – Overall Evaluation



Slight statistical difference between HUP and White students.

POSITIVE FEELINGS ABOUT SCIENCE

PROCESS of RESEARCH

CONTENT KNOWLEDGE

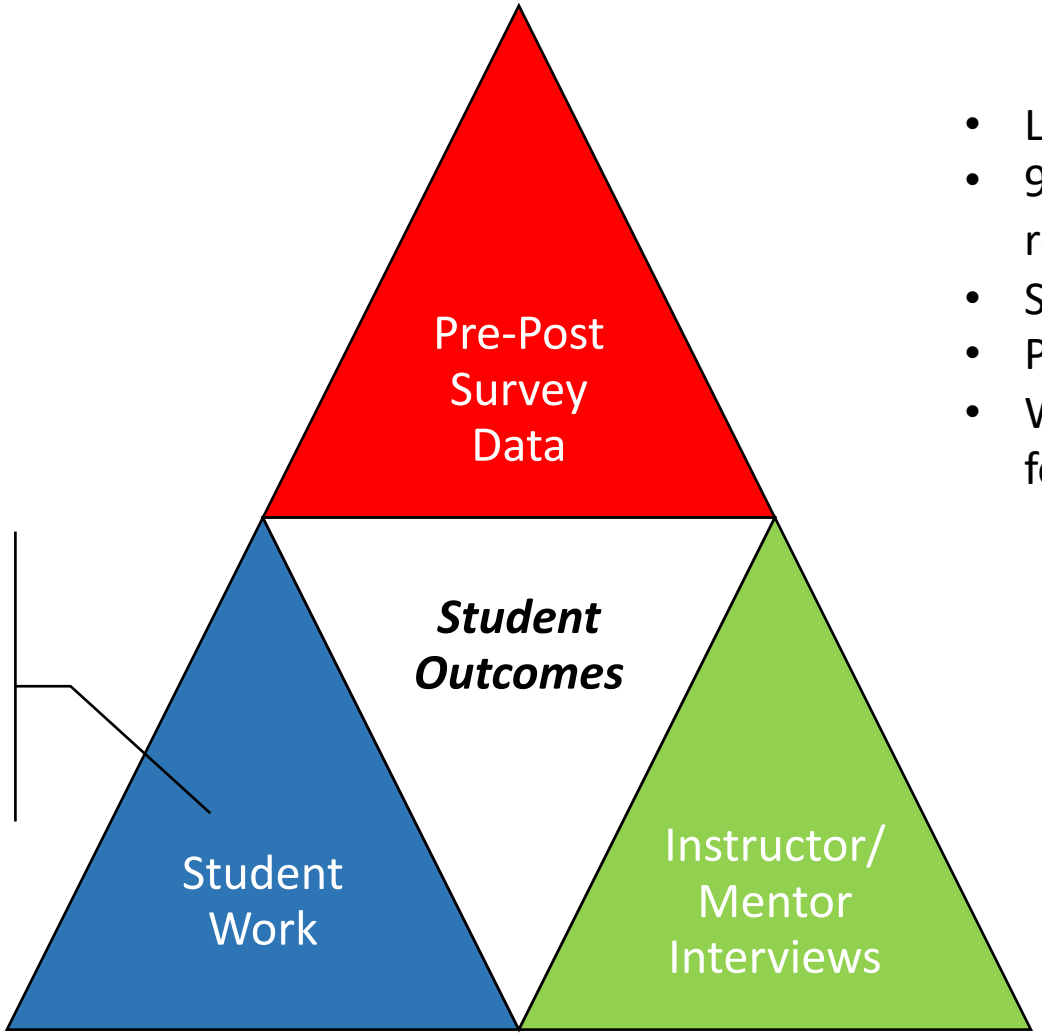
Comparison to Benchmark Data, N ≤ 17680:

* $p < 0.05$

** $p < 0.001$

*** $p < 0.000$

Assessment Plan



Lab Reports:
- Written
- Poster
- PowerPoint
- (all evaluated with ~90% similar rubric)

