Assessing Student Learning Outcomes in Undergraduate STEM Courses

Moderated by:
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Executive Director, STEM-NET
Office of the Chancellor

STEM-NET

https://www2.calstate.edu/impact-of-the-csu/research/stem-net

Assessing Student Learning in STEM Courses

Speakers

Regis Komperda, San Diego State University
Catalyzing Best Practices in Chemistry Assessment

Rachel Teasdale, Chico State
Improving Student Performance with Aligned Activities and Assessments in a Large Lecture Geoscience Course

Gina Passante, CSU Fullerton
Assessments for “Just-in-Time" Instruction

Vimal Viswanathan, San Jose State University
Assessing Student Learning in Blended-Model and Flipped Classrooms

Dermot Donnelly, Fresno State
Using Knowledge Integration Rubrics to Score Assessment Items for an Undergraduate Laboratory

Seema Shah-Fairbank & Laila Jallo, Cal Poly Pomona
Integrated Assessment Strategies: From Course to Program to Institution

Anya Goodman, Cal Poly San Luis Obispo
Can Assessment Help Students Transform from “Point Collectors” into Scientists?

Catalyzing Best Practices in Chemistry Assessment

Regis Komperda – San Diego State University

Collaborators:
Jack Barbera, Portland State University
Jordan Harshman, Auburn University

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Regis Komperda, Assistant Professor

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Project Background

Community Needs

Drawing appropriate conclusions about student outcomes requires high quality data

Data Collection

Quantitative assessment data are often collected using measurement instruments

Tests, concept inventories, surveys, etc.

How do we know if an instrument already exists or should be created?

Evaluation of Data Quality

How do we know an instrument is providing high quality data?

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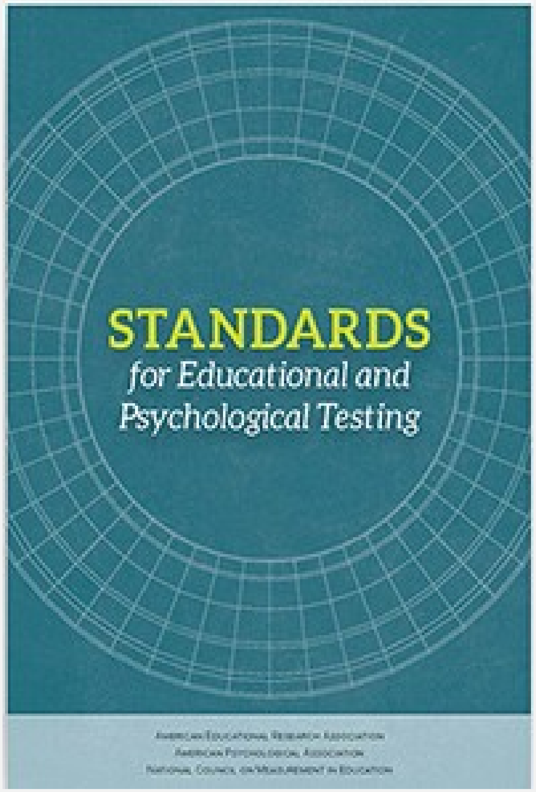
Data Quality Evidence

Guidelines established in *Standards for Educational and Psychological Testing* (AERA, APA & NCME, 2014) and within chemistry education (Arjoon, Xu & Lewis, 2013)

- Validity/accuracy: Is there evidence that the scores measure what is intended?
- Reliability/precision: Is there evidence that the measurements are consistent?

This information must be collected and evaluated **each** time an instrument is used

- *How can we keep track of this information for every instrument?*
- *How can we synthesize this information for every instrument?*



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CHIRAL Project

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- **Chemistry Instrument Review and Assessment Library (CHIRAL)**
  - Centralized resource for chemistry education community to find instrument information
  - Integrated into existing community resource supported by American Chemical Society
    - Chemical Education Xchange (ChemEdX: https://www.chemedx.org/)
- **Planned Features**
  - Searchable catalog of instruments used in chemistry education
    - List of publications using the instrument and alternative versions or translations
  - Identification of studies providing data quality evidence (validity/reliability)
  - Peer-reviewed panel summary synthesizing data quality evidence
  - Glossary of assessment terms

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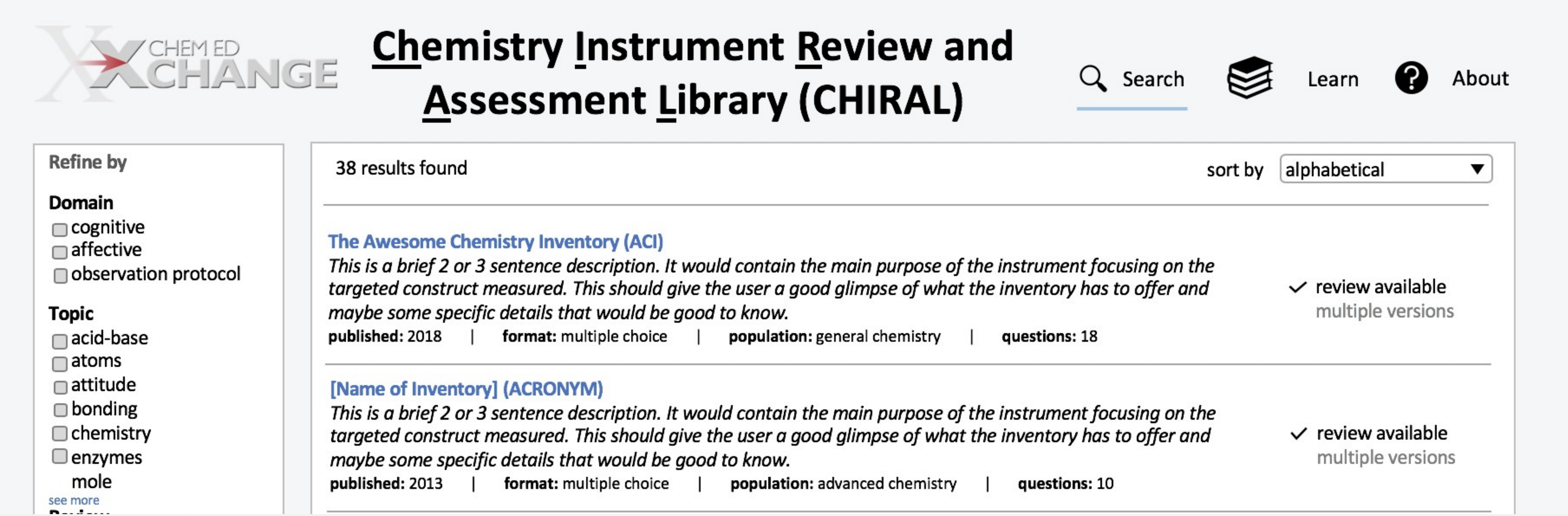
CHIRAL Website Plans



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Next Steps/Long-Term Plans

- Currently in first year of this three-year project
  - To date, nearly 100 instruments have been identified in the chemistry education literature
    - Preliminary cataloging and database construction is ongoing
  - Glossary materials are being developed
  - Interviews with target user population are helping to refine CHIRAL website design

- Planning for peer-review panels to occur in second year of the project

- CHIRAL website launch will be announced through ChemEdX website and listserv (https://cer.chemedx.org/)

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Other Resources

- **Chemistry**:
  - American Chemical Society Exams Institute (https://uwm.edu/acs-exams/)
  - Assessment Resources compiled by Bretz Group (http://chemistry.miamioh.edu/bretzsl/cer/assessment.html)
- **Physics**: PhysPort (https://www.physport.org/assessments/)
- **Geology**: https://serc.carleton.edu/NAGTWorkshops/assess/geo_concept_assess.html
- **Engineering**: Appraisal System for Superior Engineering Education Evaluation-instrument Sharing and Scholarship (ASSESS)
- **STEM**: STEM Learning and Research Center (http://stelar.edc.org/resources/instruments)
- **Education**: EdInstruments (https://edinstruments.com/)
- **Psychology**:
  - PsycTESTS: https://www.apa.org/pubs/databases/psyctests/
  - Mental Measurements Yearbook: https://buros.org/mental-measurements-yearbook

Improving Student Performance with Aligned Activities and Assessments in a Large Lecture Geoscience Course

Rachel Teasdale, Chico State
& Hannah Aird

Rachel Teasdale, Professor

Chico State, Department of Geological & Environmental Sciences

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Improving Student Performance with Aligned Activities

Project Overview

Introductory Geology (GE) Course Revision

Overarching goal: Engage students in learning about Earth, improved geoscience literacy through:

- use of relevant course topics, small group work and in-class activities

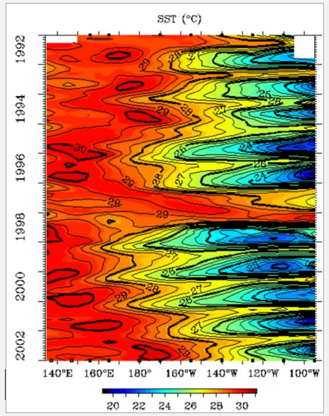
Rachel Teasdale *Chico State /Geological & Environmental Sciences rteasdale@csuchico.edu*

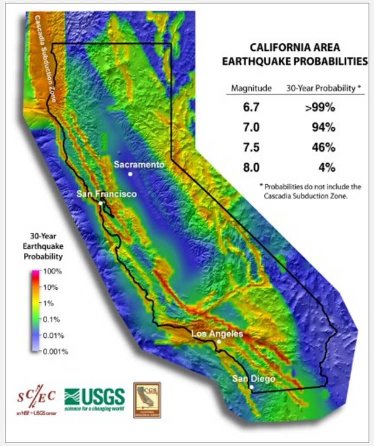
Improving Student Performance with Aligned Activities

Activities

Significant Changes (Backwards Design)

- Identified SLOs & important skills:
  - Content learning + use and interpretation of data (maps, graphs), communication, team work
- Designed assessments (formative and summative)
  - Formative: Questioning strategies (clicker questions), daily in-class small group activities (Jigsaw activities, modified Gallery Walks)
  - Summative Assessment: Two stage exams with individual + group components, MC + short answer questions
- Developed Course Activities
- Logistics: rooms, student assistants





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Results

No significant change in DFW between pre- and post- design

Self- evaluation: design, SLOs, activities use valid practices
(e.g. Wiggins & McTighe, 1998; Freeman et al., 2014, Haak et al., 2011)

Self- evaluation: Assessment
(but it's just what we've always done…)

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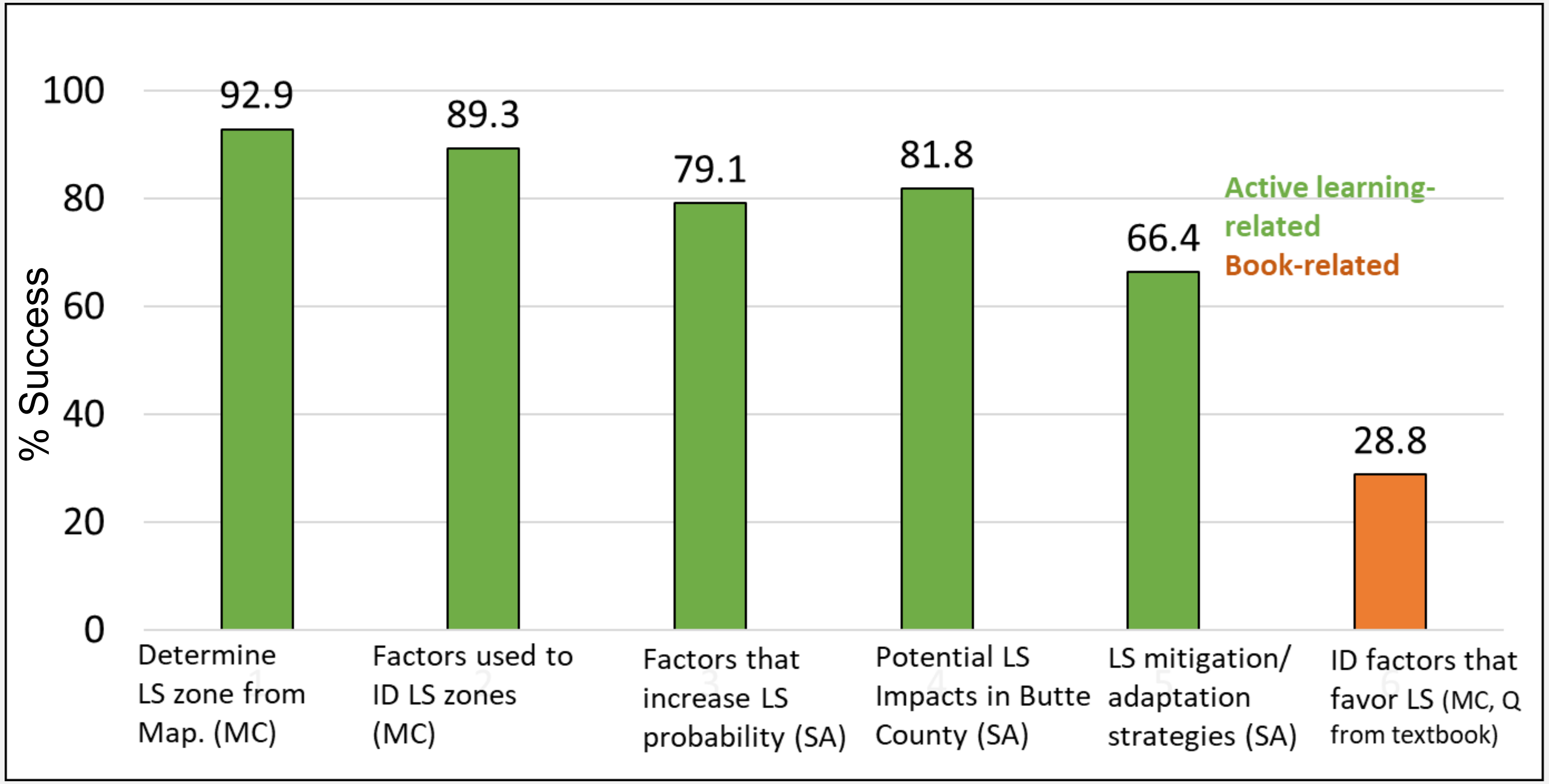
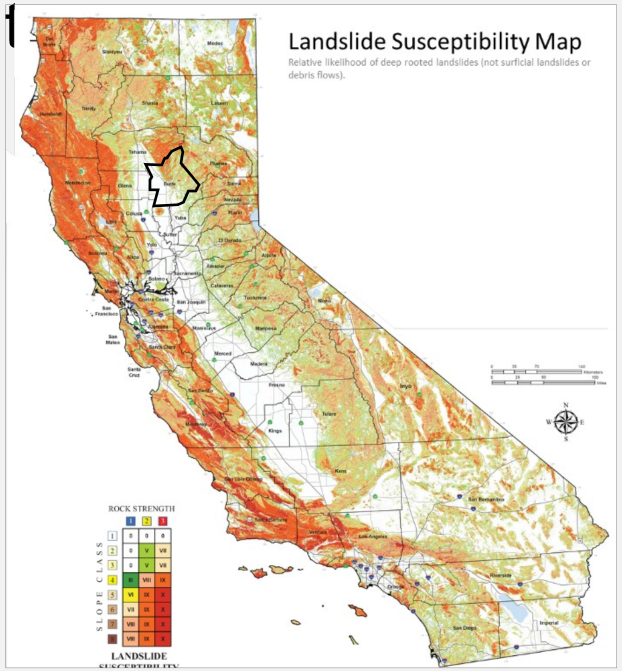
Improving Student Performance with Aligned Activities

