SIMPLE Design Framework for Teaching Development Across STEM

Jill K. Nelson, Margret A. Hjalmarson, Anastasia P. Samaras, and Lori C. Bland
George Mason University

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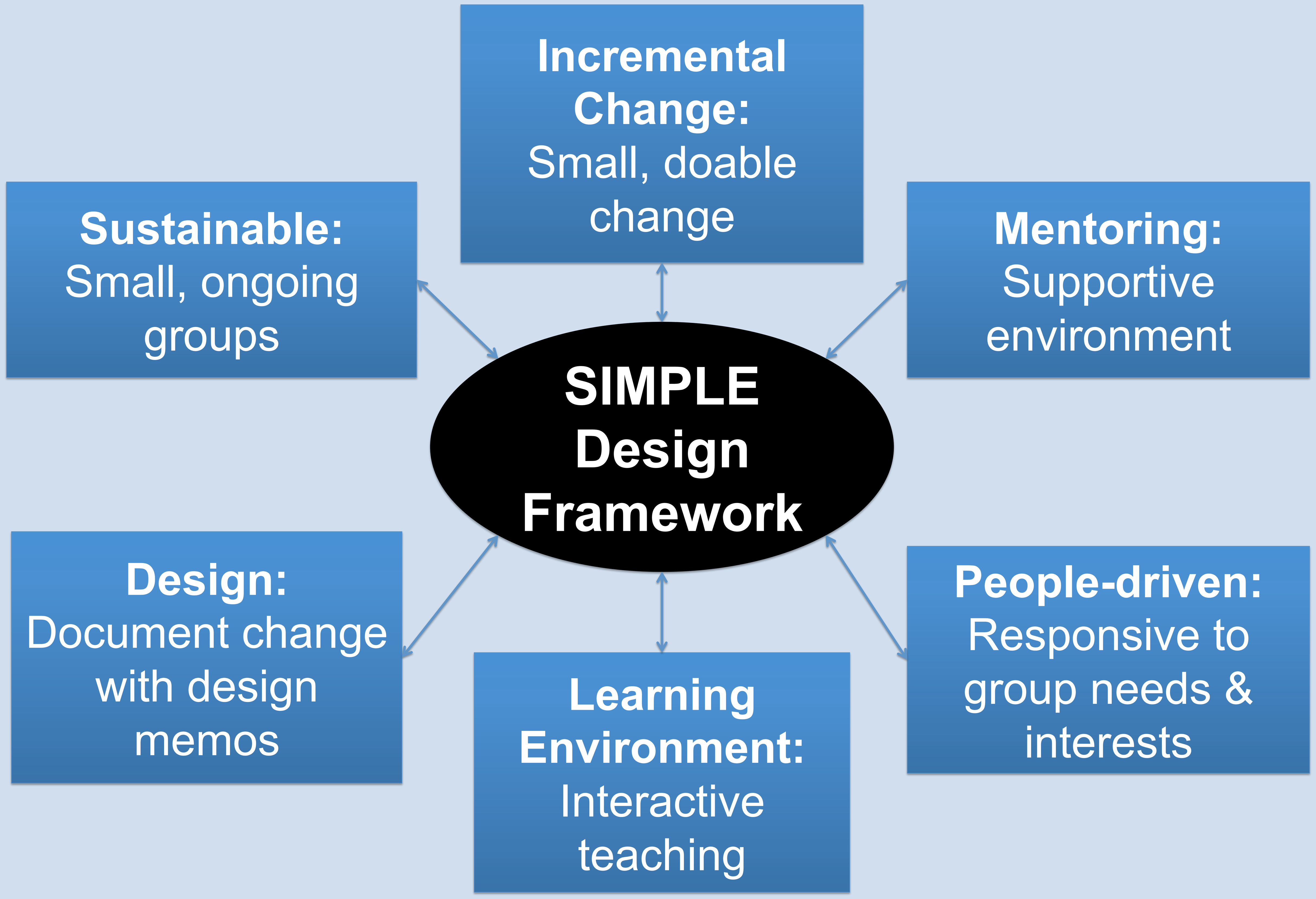
Need

How can we encourage the use of research-based practices for interactive teaching?

How can instructors engage in ongoing teaching development?

We provide a model, the **SIMPLE Design Framework**, for creating small group, design-based structures to support faculty as they implement interactive teaching strategies.



Approach

- Develop a network of **small, discipline-based** faculty learning communities.
- Participants learn about and try **interactive teaching** strategies, try new evidence-based strategies, and document their experience.
- Support **incremental change**
- Group leader scaffolds discussion.
- Data collection via meeting transcripts, interviews, and written reflections to study the experiences and evolution of teaching practices for group leaders and participants.

Variations

The SIMPLE principles are realized in diverse ways across groups.