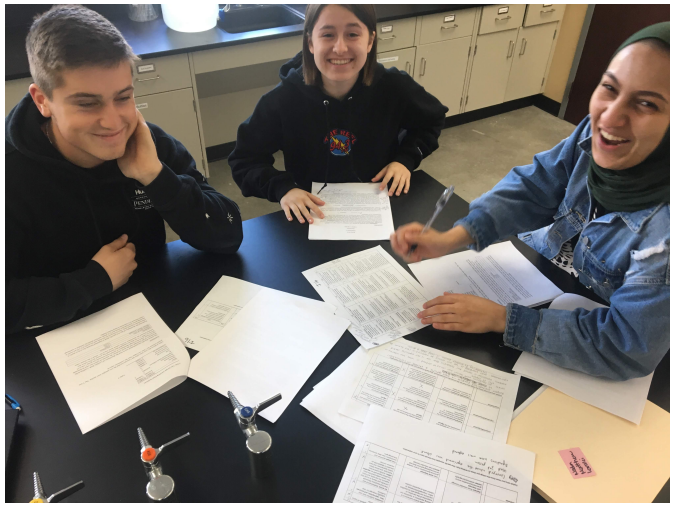
ELIPSS Project, elipss.com

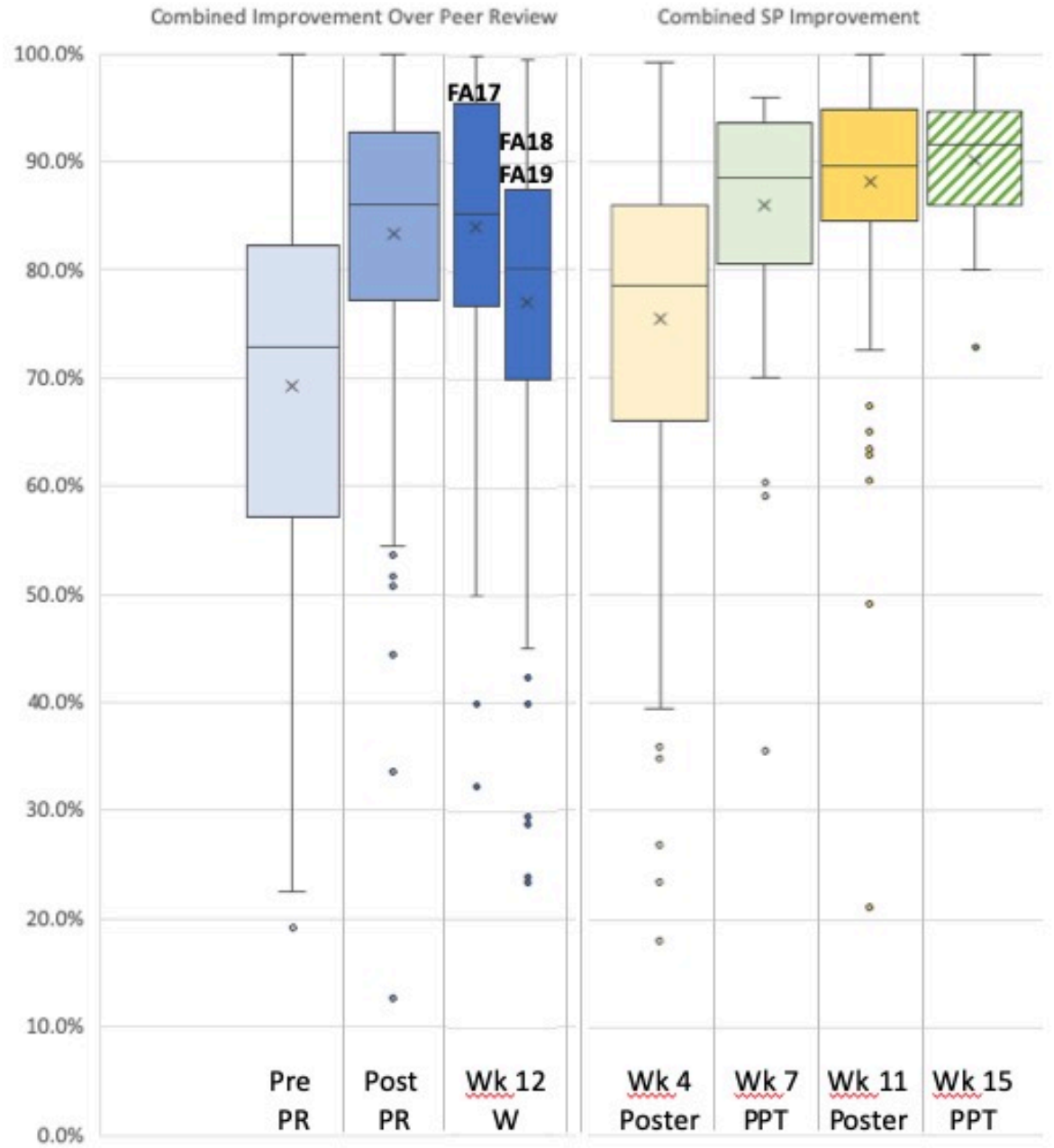
- Lab Reports scored by GAs
- 90% common rubric for all report formats
- Scaffolded writing in GCI
- Peer review in GCI
- Writing, Posters, and PPT formats in GCII

Writing

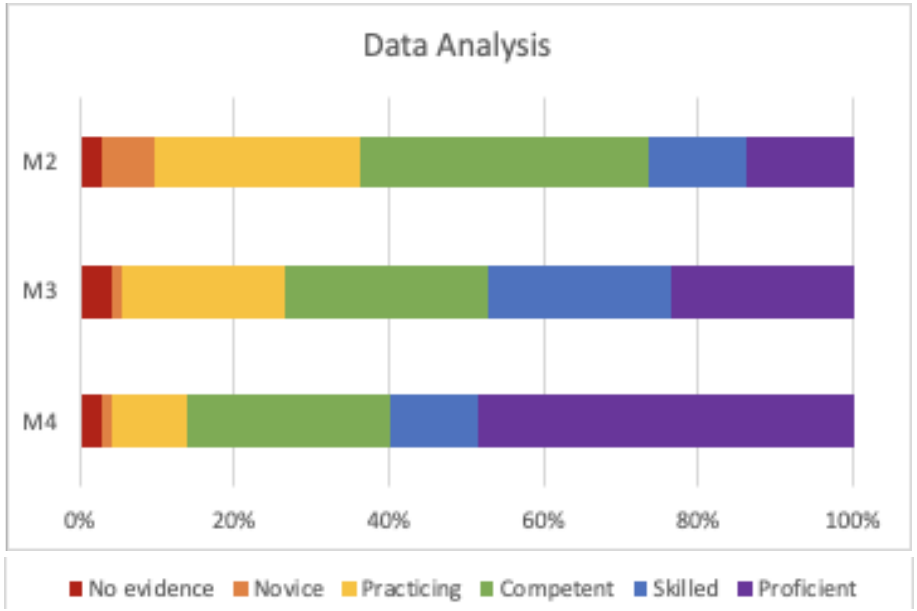
Average total lab report score through General Chemistry I and II Labs, aggregate of three years. N < 220.