Results

Self- evaluation: 3 Exams, MC Qs largest point component

Landslide MC Qs





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Improving Student Performance with Aligned Activities

Results

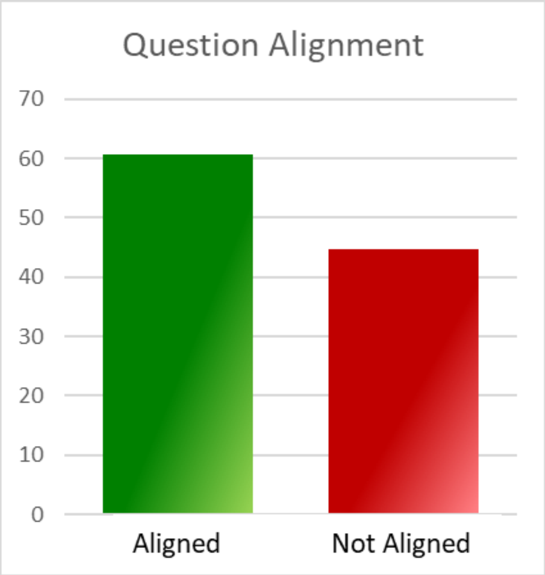
Instructional Style:

1. Textbook Reading
2. Instructor-provided reading (e.g. USGS FS)
3. Video (e.g. UNAVCO, USGS)
4. Lecture
5. In-class activities

Alignment

Assessment Style

1. Recall (identification, label a map/graphic)
2. Applying knowledge (identify a process, implications)
3. Procedural knowledge (identify a method, tools; rate best process)
4. Interpretation (evaluate/ generate an idea from data, use familiar procedure in new application)
5. Metacognition (self-efficacy rating)



Student performance is best when assessment questions are aligned with learning activities

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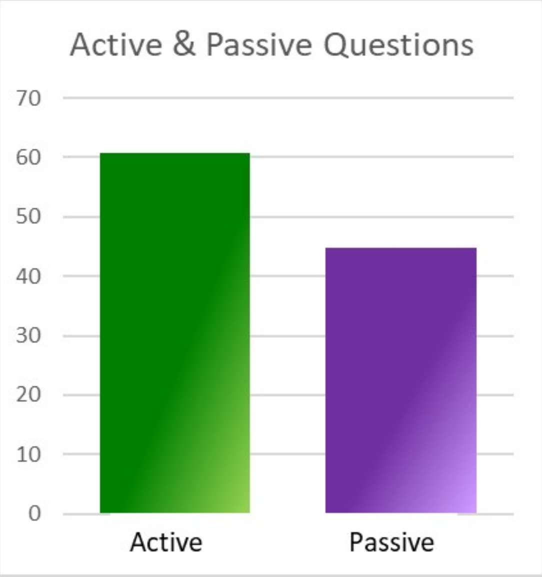
Passive

Active



Student performance is best when assessment questions measure active learning

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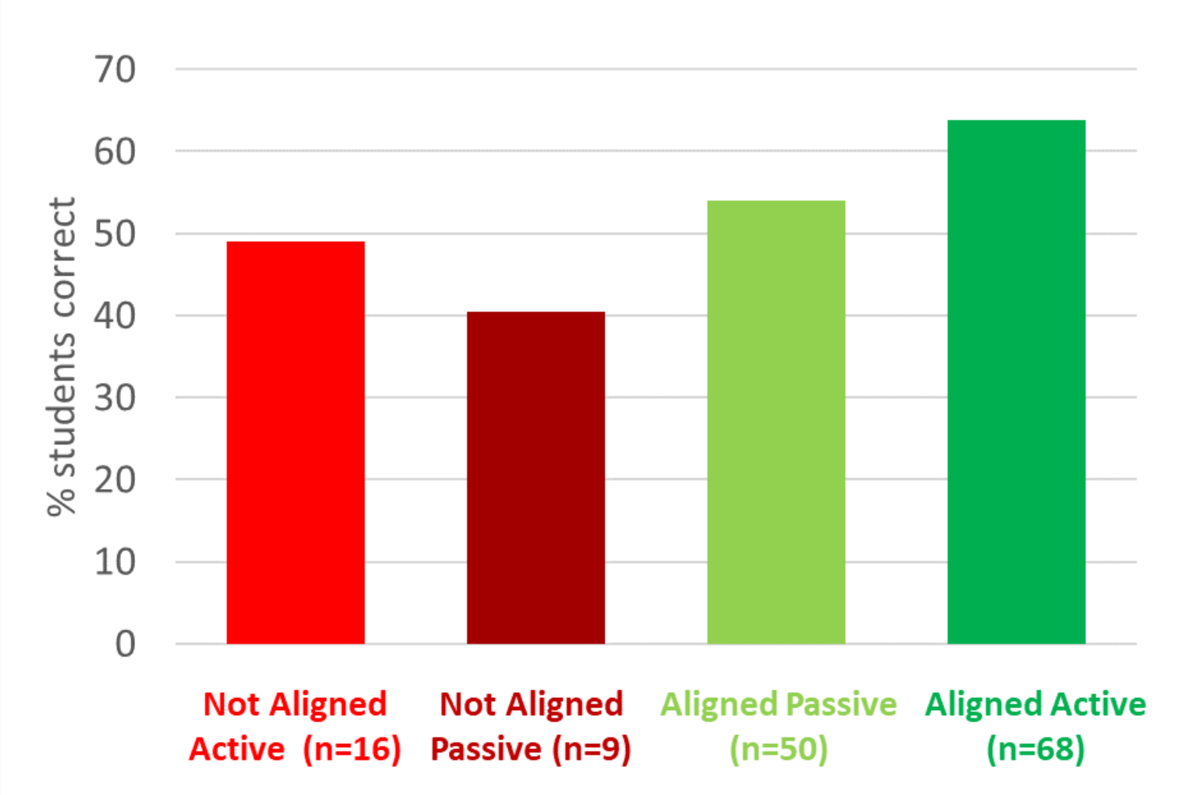
Improving Student Performance with Aligned Activities

Results

- Students perform best on aligned questions
- Students perform better on active than passive questions
- Students perform best on aligned-active questions



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Improving Student Performance with Aligned Activities

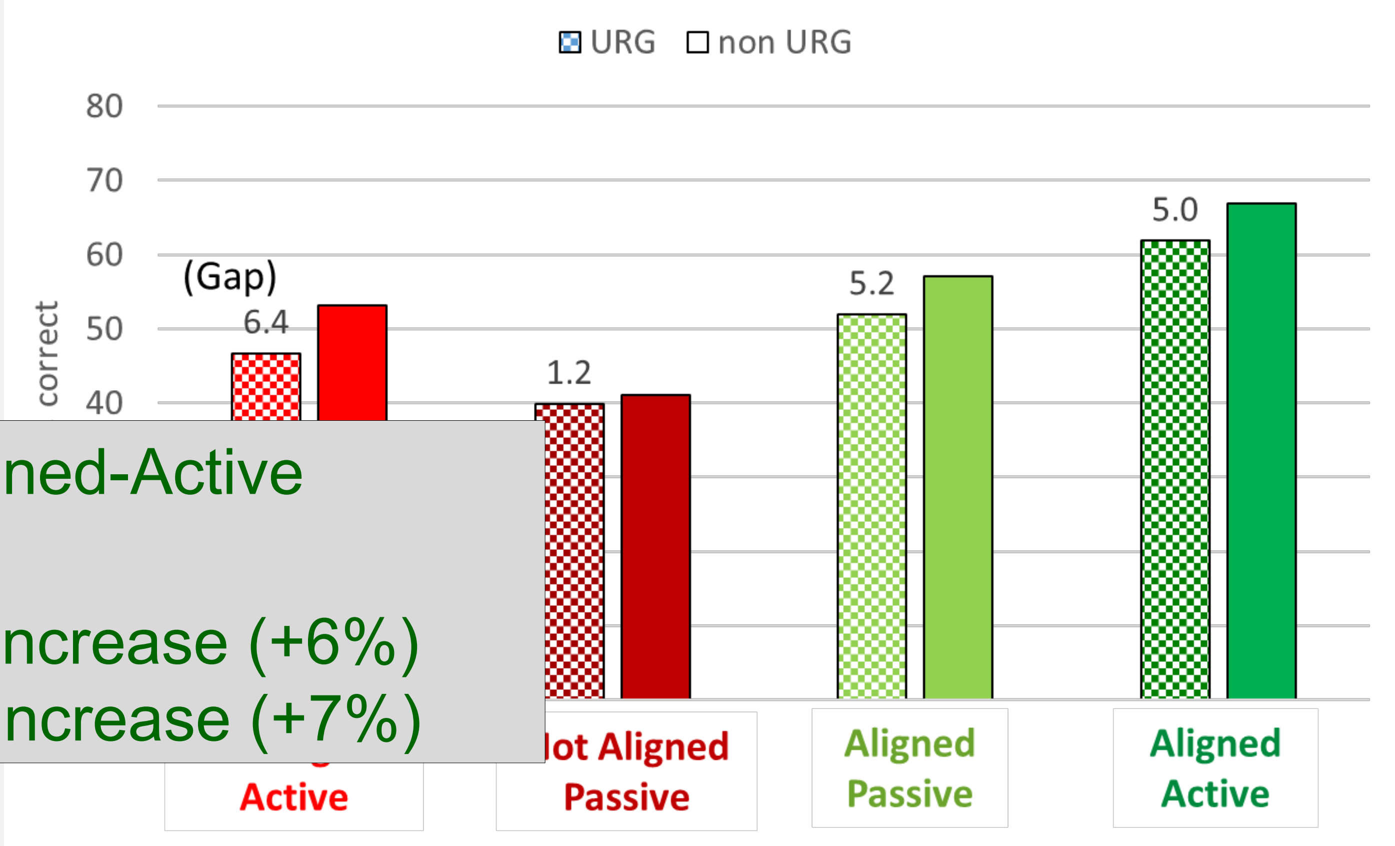
Results

Equitable assessments?

- 65% URG students

  URG = URM (43%), 1st Generation (49%), PELL-eligible (46%)

- All student groups perform best on aligned-active questions
- Performance Gap remains, but lower than 13% DFW gap



What if we had only used Aligned-Active Questions?