-Meetings: Structured or Focused

-Inclusion of Graduate Tas

-Common strategies vs. Individual strategies

-Role of the group leader

Benefits

"The most beneficial thing was talking with other people in our department, specifically talking about teaching. You know, when we go to faculty meetings or other kinds of meetings, we don't spend our time talking about different ideas or different teaching strategies, we have all kinds of business to do. So, it was nice [that it was] made up of just people who are really focused on their teaching and wanted to make improvements. "

Challenges

Our largest challenge is instructors' scarcity of time to commit to faculty development. We address this by allowing maximal flexibility in how groups are structured and the frequency and format in which they meet. Group leaders are aware of the culture in their departments and have adapted groups to suit members' needs.

Publications

Nelson, J. K., & Hjalmarson, M. (2015, June). Faculty Autonomy in Teaching Development Groups. *Proceedings of the 2015 ASEE Annual Conference and Exposition*. Seattle, Washington.

Nelson, J. K., & Hjalmarson, M. (2015, June). Faculty Development Groups for Interactive Teaching. *Proceedings of the 2015 ASEE Annual Conference and Exposition*. Seattle, Washington.

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Using Drawing to Engage Students in Large-Lecture Cell Biology: Three Approaches

J. Reid Schwebach,
Accelerator Program | Biology Department | Governor's School

This project is supported by the National Science Foundation, DUE, under Grant No. 1347675 and Grant No. 1240031.

What Drawing Approaches were used?

- Asking students to **draw cellular representations** to understand where biochemical processes happen and their mechanisms in cell function.
- **table generation alongside artwork** depicting critical cellular functions .
- **conceptually integrative artwork** that typically compared cellular processes and integrated other core concepts.

Why do I use Drawing Approaches?

- This is an ongoing area of research for me, and my biology professor colleague Julie Minbiole of Columbia College, Chicago (an acclaimed multimedia, film and art institute); she is interested to pursue related strategies for her students. We are discussing strategies to use drawing to help students understand biological concepts and we plan to survey students to their preferences of using the method.
- Many students reported that engaging in "guided-drawing" activities during lecture helped them learn (encode).

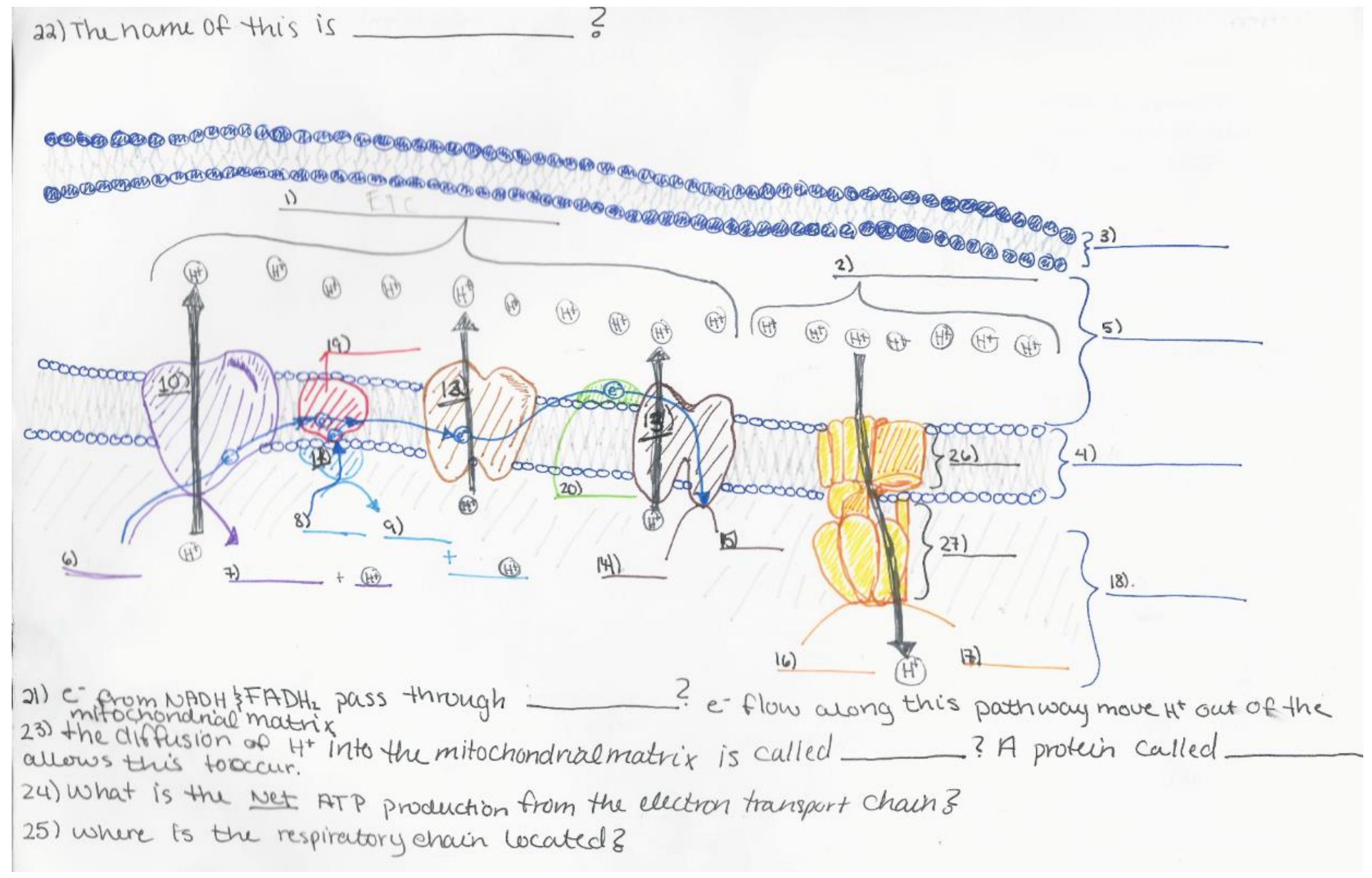
What is an example of the task?