Stripes indicate a team assignment. Color indicates lab report style; blue is written, yellow is poster, green is PowerPoint.



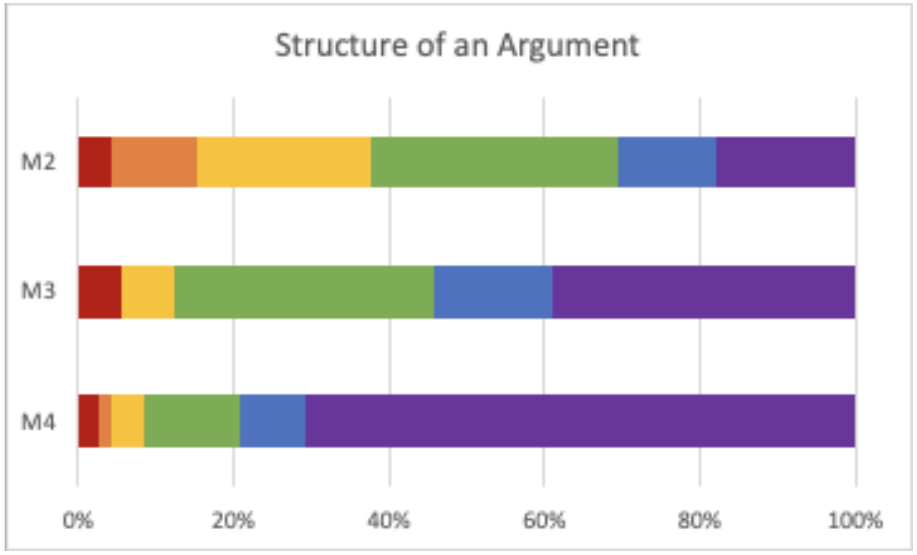


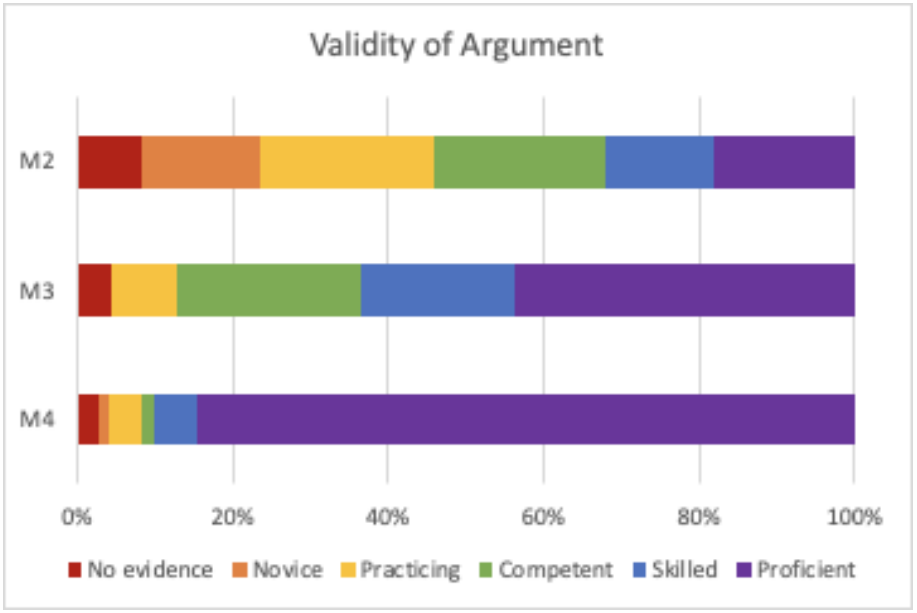
Data Analysis and Argumentation



Rating distributions over General Chemistry II Lab, SP20.