- 87% students' MC grades increase (+6%)
- URG students MC grades increase (+7%)

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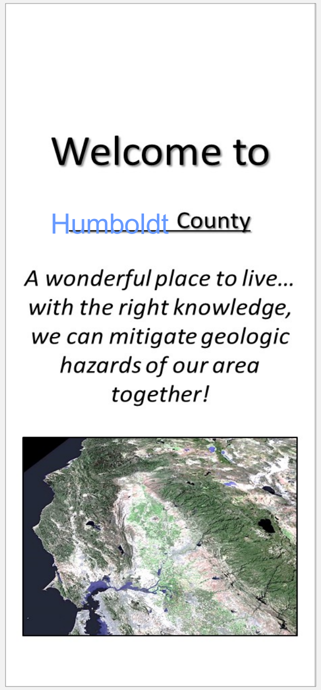
Improving Student Performance with Aligned Activities

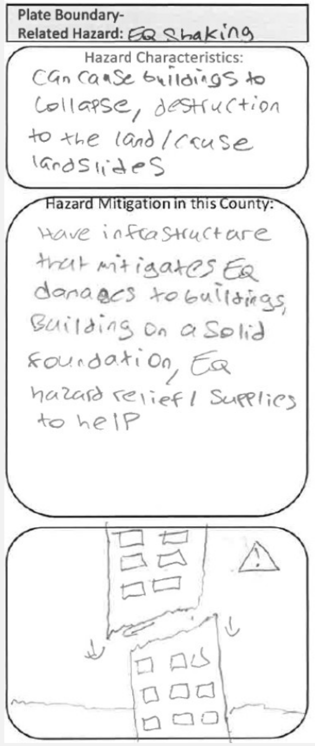
Next Steps

- Ongoing use of Aligned –Active questions (smaller number per exam)
- Ongoing analysis (Sp2020 = F2F vs. online instruction)
- Submit manuscript

- Ongoing commitment to cost-free course

- Use student feedback for new topics, activities





Modified gallery walk:
California county geologic hazards brochures

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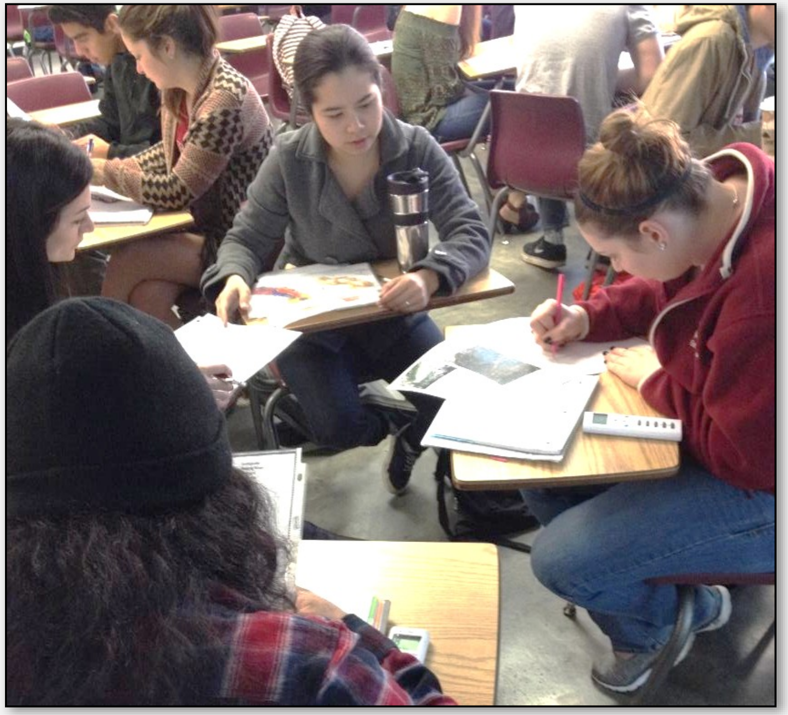
Summary

- Use of active learning strategies engage students in course material
- **Assessments**: Crafting careful questions requires time and effort but student- performance improvements are significant:
  - **Students perform best on Aligned –Active questions**
  - **All students benefit, URG students slightly more benefit**



With funding from CSU- CRT, CAL$, Josie Otwell Student Assistant Award

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Assessments for "Just-in-Time" Instruction

Gina Passante – Cal State Fullerton

Gina Passante, Assistant Professor
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Project Overview

- Two NSF-funded projects that broadly look at student learning in physics classes.
  - Collaborative Research: Research as a base to develop adaptable curricula bridging instructional paradigms in quantum mechanics (DUE-1626594)
  - Collaborative Research: Student Thinking about Measurements Across the Physics Curriculum (DUE-1809178)

Assessment of student learning is critical to these projects and forms the basis for most of our data.

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Activities

Graded Assessments:

- Course quizzes and exams
- Homework assignments
- Projects

Ungraded Assessments:

- Conceptual Inventories (Physics: FCI, FMCE, BEMA, …)
- Student surveys (ungraded)
  - Pre-lecture
  - In-lecture
  - Post-lecture

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Pre-Lecture Activities

Affordances

- Gives valuable information about student progress in 'real time'
  - Allows you to adjust your teaching to meet the students where they are
- Requires students to continually 'participate' in the class
- Can be done online so it doesn't take up any class time

Constraints

- It's more work creating weekly/daily assignments (and then reading them)
- Student perception (could it affect student opinion surveys?)

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Pre-Lecture Activities

- In my courses, online pre-lecture assignments are assigned before **every** class
- They take several different forms.
  - Research surveys: intended to gather very specific research data
  - Reading questionnaires
  - Practice something learned in the previous class
  - Remember something from a previous course
  - General feedback and questions

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Example: Beginning of semester

Is there anything in particular that you are hoping to learn in this class?

This course will use mathematical techniques that you have learned in other courses. We will use a lot of linear algebra in this course, specifically we will be using vectors and matrices a lot. How familiar are you with column vectors and matrices?

(multiple choice options)

Tell me something about yourself that has nothing to do with school.

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Example: Reading Questions

1. What did you learn from this reading?
2. What are you confused about in the reading?
3. What did this reading make you wonder about?

   What questions did it bring to mind?

Wendy K. Adams and Courtney Willis, *The Physics Teacher* **53**, 469 (2015)

Example: Previous class

Last class we found the equation for a time-dependent quantum state by solving the Schrödinger Equation.

Are there any 'caveats' or situations where this solution won't apply? (check all that apply)

- No caveats - it's a general solutions
- You can only use it when the Hamiltonian is itself time-independent
- You can only use it when the Hamiltonian is explicitly time-dependent
- You can only use it for "spin systems"
- You can only use it if the initial state is an energy eigenstate.
- I don't really know this yet...

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Example: General Feedback

How is the tempo of Phys 340 for you so far?

- Way too fast, please slow down!
- Fast, but I'm hanging on
- Seems about right to me
- A little slow
- Other:

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Example: General Feedback

How are the homework assignments in Phys 340 so far?

- Way too long/hard, please make them easier!
- A bit long/hard, but I'm dealing okay.
- Seems about right for this course
- They aren't too bad, but I'm okay with that!
- Way too easy, I want more!

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Example: General Feedback

Is there anything you want us to go over in the review class on Tuesday?

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Lessons Learned

- These assessments are valuable to
  - me the researcher
  - me the instructor
  - the students
- However, they need to be integrated into the course in a thoughtful and meaningful way

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Lessons Learned

- Some student feedback:
  "…the pre-lectures helped to make the material taught in class that day much easier"
  "The pre-lectures are helpful. It helps when I read the material before the lecture, and the pre-lectures encourage that."
  "…I get a lot out of pre-lectures with actual problems to complete and submit."   (but less from reading the textbook)

- I have never had a comment that explicitly says they don't like the pre-lectures

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Summary

- Assessments are a valuable tool for instruction (and research!)
- By incorporating them into your courses you can adjust your lectures to have the most impact
- They require thoughtful integration into your courses
  - Make them a regular element of the course
  - Provide participation credit for them
  - Read them and let students know you read them
  - Modify your lessons in response to student answers

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Thank you!

Feel free to reach out with any questions

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Assessing Student Learning in Blended-Model & Flipped Classes

Vimal Viswanathan – San Jose State University

Collaborators:
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Dr. Eric Hamilton – Pepperdine University

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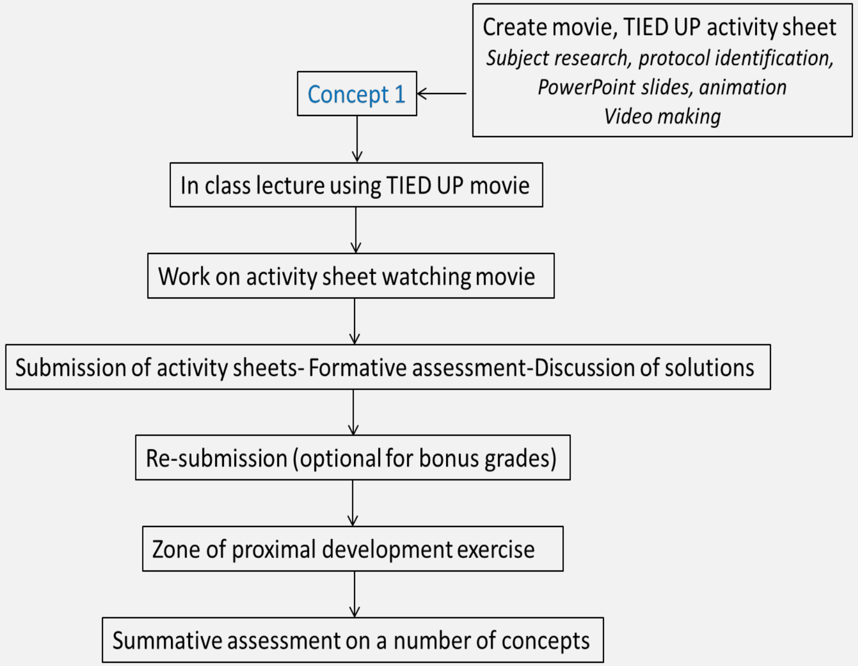
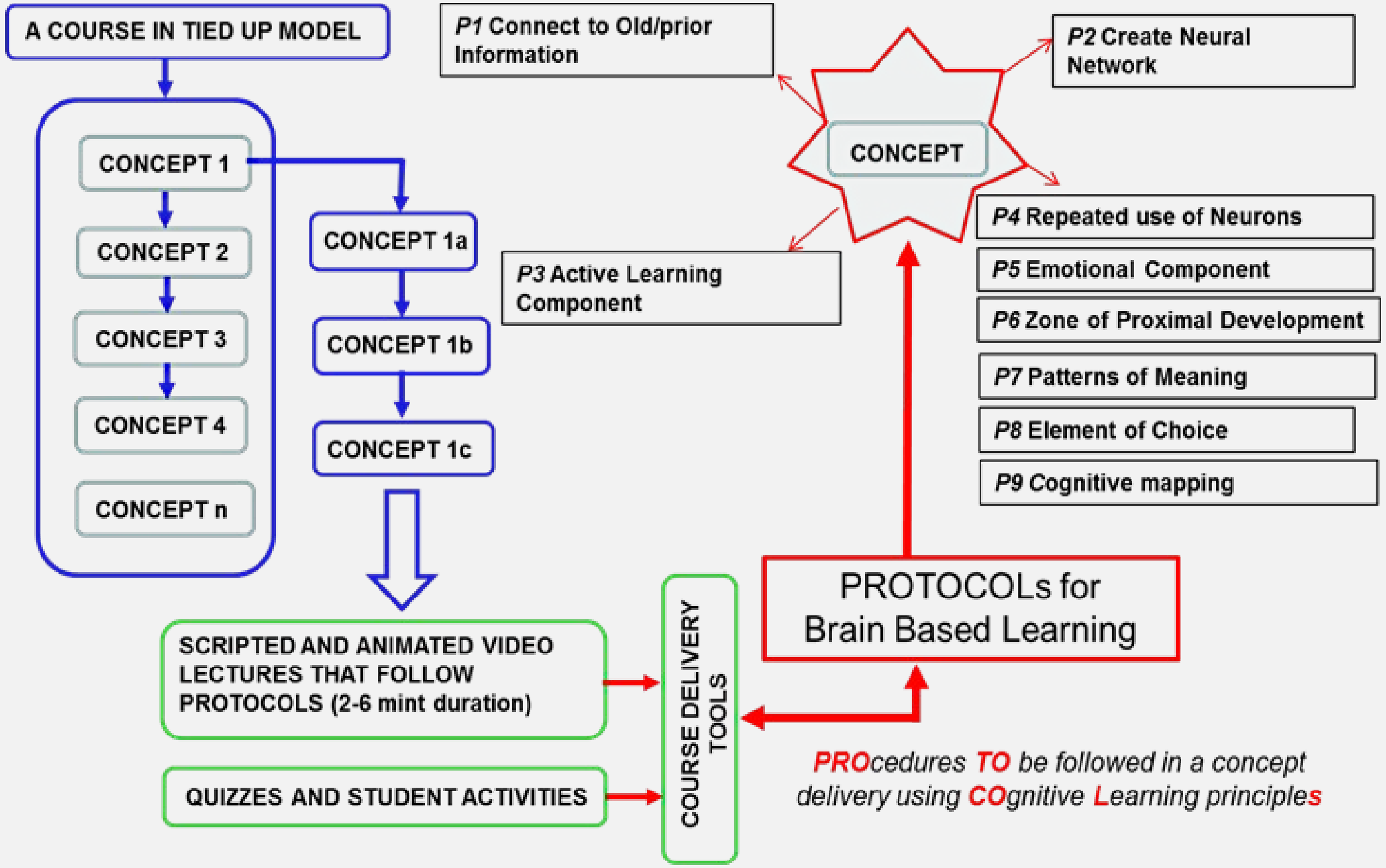
Project Overview

- Brain-based blended-instructional model





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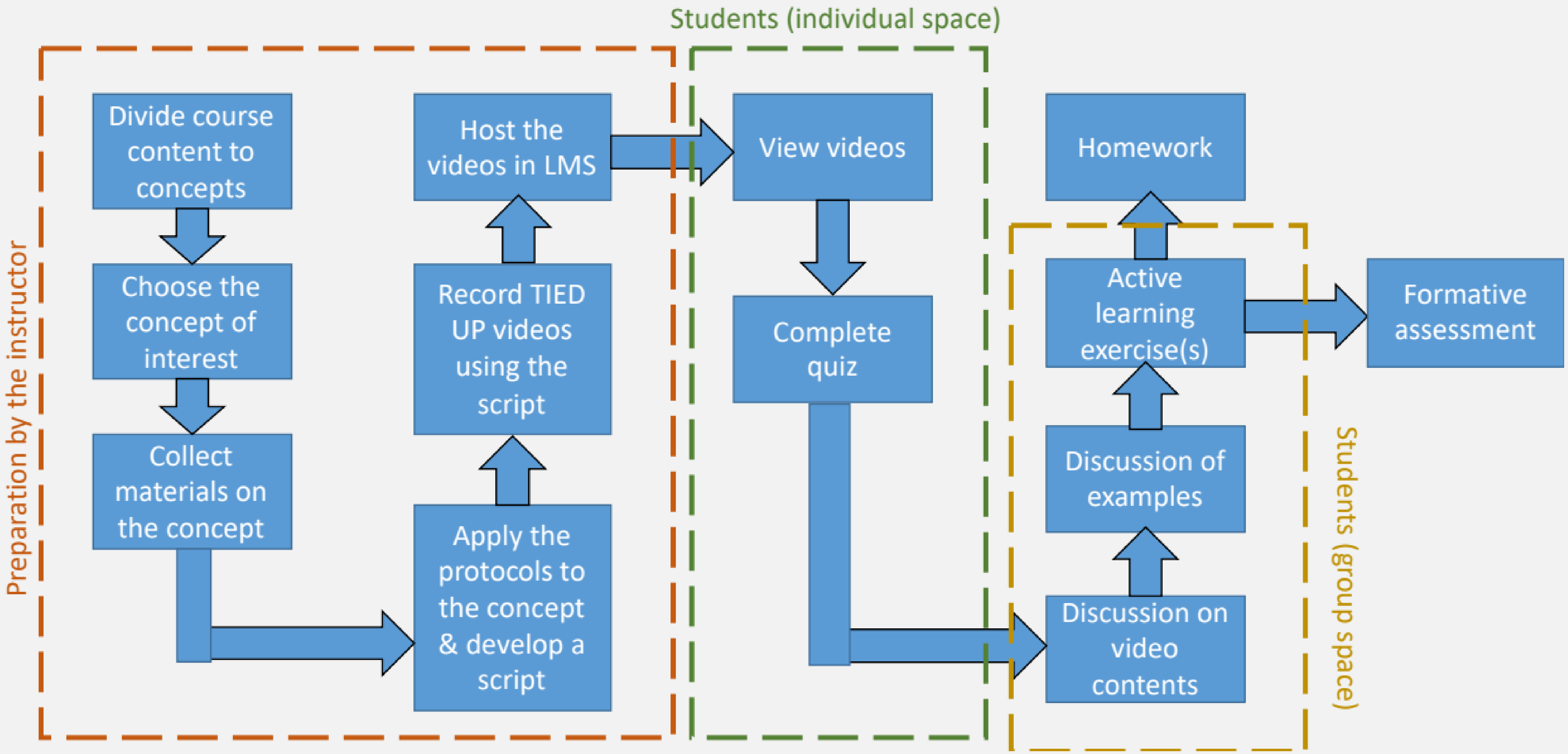
Blended-model & Flipped Classes