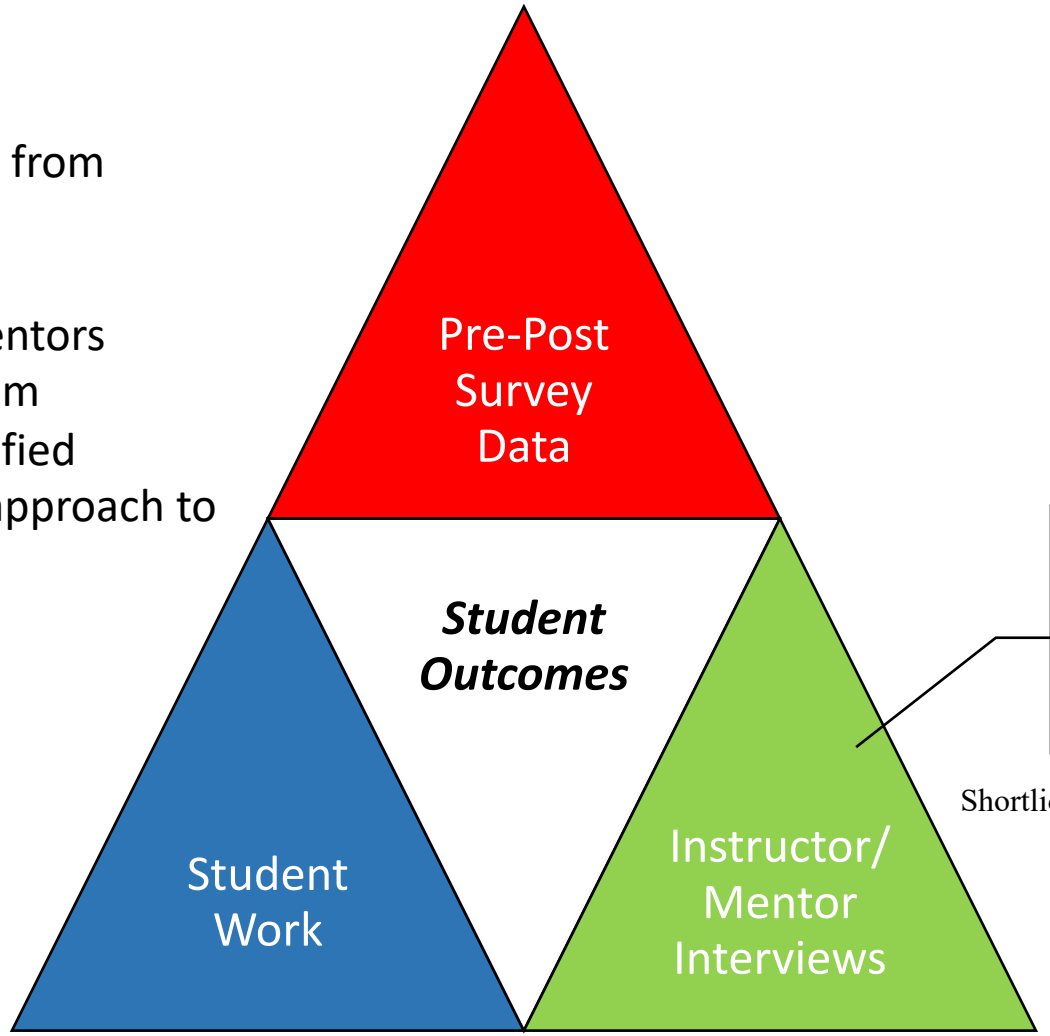
Modules 2, 3, and 4 are indicated by M2, M3, and M4 and correspond to the Week 4 poster report, Week 7 PPT report, and Week 11 poster report, respectively. N = 72.





Assessment Plan

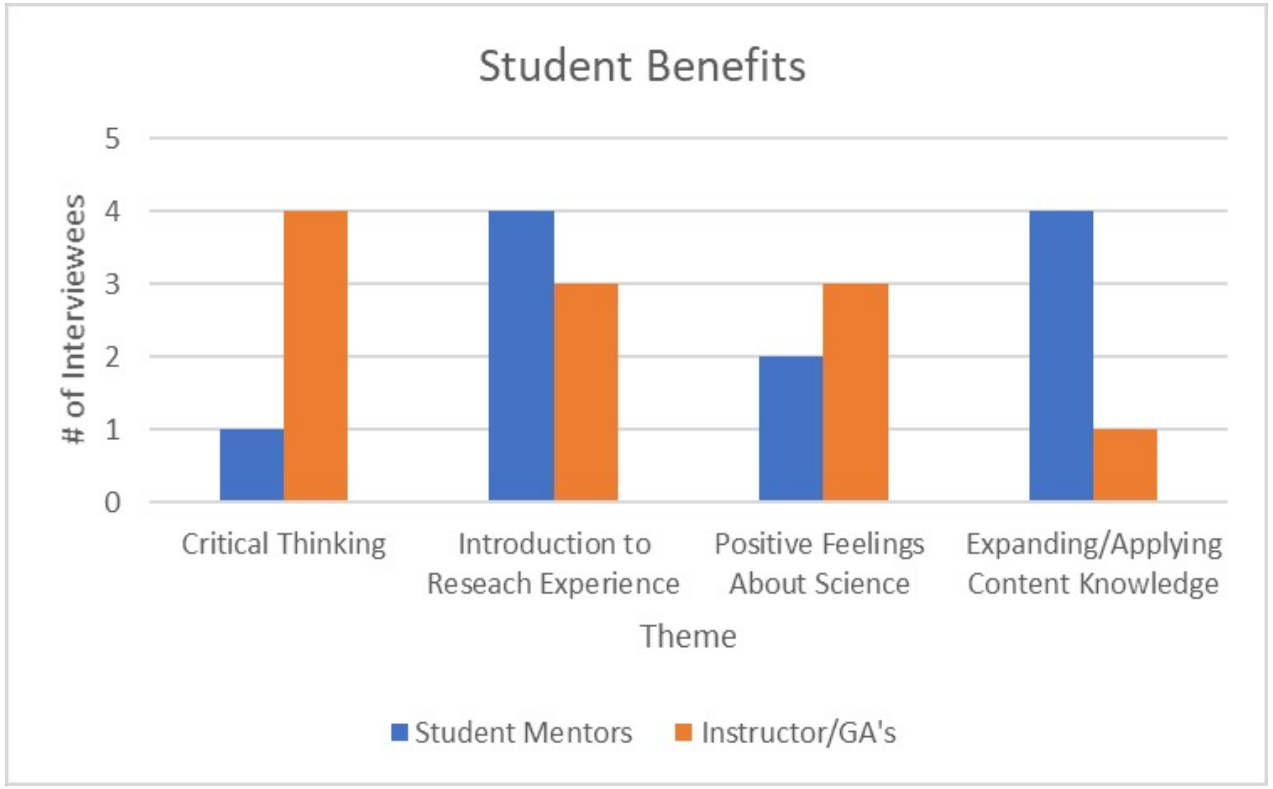
- Questions modified from Shortlidge
- 1 instructor, 4 GAs
- 5 Peer Research Mentors
- Interviews over Zoom
- Transcripts deidentified
- Iterative inductive approach to coding in ATLAS.ti



Semi-Structured Interviews:
- Graduate Assistants
- Instructors
- Peer Research Mentors (former students)

Shortlidge, E. E., et. al. *Bioscience* **2016**, *66* (1), 54–62.

Interview Themes

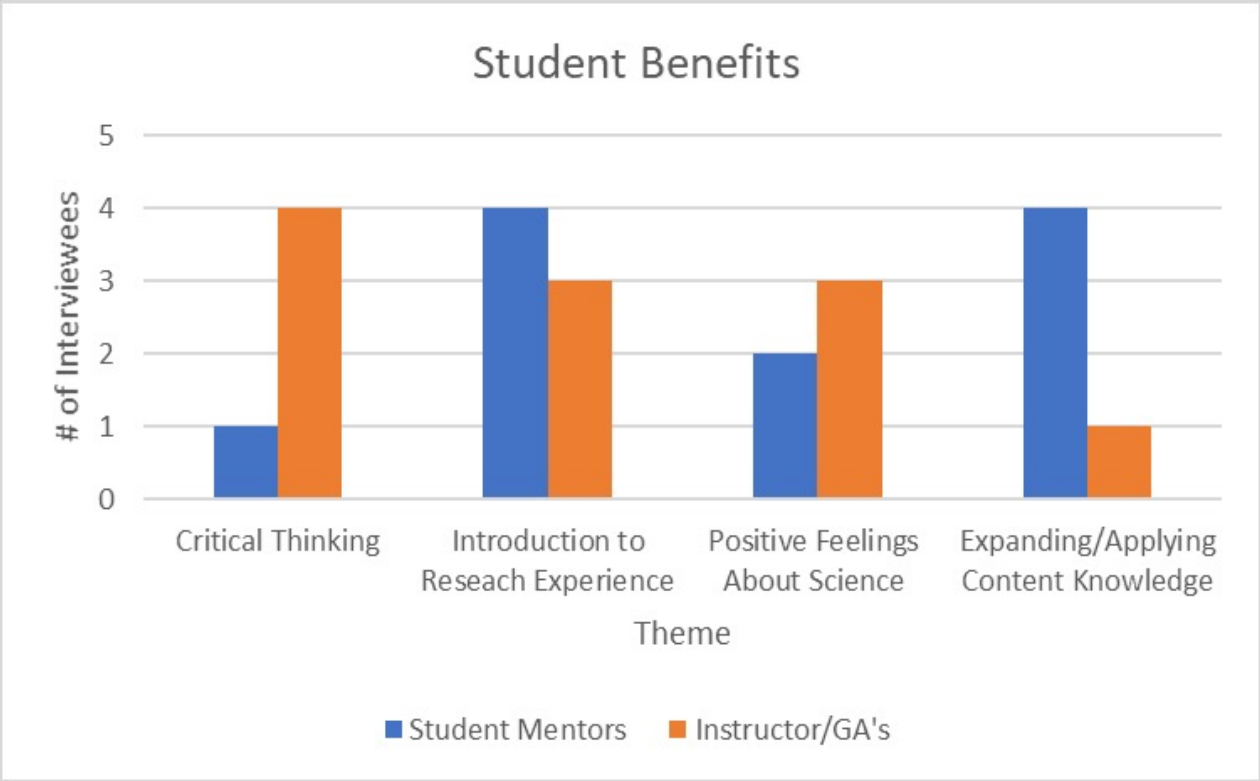


Critical Thinking: ⅕ PRMs, ⅘ GA/Is

"It teaches them to kind of be able to ***take it a step further and think on their own and kind of maybe come up with a plan and see how it fails****. Or [see] some of the obstacles that might come up throughout that plan. I mean [it's] really not just a skill related to chemistry, but any kind of learning," - GA/I 3*

"It's guided still so you're not completely on your own but you're ***really able to think for yourself*** *and develop those ideas." - PRM D*