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Blended-model & Flipped Classes

	Traditional Classroom	Blended Classroom	Flipped Classroom
Group space	• In class lectures • "sage on the stage" • Problem solving • Note taking	• Video viewing • Discussion on videos • Active learning • Group problem solving • Peer mentoring	• Discussion on videos • Active learning • Group problem solving
Individual space	• Homework (difficult problems) • Learning for exams and quizzes	• Continuation of the classwork • Learning for exams and quizzes	• Preparation for class (e.g., watching videos) • Homework • Learning for exams and quizzes

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Blended-model & Flipped Classes

Assessment Activities

- Summative Assessment
  - Pre- and post content tests: Statics Concept inventory, Dynamics Concept Inventory, Force Concept Inventory
  - Pre- and post survey: critical thinking ability test (CAT)
  - Concept-level grading of exam questions
- Formative Assessment
  - Activity sheets – given in every class and collected at the end of the class
  - iClicker Quizzes
  - In-class polls
  - Concept maps

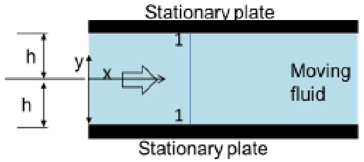
Concepts 5.1 Viscosity TIED UP- In Class

Date: **Name:**

No. time listened	1	2	3	4	5	6	7								

After listening each time, please try to answer the following.

1. Sketch an approximate velocity distribution at location 1-1 in the following flow configuration. Assume no slip at the boundary.



2. Shear stress developed in a given plane of a flowing fluid is directly proportional to---
3. Ratio of shear stress to shear strain rate is called--
4. Co-efficient of dynamic viscosity of water is 0.4 Ns/m^2 Calculate kinematic viscosity.
5. **In problem 1, If the velocity of fluid at a given location , y is $V(y) = 2 - \{1 - (\frac{y}{h})^2\}$ m/sec . The coefficient of dynamic viscosity is 0.5 Ns/m^2**
   a) Calculate (i) $V(y)$ at $y = h$ and (ii) $y = -h$ and (iii) $y = 0$
   b) Calculate fluid velocity at the center.
   c) Is it satisfying no-slip conditions?
   d) Calculate $\frac{dV(y)}{dy}$
   e) Calculate $\frac{dV(y)}{dy}$ at at $y = h$ and (ii) $y = -h$ and (iii) $y = 0$

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Assessment Activities

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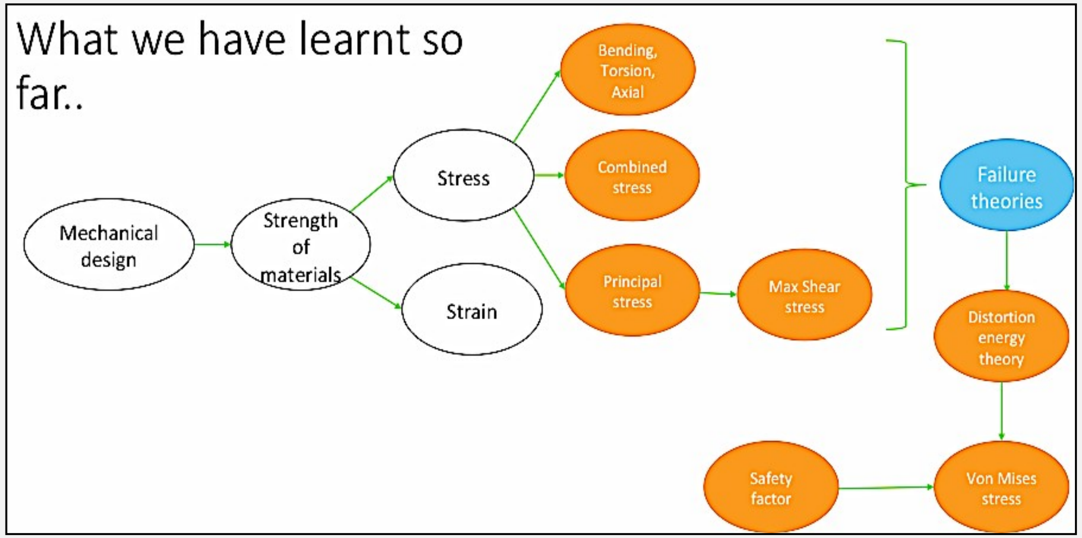

Grade	Explanation
5	Identified the required concepts, made necessary connections and solved the question
4	Identified the required concepts, made necessary connections, but made errors in solving the question
3	Identified the required concept, but the connections made were not satisfactory
2	Identified the required concept, but failed to establish any connection between the concept and the question
1	Could not identify any concept associated with the question
0	No attempt to solve the question

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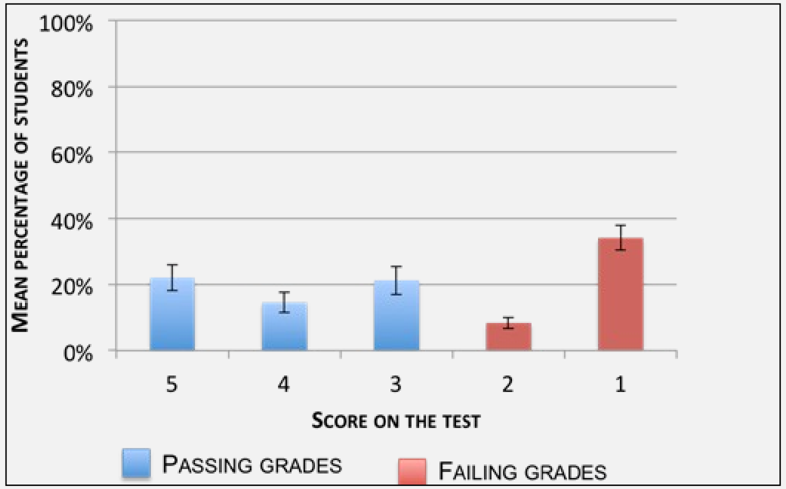
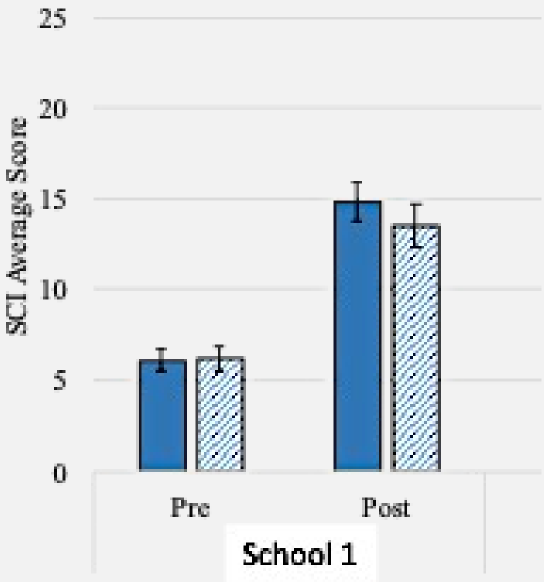
Blended-model & Flipped Classes

Sample Assessment Results

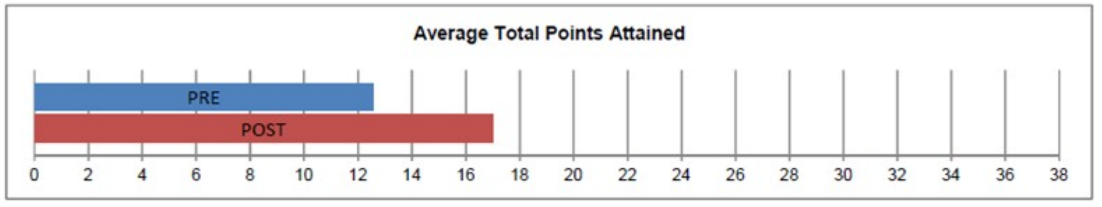
Pre-concept quiz



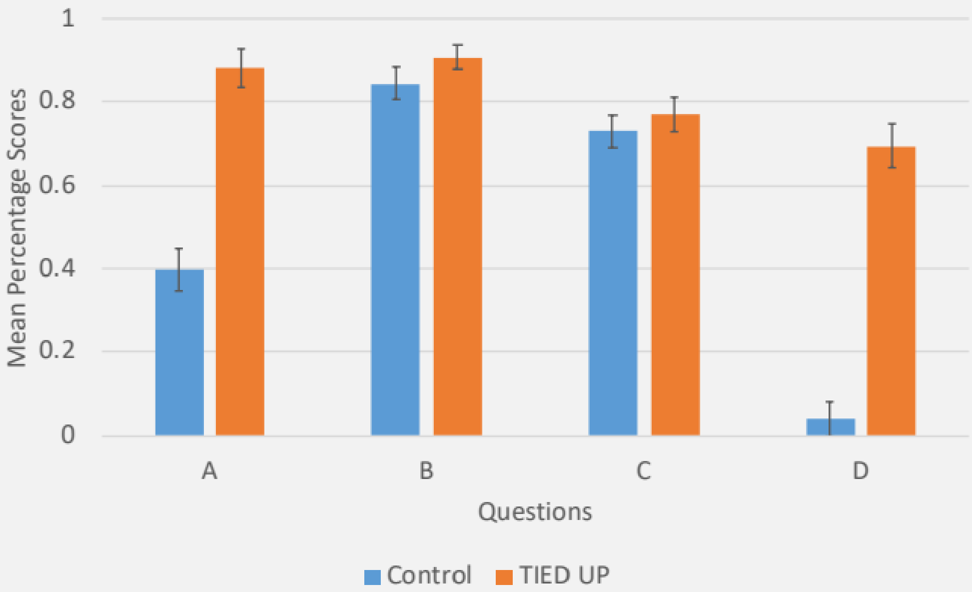
Concept inventories



CAT test



Comparison of student grades



Qualitative outcomes

"I appreciate and love Dr. Viswanathan teaching style. I like the fact that we spend class time to work on classwork. I also like how he is very available and approachable for any questions that we have. I really appreciate that he spends extra time to record videos of his lectures and carefully explains every detail to us."

Vimal Viswanathan *SJSU/Mechanical Engineering* *vimal.viswanathan@sjsu.edu*

Lessons Learned

- Focus on students
- Hands-on activities, active learning and demonstrations can take us a long way!
- Despite initial resistance, students will support instructional innovations
- Do not try to implement everything in a single semester
- To evaluate effectiveness of pedagogies and instructional practices
  - Combination of formative and summative assessment
  - Combination of quantitative and qualitative methods

https://www.youtube.com/watch?v=rUnNYQNfK6w

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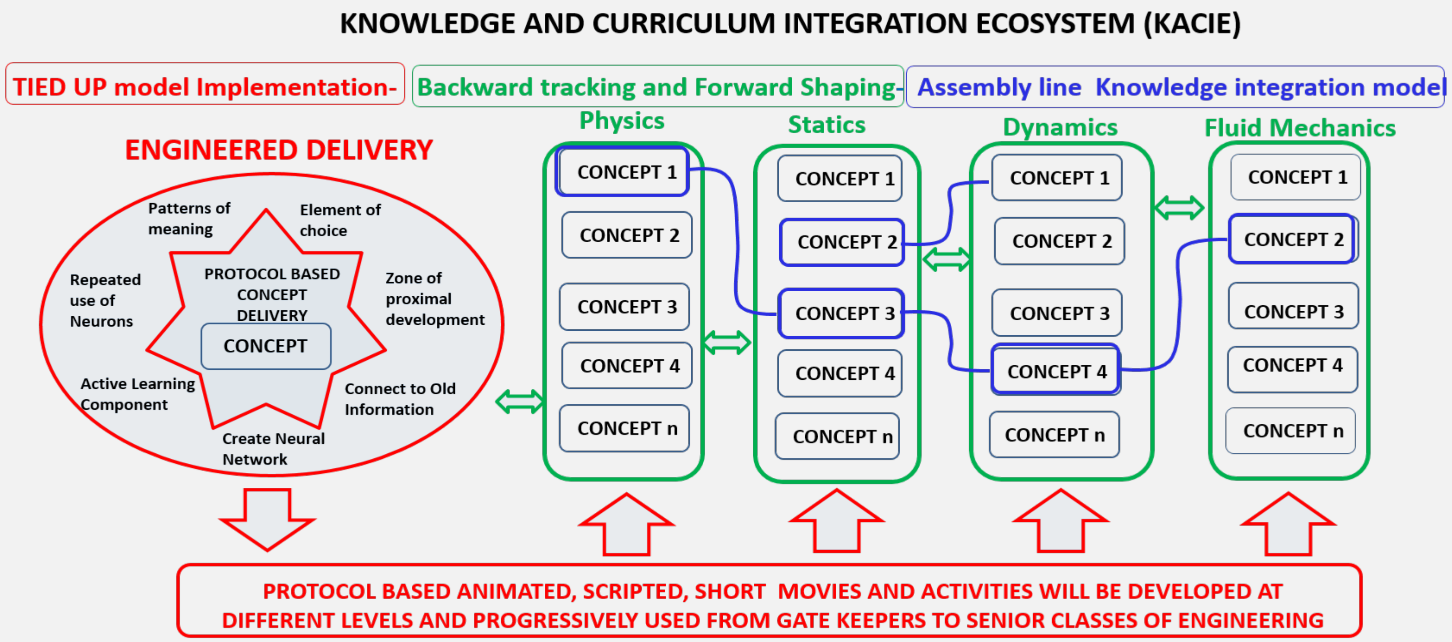
Next Steps/Long-Term Plans