Interview Themes

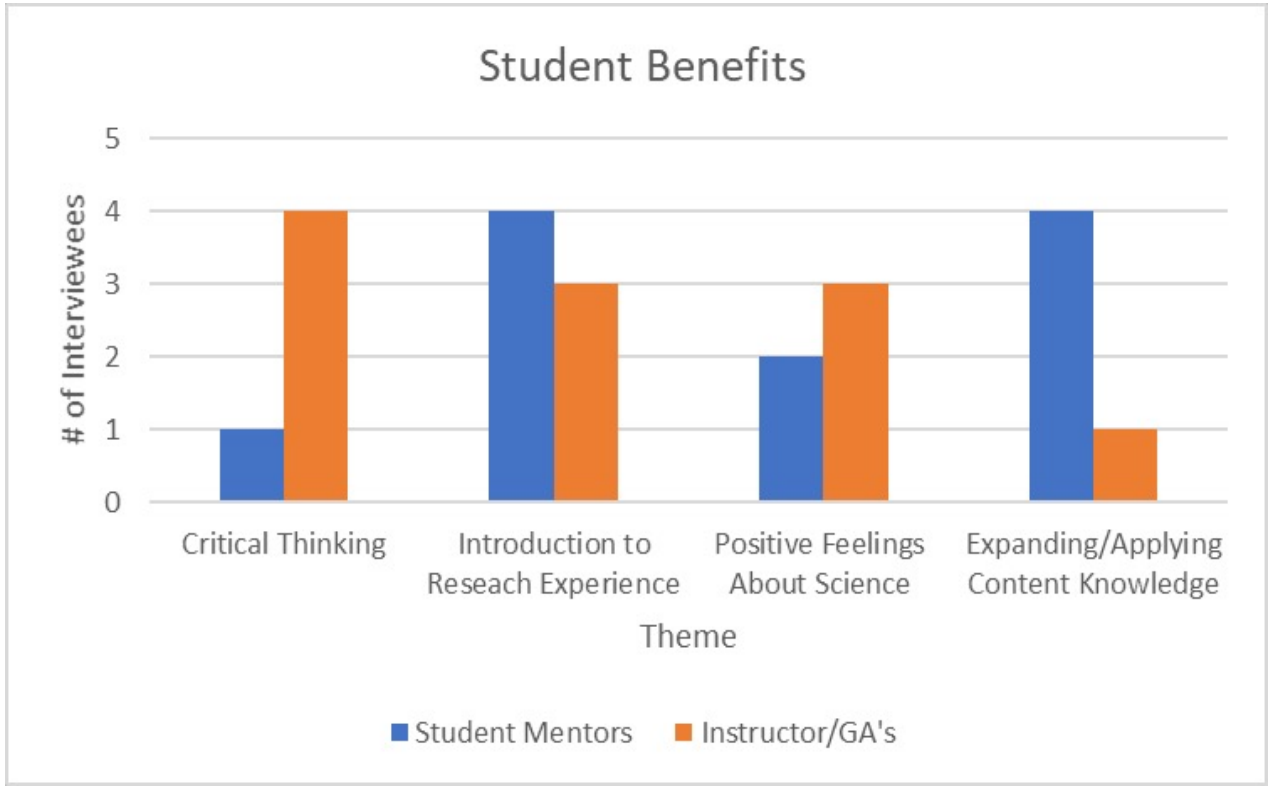


Introducing Research: ⅘ PRMs, ⅗ GA/Is

"...not only just you come one week and it's like a cookbook, but ***they were able to use what they wanted, what they thought would work for an experiment for their research goal*** *and apply that." - GA/I 4*

"I think that the process of scientific inquiry that they kind of went through with the SAMs project ***really mimics that of real research and I think that that's a really valuable experience*** *even if they won't end up doing undergraduate research." - PRM A*

Interview Themes

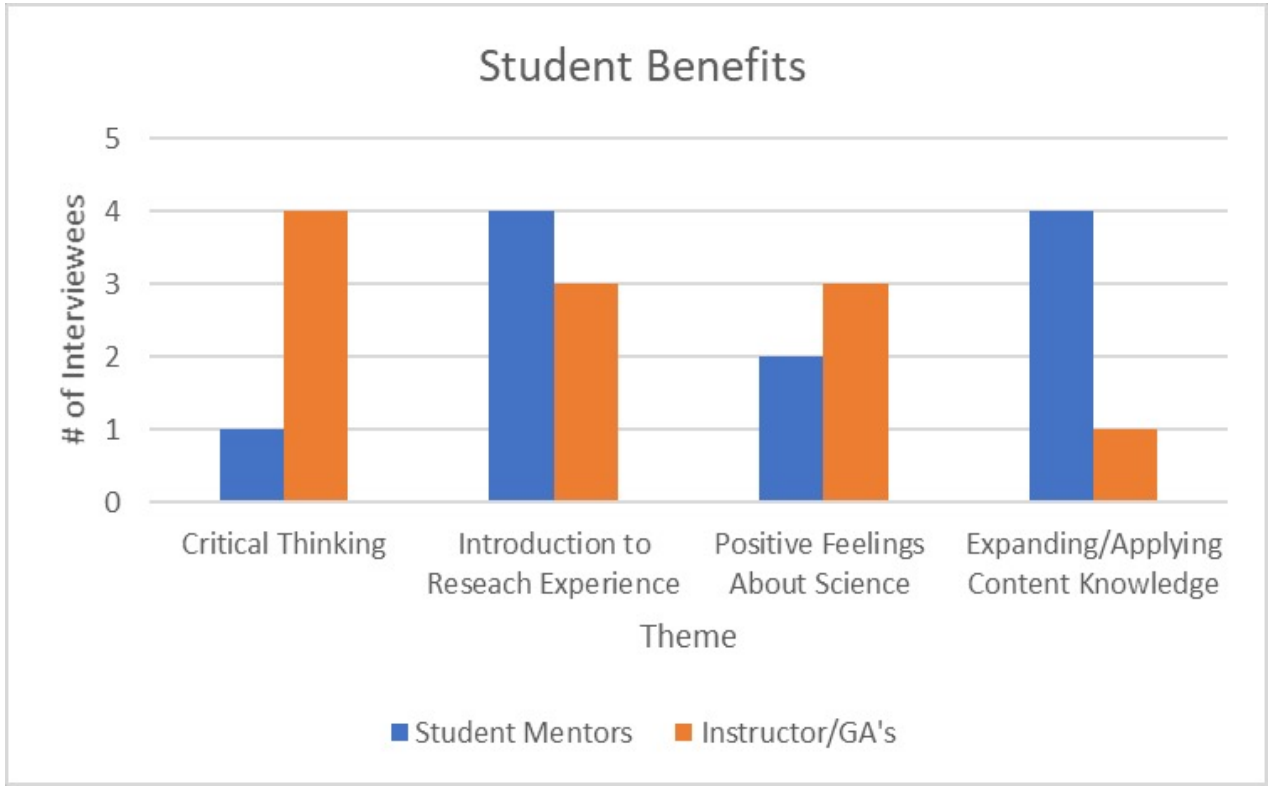


Positive Feelings about Science: ⅖ PRMs, ⅗ GA/Is

"I think the CURE is really helpful for students to ***realize how much they like science*** *or like the scientific process." - GA/I 1*

*"...it kind of got me thinking like, '****Huh. Maybe I would be interested in doing this,*** *you know?" - PRM C*

Interview Themes



Content Knowledge: ⅘ PRMs, ⅕ GA/Is

"I think the students were able to ***grasp concepts from gen chem lecture and apply those concepts in the lab****." - GA/I 4*

"It gives them just a different way to look at ***applications of what they're learning****, in the real world by doing the research." - PRM E*

Additional Comments

Communicating Science:

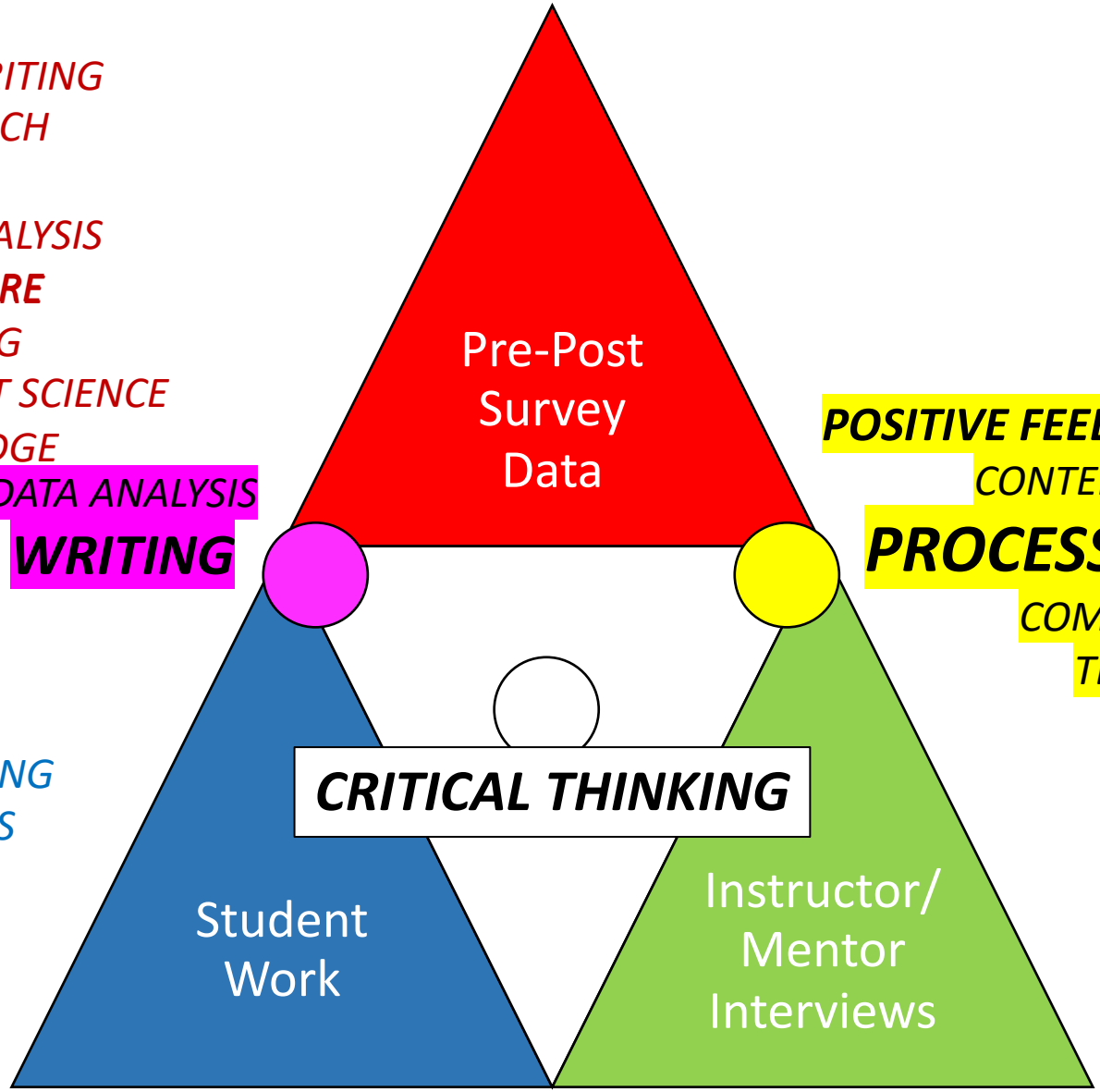
"I think ... having [students] ***speak in front of a classroom*** *is something that you kind of miss out in some other lab experiences." - GA/I 1*