- Assembly line model for delivering course concepts in multiple engineering courses
  - E.g., statics, dynamics, fluid mechanics, mechanical design…
- Implementation in progress in Physics and Math classes



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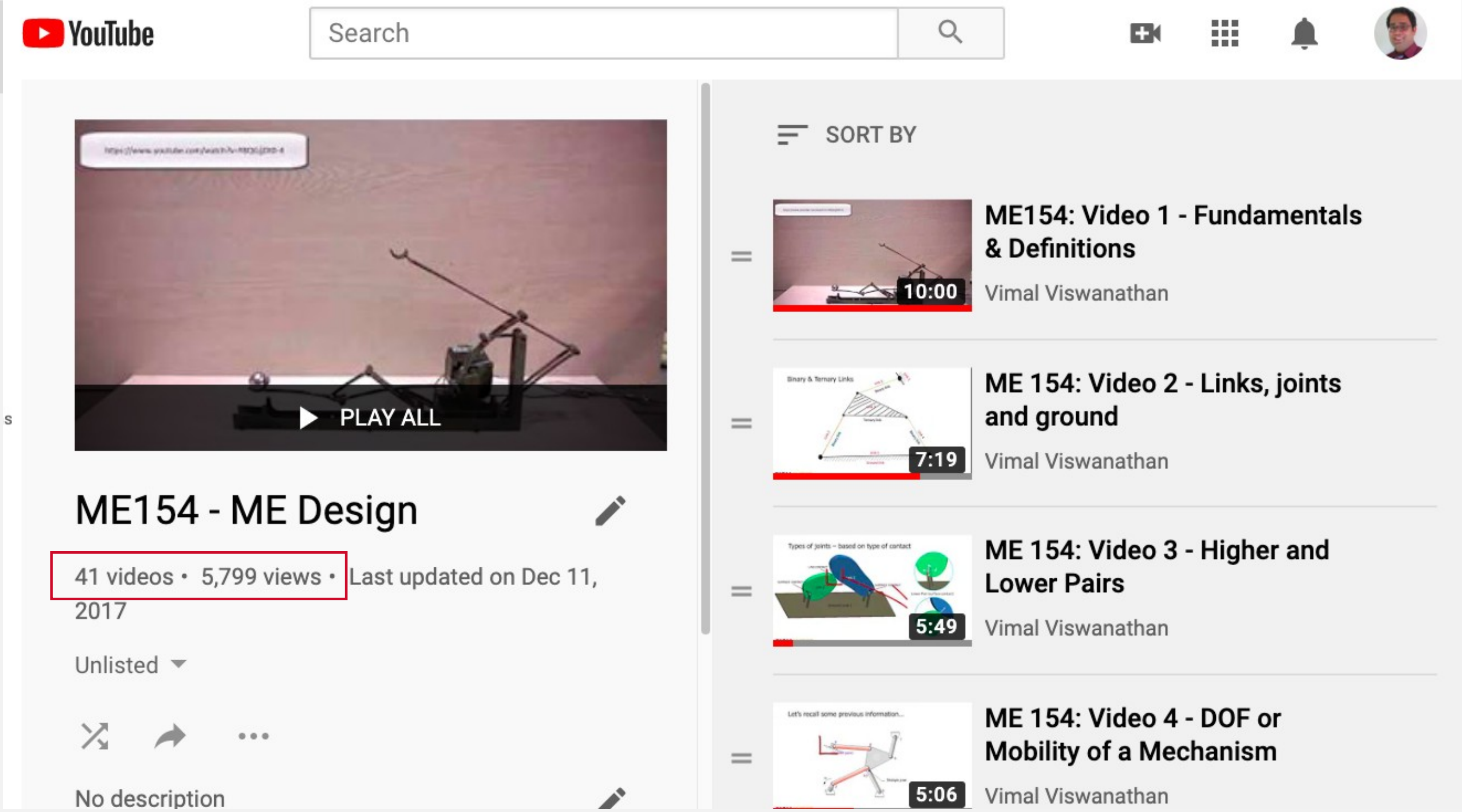
Blended-model & Flipped Classes

Summary

- The blended-model and the flipped version were found to be very successful
- Improved engagement
- Improved learning outcomes
  - Grades
  - Understanding of concepts
  - Critical thinking



https://tinyurl.com/uuxezjv

Acknowledgements & Publications

DUE 1504692
& 1504696

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Using Knowledge Integration Rubrics to Score Assessment Items for an Undergraduate Laboratory

NSF #1712279

Dr. Dermot Donnelly-Hermosillo – Fresno State

Collaborators: Dr. Fred Nelson (Associate Professor, Kremen School of Education) and Dr. David Andrews (Emeritus Professor, Department of Biology)

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Project Overview – Enhancing the Quality of Undergraduate Investigations in Physical Science (EQUIPS)

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Activities – KI Rubric (Linn & Eylon, 2011) – 9 Open-Response Items

Question: Would a metal, wooden, or plastic spoon feel hotter after being left in hot water for 10 minutes? Explain.

KI Score	Idea	Example
1	Student does not know	I don't know.
2	Non-normative idea	Plastic is the better conductor.
3	Partial normative idea	The metal spoon will be hotter because metal is good conductor.
4	Normative idea	The metal spoon will be hotter than the wood or plastic spoon because metal is a better conductor than wood or plastic
5	Links two normative ideas	Metal feels warmer even though it may be the same temperature as the other spoons but when it is in hot water, metal is a better conductor than wood or plastic so it is actually hotter.

Results (Across Four Semesters of Data Collection)

- Students enter the course with non-normative ideas, leave with partial

  (Hinde & Donnelly, 2018; Meadows et al, 2019; Sangha et al., 2019)

- Students consistently do better on Physics and Integrated items

  (Cruz-Guzmán et al., 2018; Sangha et al., 2019)

- Some semesters show laboratory instructor effect

  (Meadows et al., 2019; Sangha et al., 2019)

- Students initially struggle with designing experiments

  (Click et al., In Preparation; Sangha et al., 2019)

- Students enjoy the ownership of their investigations

  (Click et al., In Preparation; Sangha et al., 2019)

Lessons Learned

- Construct validity – Chemistry, Physics, and Integrated items
- Interrater agreement for open-response items
- Conflicting views for Chemistry/Physics laboratory instructors – Disciplinary bias
- Critical need for instructor professional development (PD)

Next Steps/Long-Term Plans

- Conventional lab. Vs. Guided-Inquiry lab.: 1 instructor comparison
- Embedding more technology tools
- Advocating for longer PD opportunities for laboratory instructors
- Collaborations with other CSU campuses

Summary

- Importance of eliciting student ideas in laboratory settings
- Value of research experiences no matter the student science background
- Value of open-response assessments for deep insights in student thinking

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Integrated Assessment Strategies: From Course to Program to Institution

Seema Shah-Fairbank and Laila Jallo – Cal Poly Pomona

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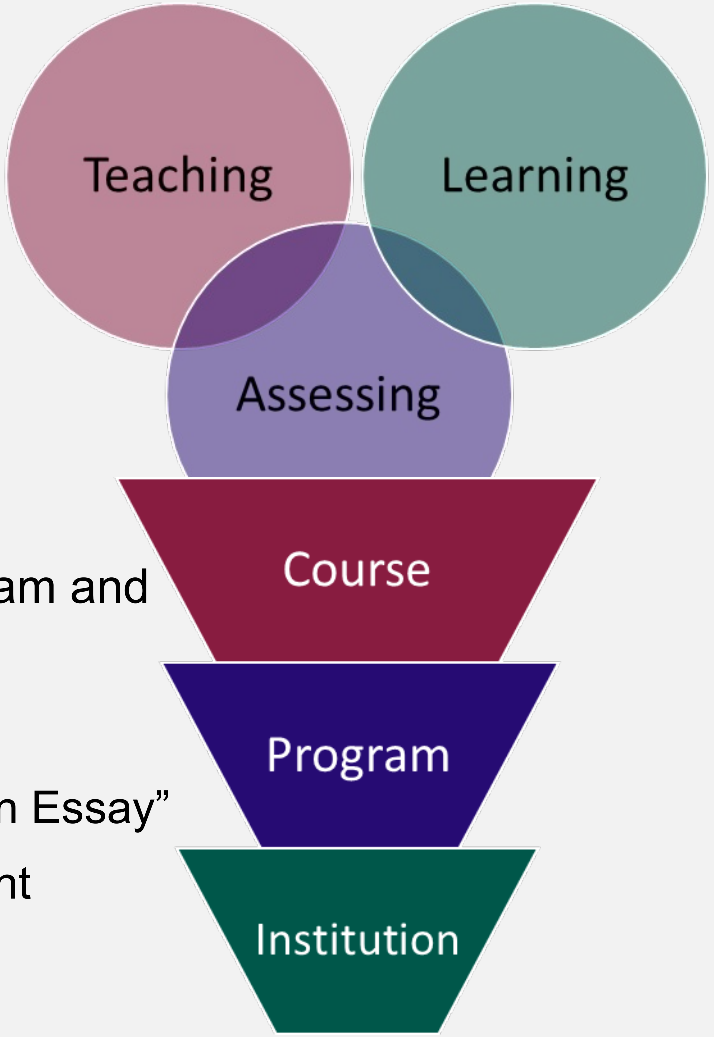
Integrated Assessment Strategies: From Course to Program to Institution

Project Overview

- **Desired Conversation**
  - Student learning is about using content to solidify student learning.
  - Faculty and instructors can improve teaching
  - Continuous improvement and close the loop

- **Faculty Driven Process** – Course based Assessment can guide Program and Institutional Assessment
  - Course/Program Level Assessment – "ConcepTest"
  - Course/Program/Institutional Assessment at Department Level – "Written Essay"
  - Course/Program/Institutional Assessment at College Level – "Assignment Design"



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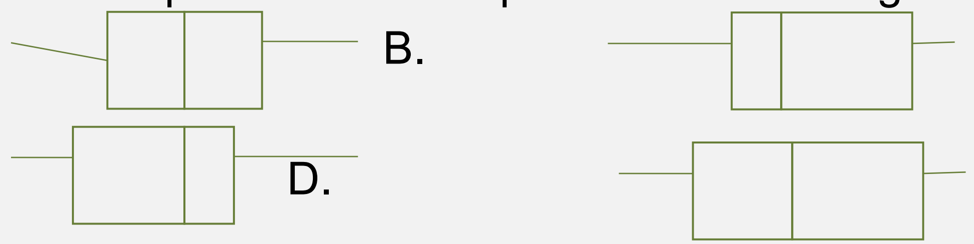
Activity – ConcepTest

- **Motivation**
  - Course faculty looking for innovative ways to improve instruction
  - Students struggling with fundamental concepts in programming and engineering statistics courses
- **“ConcepTest” questions:**
  - Conceptual multiple-choice questions that focus on one key concept
  - Rapid method of formative assessment of student understanding”

Example: Which represents the boxplot for the following values: 42, 62, 72, 82. 97.