Teamwork/Community:

"In my experience, I was able to pick my team and they were two people that I was like really comfortable with... So we were able to work together really well and I think it was just a really cool experience because... ***it was almost like a mini research team****..." - PRM C*

Triangulation of Student Outcomes

COMMUNICATION/WRITING
PROCESS of RESEARCH
TEAMWORK
DATA COLLECTION/ANALYSIS
PRIMARY LITERATURE
CRITICAL THINKING
POSITIVE FEELINGS ABOUT SCIENCE
CONTENT KNOWLEDGE



DATA ANALYSIS
WRITING

POSITIVE FEELINGS ABOUT SCIENCE
CONTENT KNOWLEDGE
PROCESS of RESEARCH
COMMUNICATION
TEAMWORK

CRITICAL THINKING
DATA ANALYSIS
WRITING

COMMUNICATION
PROCESS of RESEARCH
TEAMWORK
CRITICAL THINKING
POSITIVE FEELINGS ABOUT SCIENCE
CONTENT KNOWLEDGE

Outcomes Reported in the Literature

	Outcome	CURE References
Probable	Increased content knowledge	Lopatto et al. 2008; Shaffer *et al.*, 2010, 2014; Siritunga *et al.*, 2011; Brownell *et al.*, 2012; Rowland *et al.*, 2012; Jordan *et al.*, 2014; Kloser *et al.*, 2013
	Increased analytical skills	Shaffer *et al.*, 2010, 2014; Siritunga *et al.*, 2011; Bascom-Slack *et al.*, 2012; Brownell *et al.*, 2012; Hanauer *et al.*, 2012; Alkaher and Dolan, 2014; Jordan *et al.*, 2014
	Increased self-efficacy	Drew and Triplett, 2008; Lopatto *et al.*, 2008; Shaffer *et al.*, 2010, 2014; Siritunga *et al.*, 2011; Kloser *et al.*, 2013; Jordan *et al.*, 2014
	External validation from a science community	Hatfull *et al.*, 2006; Lopatto *et al.*, 2008; Caruso *et al.*, 2009; Shaffer *et al.*, 2010, 2014; Jordan *et al.*, 2014
	Persistence in science	Drew and Triplett, 2008; Harrison *et al.*, 2011; Hanauer *et al.*, 2012; Bascom-Slack *et al.*, 2012; Brownell *et al.*, 2012; Jordan *et al.*, 2014; Shaffer *et al.*, 2014
	Increased technical skills	Drew and Triplett, 2008; Shaffer *et al.*, 2010; Jordan *et al.*, 2014; Rowland *et al.*, 2012
	Career clarification	Drew and Triplett, 2008; Harrison *et al.*, 2011; Shaffer *et al.*, 2014
Possible	Increased project ownership	Shaffer *et al.*, 2010; Hanauer *et al.*, 2012; Alkaher and Dolan, 2014
	Increased communication skills	Lopatto *et al.*, 2008; Jordan *et al.*, 2014; Shaffer *et al.*, 2014
	Increased motivation in science	Shaffer *et al.*, 2010, 2014; Alkaher and Dolan, 2014
	Increased collaboration skills	Shaffer *et al.*, 2010, 2014
	Increased tolerance for obstacles	Jordan *et al.*, 2014; Shaffer *et al.*, 2014
	Increased sense of belonging to a larger community	Jordan *et al.*, 2014; Shaffer *et al.*, 2014
	Enhanced science identity	Hanauer *et al.*, 2012; Alkaher and Dolan, 2014
	Increased positive interaction with peers	Shaffer *et al.*, 2010; Alkaher and Dolan, 2014
Proposed	Increased access to faculty interaction	Alkaher and Dolan, 2014
	Increased access to mentoring functions	Hanauer *et al.*, 2012
	Enhanced understanding of the nature of science	Russell and Weaver, 2011
	Development of self-authorship	Alkaher and Dolan, 2014

Dolan, E. L., Report by the Committee on Strengthening Research Experiences for Undergraduate STEM Majors **2016**

Conclusions

- Impactful experience
- Many significant gains
- Outperformed benchmark data
- Inequitable outcomes?

- Unsustainable CURE model

Related Work

- Instructor/GA and Peer Research Mentor outcomes from interviews
  - Mantas Miliauskas Capstone FA20
- Laboratory Observations
  - Ashley Lardi Capstone SP21
- Longitudinal Impact – survey of participation in research experiences
  - Zach Minogue Capstone SP21
- Curriculum Revision
  - Consider inequitable outcomes

Related Work

- During COVID we adjusted our curriculum to be completely virtual. How did that impact student responses to the CURE survey?
- Deployed with the CURE surveys was a Mindset survey. How did student Mindset change over the course of SP21 semester? How does that compare to the SP20 semester?

    - Michelle Tiltges Capstone SP22

THANK YOU!