A. B. C. D.



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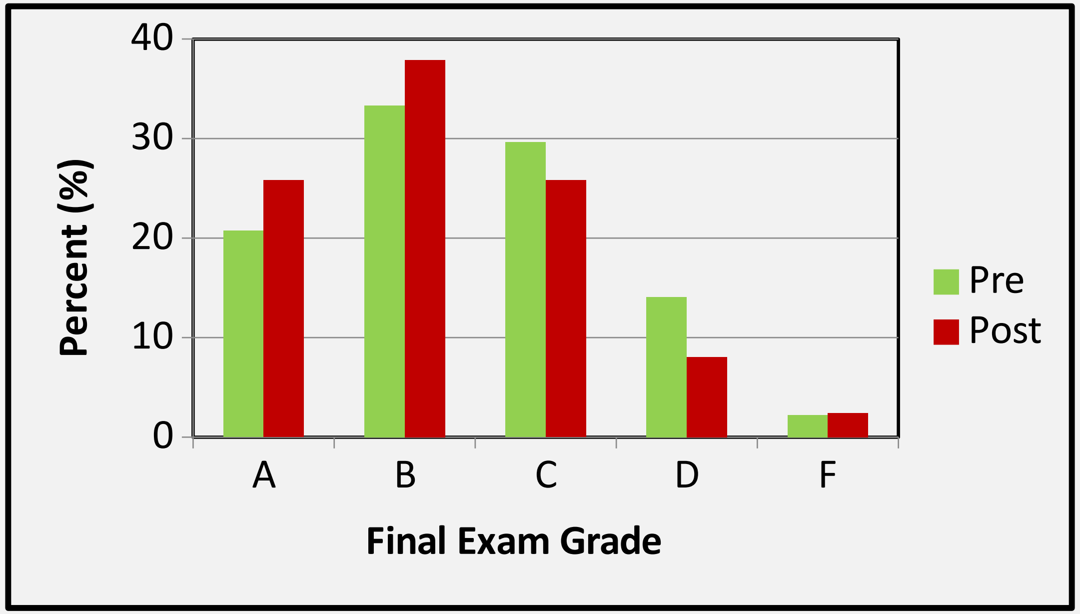
Results – Chemical Engineering I

ANOVA - α = 0.05

	Exam #1 – **Pre** **n = 135**		Exam#1 **Post** **n = 135**	
	Ave. (%)	P-value	Ave. (%)	P-value
Section A	55	0.01	61	0.70
Section B	41		57	
Section C	50		58	

	Final Exam – **Pre** **n = 135**		Final Exam – **Post** **n = 135**	
	Ave. (%)	P-value	Ave. (%)	P-value
Section A	82	0.15	83	0.87
Section B	78		82	
Section C	81		82	

Overall Grade Distribution



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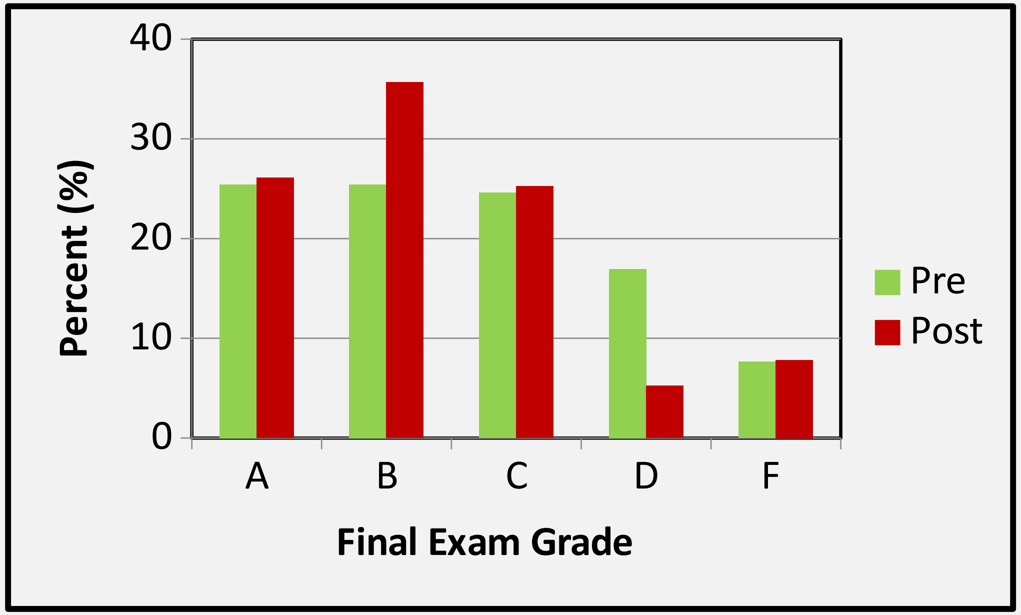
Results – Chemical Engineering II

ANOVA - α = 0.05

	Exam #2 – **Pre** **n – 118**		Exam#2 - **Post** **n = 115**	
	Ave %	P-value	Ave %	P-value
Section A	53	0.04	67	0.11
Section B	62		74	
	Final Exam – **Pre** **n = 118**		Final Exam, **- Post** **n = 115**	
	Ave %	P-value	Ave %	P-value
Section A	75	0.00	80	0.10
Section B	83		84	

Overall Grade Distribution



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Lessons Learned

Discussion of Results

- Course is aligned to **ABET SO 1** - ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- Implementation of "ConcepTest"
  - improved consistency in student performance. (Instructor Consistency)
  - engaged students in a traditional lecture
  - improved overall student performance on each exam and overall course
  - student are overall satisfied with the course (through indirect assessment)

Close the Loop

- Increasing complexity of "ConcepTests" within Chemical Engineering I & II.
- Implementing more "ConcepTests" into various courses.

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Activity – Contemporary Issues Essay Design

- **Motivation**
  - Civil Engineering students struggle with written communication
  - Can a single assignment be used to assess multiple outcomes
- **Essay Assignment on Contemporary Issues (Spring 2020)**
  - Task: Write a critical evaluation on the Orville Dam. Support your position through peer-reviewed and other relevant sources
  - Evaluated based: Problem/Issue; Perspective/Position; Evidence; Conclusion; Citation
  - Classroom Instruction: Background regarding Orville Dam and Written Communication Modules

ABET Student Outcomes
ABET SO 3: An ability to communicate (written) effectively with a range of audiences.
ABET SO 4 - an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
ABET SO 7: An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

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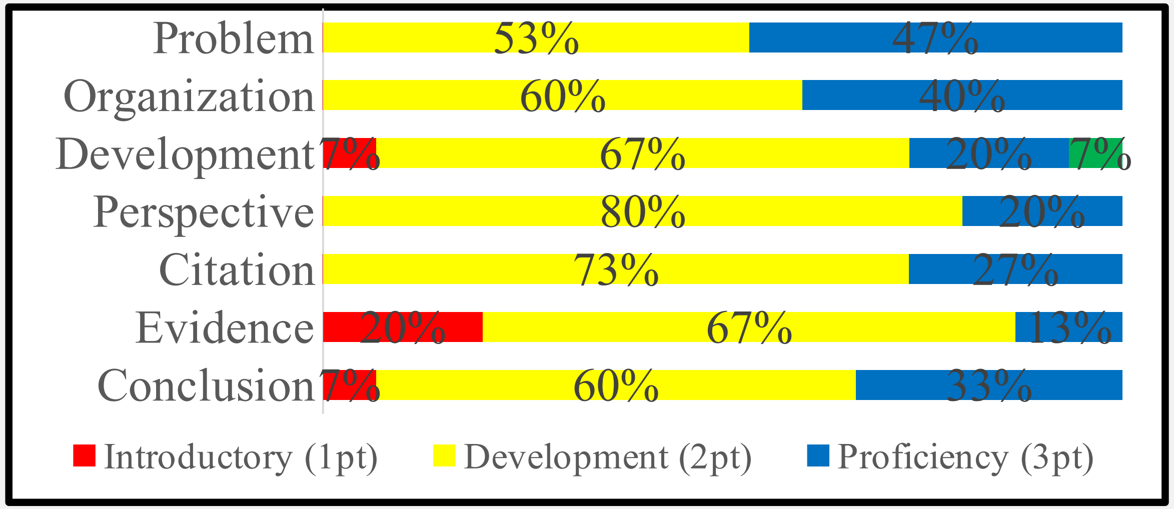
Results – Civil Engineering I

Criteria	Mastery (4pt)	Proficient (3pt)	Developing (2pt)	Introductory (1pt)
Problem & Issue SO 3 & SO 4				
Organization SO 3 & SO 4				
Development SO 3 & SO 7				
Perspective SO 3 & SO 7				
Citations SO 3 & SO 7				
Evidence SO 3 & SO 7				
Conclusion SO 3, SO 4 & SO 7				

Scoring Rubric

Results



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Lessons Learned - Close the Loop

- Need to close the loop
- Institutional Assessment
  Information Literacy & Written Com.

30% Developing and Introductory for Evidence and Sources

45% Developing and Introductory for Citation

30% Developing and Introductory for Development of Ideas

20% Developing and Introductory for Grammar and Mechanics

- Office of Assessment and Program Review at CPP
  - Rubric Design
  - Transparent Assignment Design
  - Written Communication - Within the Discipline
  - Information Literacy

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Activity - Redesign

- Collaboration between faculty from civil engineering and campus librarians
- Developed a Scaffolded Instruction for the Assignment: Annotated Bibliography; Draft Essay; In-class; Peer Review; and Final Essay
- Targeted Instruction
  - Engineering librarian visited the course twice over the semester to provide detailed instruction on finding, evaluating, and citing sources.
  - Detailed Review of Grading Rubric
  - Instruction on Engineering Situation
- Transparent Assignment Design
  - Provides clear purpose, learning objective, tasks, and evaluation criteria.
  - Asked to provide a critical evaluation on Hurricane Harvey

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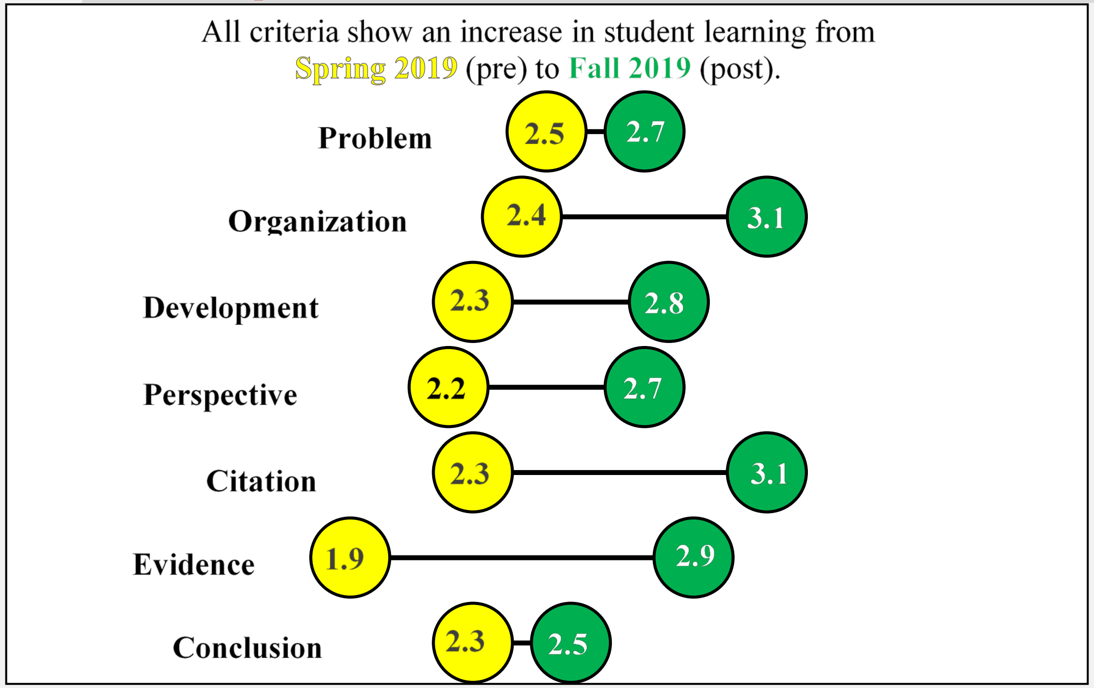
Comparison – Lessons Learned



Criteria	Average		p-value
	Spring	Fall	
Problem	2.47	2.73	0.100
Organization	2.40	3.07	0.005
Development	2.27	2.80	0.045
Perspective	2.20	2.73	0.015
Citation	2.27	3.07	1.21E-06
Evidence	1.93	2.87	3.58E-04
Conclusion	2.27	2.53	0.176

- Close the Loop
  - Additional Library Instruction (Spring 2020)
  - Intentional course based instruction on ethical and professional responsibilities (Spring 2020)

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Activity – College of Engineering Capstone Assignment

Motivation

- 2018 College of Engineering received an exemption for Critical Thinking (GE A3)
  - College needs to create an assignment for assessment for critical thinking
- Positive results from Civil Engineering Course
- Senior engineering projects are team based, and difficult to find individual artifacts to assess student learning
- Develop assignment which can be used to assess multiple ABET and Institutional Outcomes.

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Activity – College of Engineering Capstone Assignment

Purpose: Assess engineering students' critical thinking, written communication and information literacy skills.

Prompt: You are considered for an on-site job interview and are required to discuss your senior project work. The panel is skeptical about your findings. Defend your work by writing a **summary** of your project. The summary should address:

- The problem/issues addressed
- Others' perspective (literature search) and the author's perspective
- The objective(s) of your the project
- Results and discussion of results.
- Conclusions
- References

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Next Steps/Long-Term Plans

- Collected 100 student samples Spring 2020
  - Assess using Critical Thinking Rubric
  - Create a stratified random sample – Summer 2020
  - Norm and score student artifacts
- Present results to CoE faculty Fall 2020
- Close the Loop Fall 2020
- Continue assessment Spring 2021…Evaluate additional outcomes

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Summary

- Course based ConcepTest improved student performance
- Improved assignment design improved student performance
- Additional and intentional lessons improved student performance
- Assessment of student learning improved faculty engagement and performance

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Can assessment help transform students from "point collectors" into scientists?

Anya Goodman *Cal Poly, San Luis Obispo, CA*

Collaborators at Cal Poly: Eric Jones Ph.D, Andrea Laubscher, students

BASIL

Biochemistry
Authentic
Scientific Inquiry Lab

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Goal: curriculum design to

help students develop into

STEM researchers

disciplinary skills,

research skills, and

science identity

Mentored undergraduate research
great experience, but does not scale…
and some students do not seek it.

Scale and make research experience for all via

Course-based Undergraduate Research Experience (CURE)

Five dimensions

- Scientific practices
- Discovery
- Relevance
- Collaboration
- Iteration

Auchincloss et al. 2014

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"Point collectors" to Scientists?

Biochemistry Authentic Scientific Inquiry Lab (BASIL)

BASIL

Faculty community focused on biochemistry CURE curriculum development and assessment.

Curriculum freely available https://basilbiochem.github.io/basil/index.html

BASIL CURE implementation at Cal Poly:
upper level lab, 7 hours/week, 2 sections, 16 students each

alignment of **learning goals** and **research goals**

learning goals	research goals
understand how to purify proteins and study their activity	purify protein of unknown function and test for predicted biochemical activities

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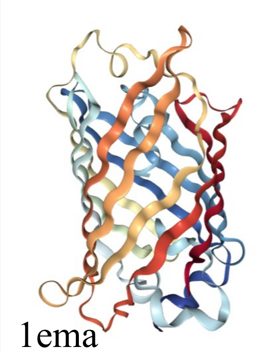
“Point collectors” to Scientists?

Transition to CURE

Before:

1. All students purify *E. coli* alkaline phosphatase, assay activity and study kinetics (6 weeks)

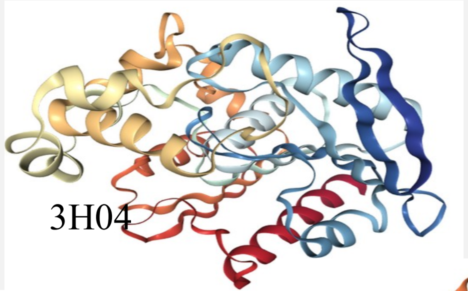
2. All students purify His-tagged GFP, analyze purification and function (4 weeks).

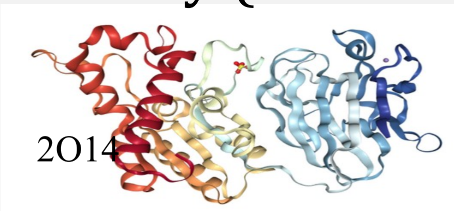


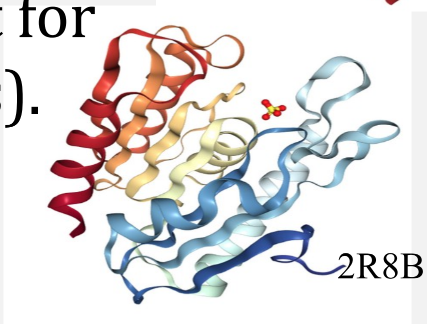
After:

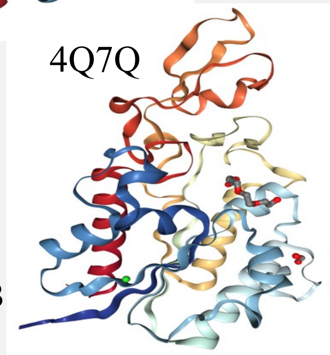
1. All students purify *E. coli* alkaline phosphatase, assay activity and study kinetics (5 weeks)

2. **Research:** students purify His-tagged proteins of unknown function and test for activity (5 weeks).









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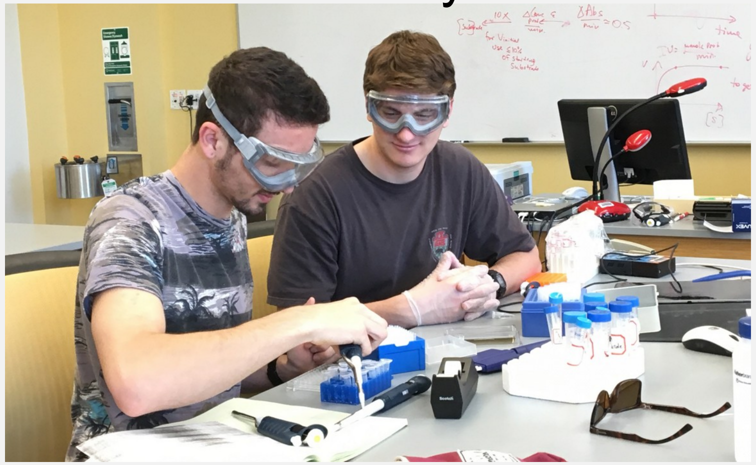
“Point collectors” to Scientists?

Transition to CURE

Goal: help students develop into STEM researchers

- disciplinary skills,
- research skills, and
- science identity



Cal Poly BASIL CURE lab-v.1

Learning goals
understand how to purify proteins and study their activity; conduct research

Activities
1. Protein 1: follow protocols–replicate results-explain
2. Research project: design experiments, analyze data

Assessment:
lab reports, lab notebook, tests

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Problem: disconnect between goals and assessments/rewards

Trying to nurture traits:

- inquisitive,
- self-motivated,
- original deep thinkers,
- resilient to failure.

Questions students ask:

- Is this going to be on the test?
- How many points is this worth?
- How many points will I loose, if I do not get the right answer on the research project?

Reward system: X points;
list of things to do/assessments:
tests, lab reports, notebook checks;
every time students make a mistake, they loose points.

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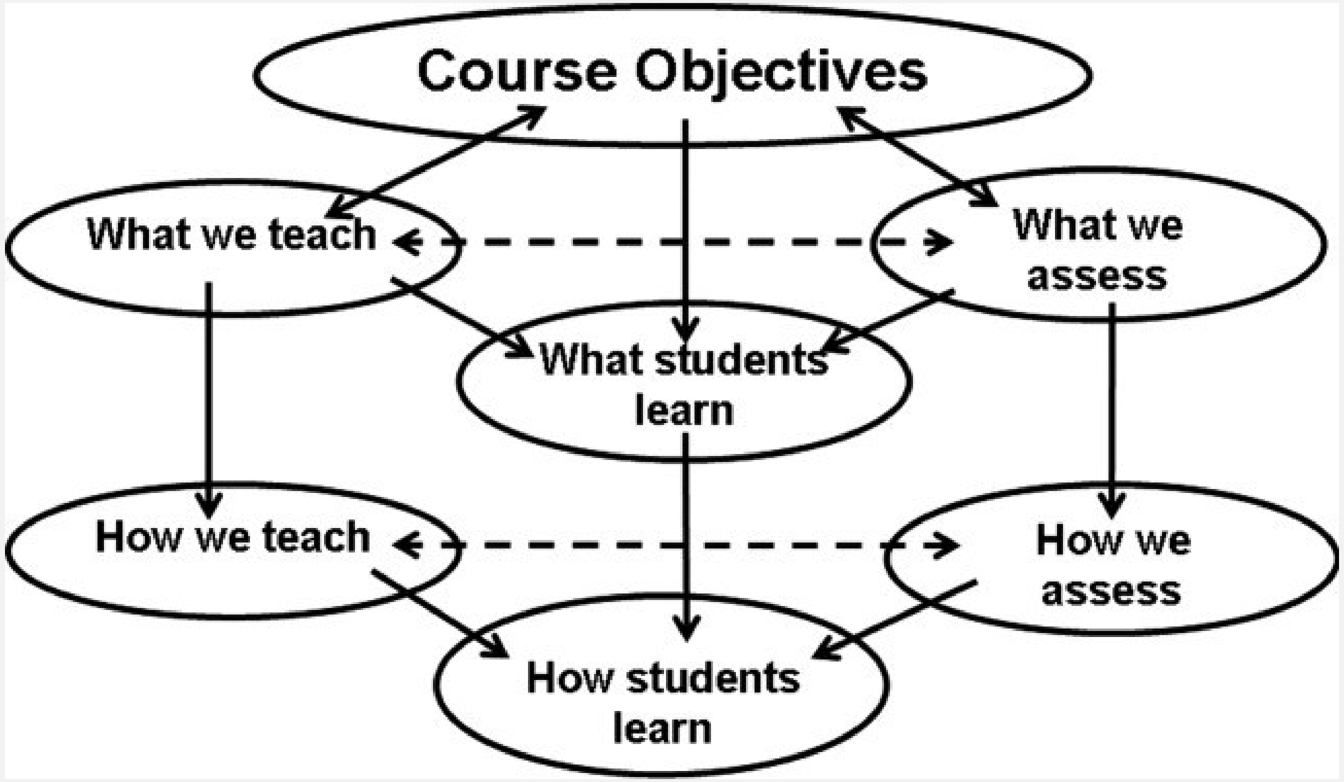
Need better alignment between course objectives, learning activities and assessments



- **Use what you assess to influence what students learn**
- **Use how you assess to determine whether students will use a surface or deep approach to learning**

Anderson (2007) Bridging the educational research-teaching practice gap. *Biochem Mol Biol Educ*. 35(6): 471-477

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“Point collectors” to Scientists?

Transition to CURE

Goal: help students develop into STEM researchers
- disciplinary skills,
- research skills, and
- science identity

Cal Poly BASIL CURE lab-v2

Learning goals

understand how to purify proteins and study their activity; conduct research

Activities

1. “Bootcamp”: follow protocols–replicate results-explain
2. Research project: design experiments, analyze data

Assessment:

lab reports, lab notebook, tests - include 3D LAP, poster presentation, demonstrate achievement above expectations for a “C”

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Three-dimensional Learning Assessment Protocol (3D-LAP)

Disciplinary core ideas +

Scientific and Engineering Practices	Crosscutting Concepts
1. Asking Questions (for science) and Defining Problems (for engineering) 2. Developing and Using Models 3. Planning and Carrying Out Investigations 4. Analyzing and Interpreting Data 5. Using Mathematics and Computational Thinking 6. Constructing Explanations (for science) and Designing Solutions (for engineering) 7. Engaging in Argument from Evidence 8. Obtaining, Evaluating, and Communicating Information	1. Patterns 2. Cause and Effect: Mechanism and Explanation 3. Scale, Proportion, and Quantity 4. Systems and System Models 5. Energy and Matter: Flows, Cycles, and Conservation 6. Structure and Function 7. Stability and Change

Table 1. The scientific and engineering practices and crosscutting concepts as listed in the Framework (NRC A Framework for K-12 Science Education NAP, 2012).

From: *Laverty et al. 2016*

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Assessment example: selected response

Data from alkaline phosphatase purification:

Whole cell lysate: 0.91 IU activity

Cold water wash: 0.78 IU activity

DEAE pool: 0.50 IU activity

Which statements provide a likely explanation for the results? Circle one or more.

A. Incomplete hypotonic lysis of outer membrane

B. DEAE column buffer pH too high

C. DEAE column buffer pH too low

D. Poor expression/synthesis of protein in *E. coli*

E. Assay buffer pH too low

Requires both disciplinary concepts and scientific practices!

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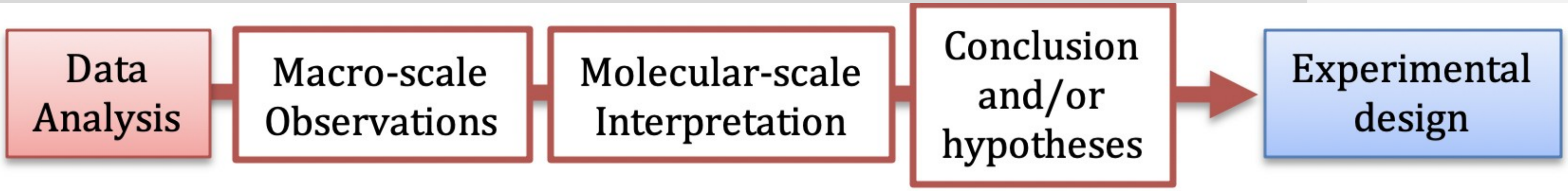
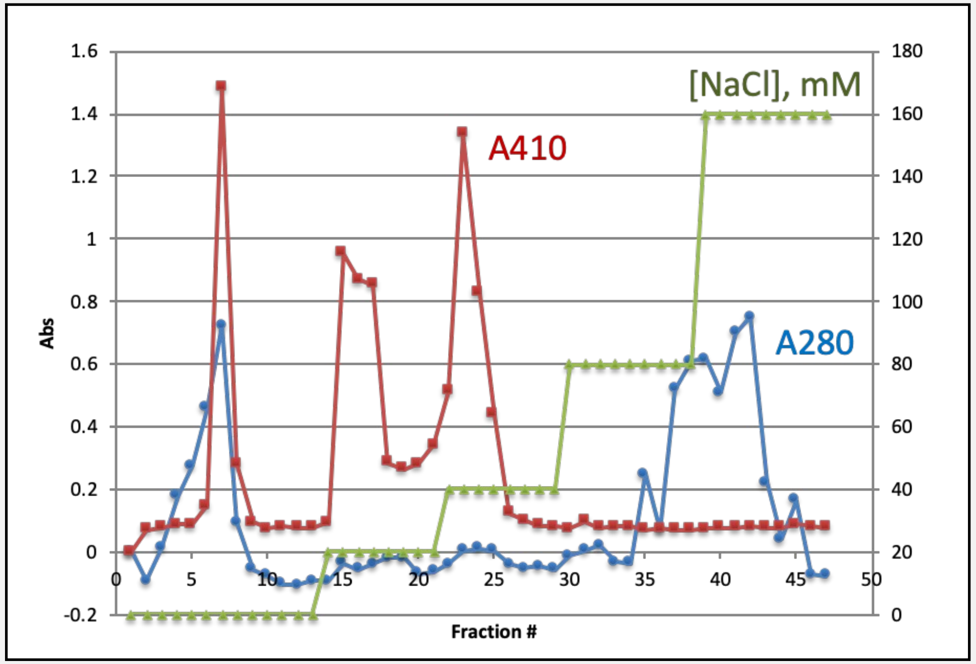
“Point collectors” to Scientists?

Scaffolded activities and formative assessment

Model reasoning based on real data using in-class activities



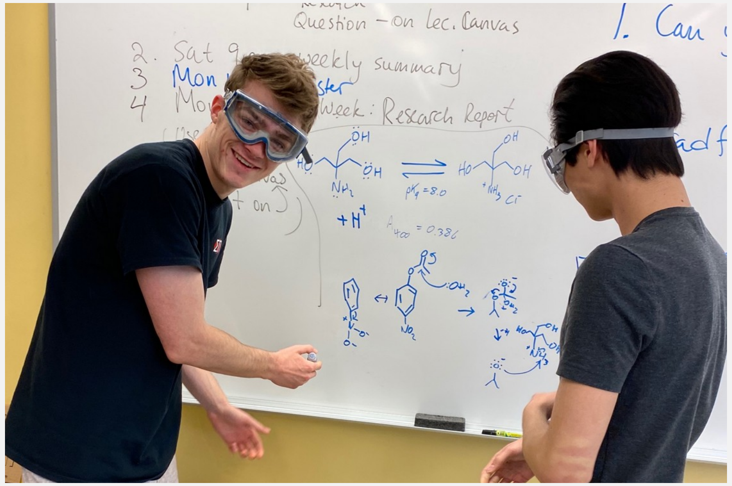


What do you see?

What does it mean?

Come up with a hypothesis.

Propose experiment to test your hypothesis.



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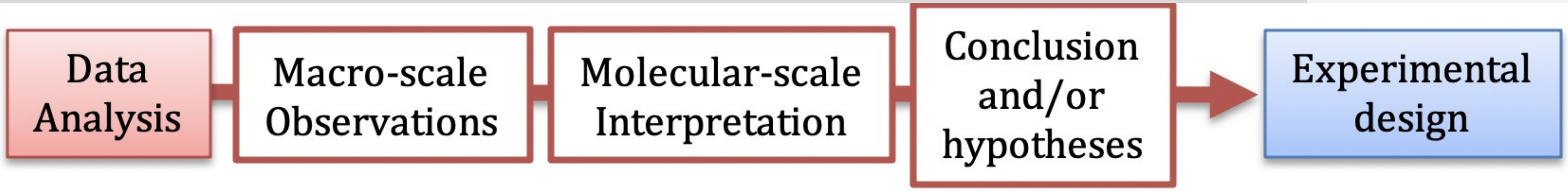
Example of formative assessment: guided practice

Practice reasoning based on real data – homework and class activities

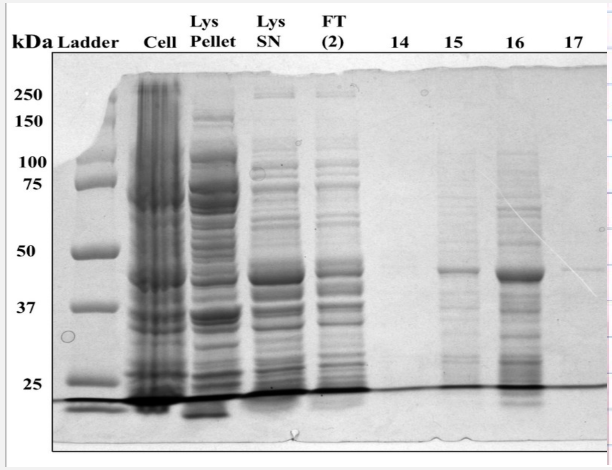


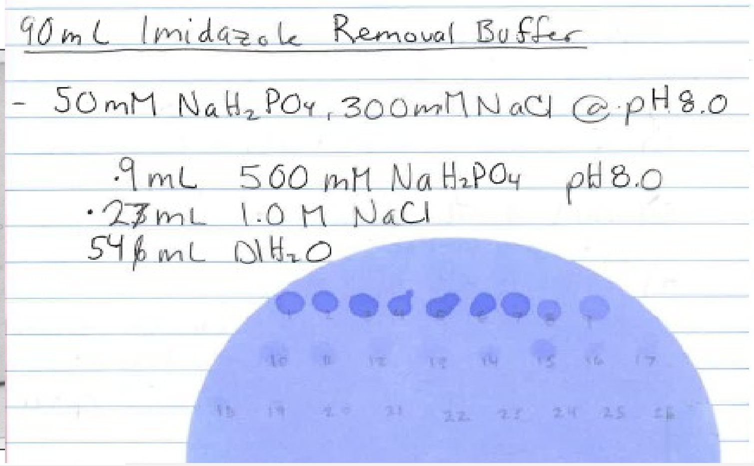
What do you see?

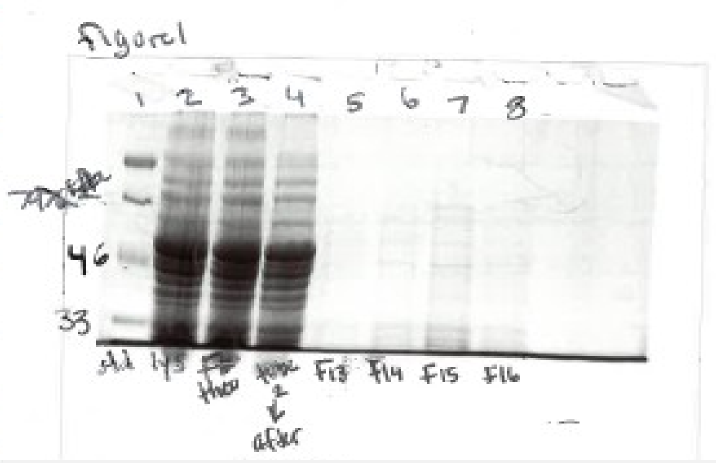
What does it mean?

Come up with a hypothesis.

Propose experiment to test your hypothesis.







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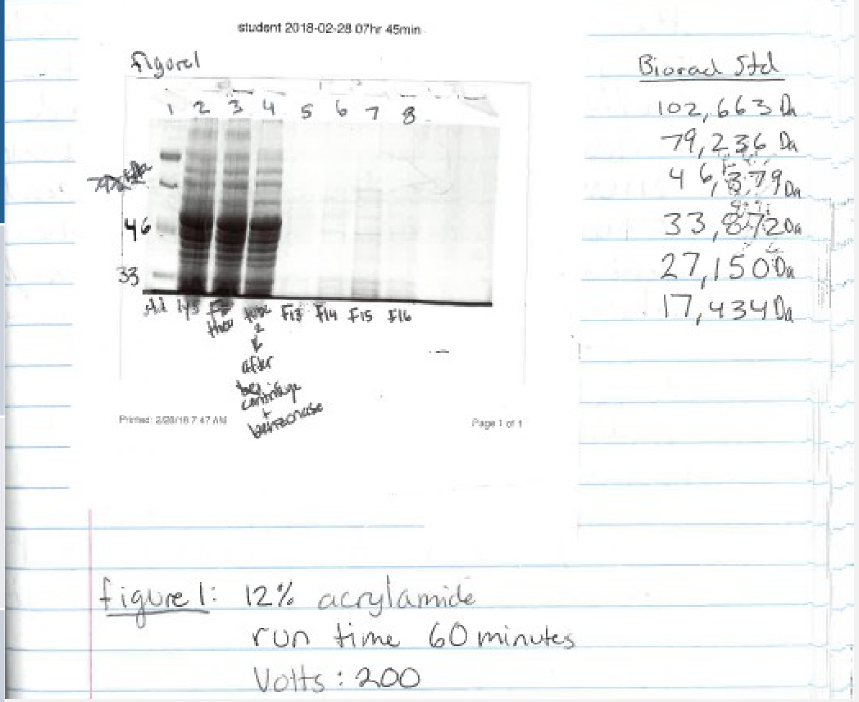
Example of formative assessment: guided practice

A. Observations and interpretation

Interpretation	Was the desired outcome achieved?	Observation that supports your interpretation/conclusion OR why success at this stage cannot be confirmed
Cell were lysed	Yes No Uncertain	protein in both crude lysate, and supernatant after centrifugation
Protein of interest (PoI) was soluble	Yes No Uncertain	POI in lane 4
PoI bound column	Yes No Uncertain	Flow through and Sup have the same amount of PoI



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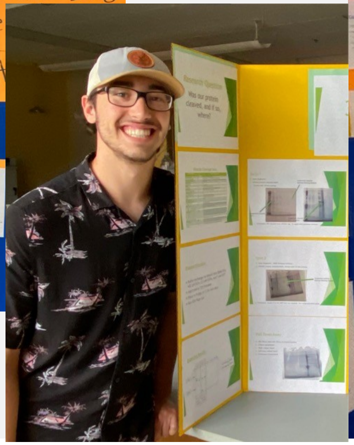
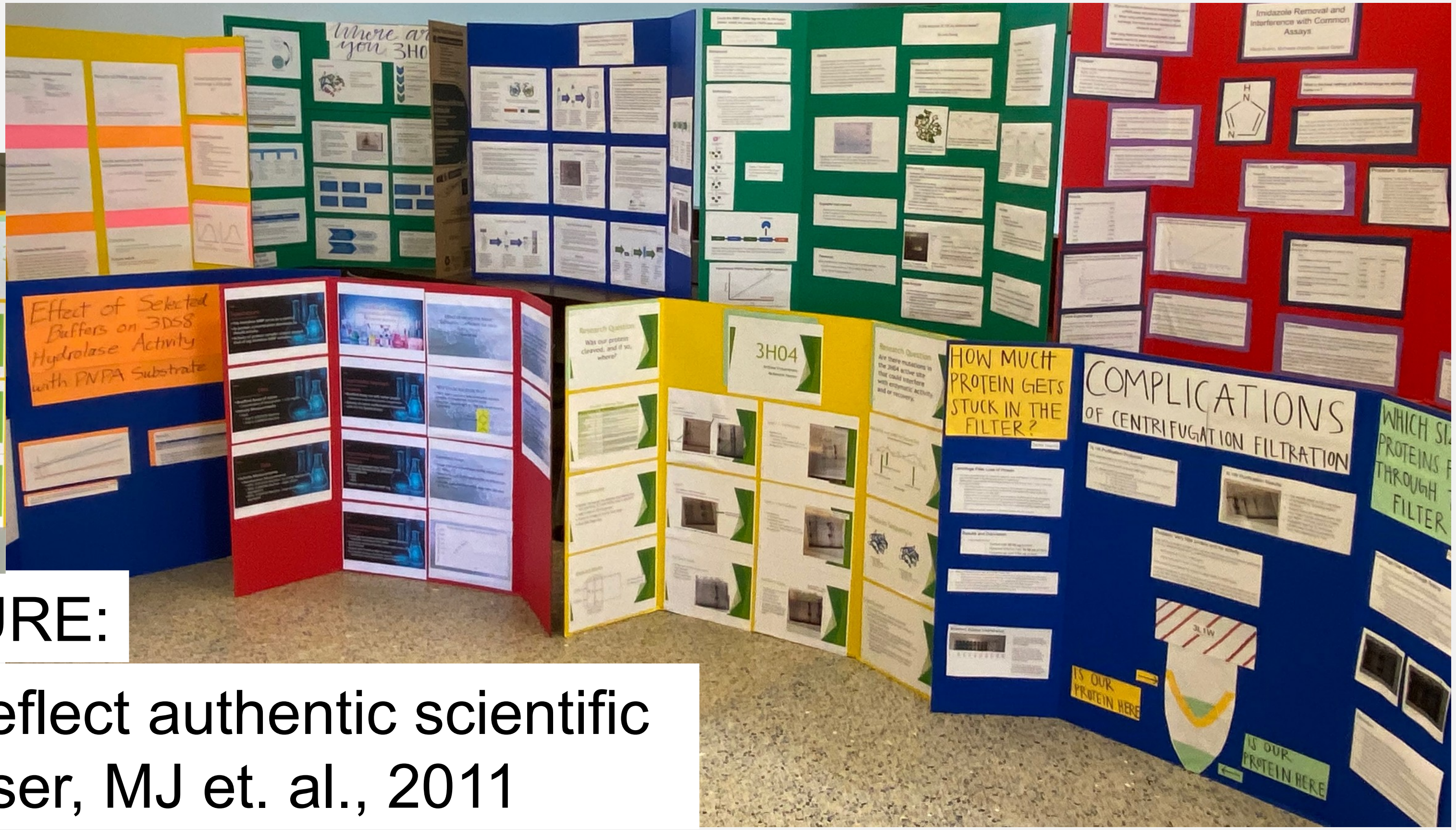
“Point collectors” to Scientists?

Summative assessment: poster presentation





Recommendation for CURE:

Course assessments to reflect authentic scientific communication. Kloser, MJ et. al., 2011

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Summative assessment: lab practical

Does unknown sample contain hydrolase activity?
If yes, how much? If no, what is the evidence?

Demonstrate your skills at

- performing the procedures you practiced in lab,
- keeping a good record of your procedures and results,
- drawing conclusions, and
- writing a brief discussion evaluating your results

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“Point collectors” to Scientists?

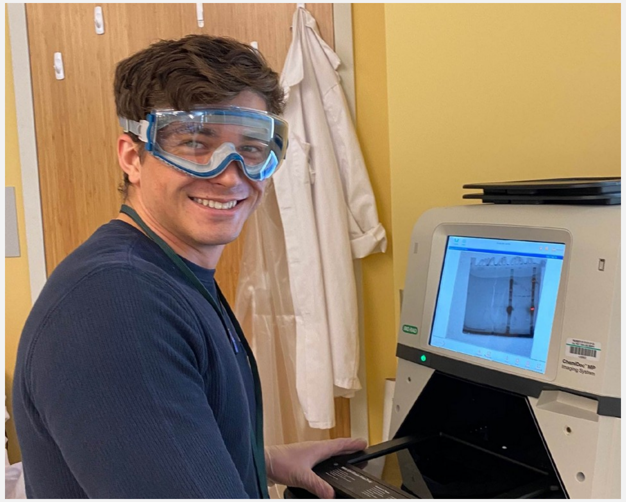
Summary

CURE Implementation and assessment:

1. Align assessments with learning outcomes and learning activities

2. Create scaffolded learning paths with formative assessment “checkpoints”

3. Use authentic summative assessments



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“Point collectors” to Scientists?

Next Steps:

1. Share curriculum

Roberts R, Hall B, Daubner C, et al. **Flexible Implementation of the BASIL CURE.** *Biochem Mol Biol Educ*. 2019;47(5):498-505.

Published lab manual, freely available on GitHub https://basilbiochem.github.io/basil/index.html

2. Currently: focusing on fully online version of the lab

3. Anticipated learning outcomes → Verified learning outcomes

BASIL: NSF IUSE 51453

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- Irby SM, Pelaez NJ, Anderson TR. **Anticipated learning outcomes for a biochemistry course-based undergraduate research experience aimed at predicting protein function from structure: Implications for assessment design.** *Biochem Mol Biol Educ*. 2018; 46(5):478-492. doi:10.1002/bmb.21173
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Questions & Answers

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Next Steps/Closing Remarks

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https://www2.calstate.edu/impact-of-the-csu/research/stem-net