What biochemistry happens in the mitochondria?

An example of the drawing cellular representations strategy.

1. A textbook image of the mitochondria was displayed.
2. Students were asked to explain where glycolysis, cellular respiration, and electron transport were happening on the mitochondria.
3. Students were shown how to draw a portion of the mitochondria, using the overhead projector.
4. Students were then asked to work with their peers to draw the enzymes needed for a biochemical process on the relevant mitochondrial surface.
5. Students labeled their art with the specific functions mentioned in the example in the section above.
6. Student names were randomly called on, and with the student's permission, the student artwork was shown on the overhead projector, for participation credit.

Case Study of Student Understanding(s)



What are the logistics?

- Drawing assignment is started by instructor on whiteboard, helping students see "how much white-space they should plan to use."
- Random calling on students, or additional oral interaction with students is important.
- Students are given quiet time to draw for 2 minutes after a guiding question.
- Students continue drawing while additional information is fed to them to help encode.
- Activity counts towards students' participation grade (i.e., points are assigned for work completed).

What are important considerations?

- A class culture of working with Learning Assistants and participating in group-learning activities seems to help student willingness to participate.
- Cell biology topics are often appropriate activities for students to "draw about." Be able to explain: "why do we want to draw about this?"

Collaborative Mini-Projects in a General Education Astronomy Course

Jessica Rosenberg, Department of Physics and Astronomy

This project is supported by the National Science Foundation, Division of Undergraduate Education, under Grant No. 1347675.

What are Collaborative Mini-Projects?

- These are small group exercises of an exploratory nature that students present to their peers upon completion.
- Students are prepared for the activity by answering several specific questions and a couple of open-ended questions designed to challenge them.
- The activity concludes with students constructing and presenting 2-3 slides. This helps them organize their thoughts and also keeps them on task.

Why do I use Collaborative Mini-Projects?

- The projects encourage students to think critically about class ideas and explore them on their own.
- Mini-projects are also a good way to start a group discussion of a class topic.

What is an example of the task?

How do we learn about other planets?

- In groups of 2 go to www.google.com/mars/
- Explore different regions noting color scale on map
- Pick 1 feature to discuss – all groups at a table must pick different kinds of features
- What do you think this feature is and why?
- What else might this feature be?
- How might you verify what this feature is? Can you verify it without visiting the site?
- Put together 2-4 slides showing the feature, what you think it might be, why you think this, and how you might verify what this feature is.

Skill Development in Mini-Projects

Assignments	Skills Developed
Answer specific questions	Build knowledge
Answer open-ended questions	Improve critical thinking
Prepare short presentation	Build teamwork skills
Give short presentation	Develop presentation skills

What are the logistics?

- Done in groups of 2-3. Larger groups lead to some members “zoning out” and not participating.
- Assign groups and switch them half way through the semester.
- Activity counts towards students’ participation grade (i.e., points are assigned for work completed).
- To save class time, groups are assigned different questions, then only one group presents answers to each question.

What are important considerations?

- A class culture of working in groups and whole-class presentations needs to be cultivated. Including such exercises from the beginning of the semester helps decrease resistance.
- The topics for the mini-projects can be flexible, but they need to include at least a small open-ended component.

Peer Review
As part of the Undergraduate Lab Report

Chelsie Romulo, Department of Environmental Science and Policy

This project is supported by the National Science Foundation, Division of Undergraduate Education, under Grant No. 1347675.

What is the Peer Review Activity?

- Students participate in a single blind review for one of their lab reports.
- Peer review is designed to be integrated into an existing lab report assignment.
- The goal is to increase student understanding of the scientific method as well as the lab activity.

Why do Peer Review?

Peer Review provides students with:

- Incentive to understand and critically evaluate the formal lab report .
- Opportunity to improve the formal lab report based on input from their peers prior to submission to instructor.
- Unique experiential learning opportunity.

Peer Review provides instructors with:

- Opportunity to clarify assignment.
- Potential for higher quality submissions.

Example Instructions

- Using the grading rubric, assign Full, Half, or Zero credit for each component and tally the final score at the end.
- Please provide positive written comments on how to improve the assignment.
- Full credit will be given for being present on the day of peer-review, bringing two hard-copies of the formal lab report, and providing reviews and grades of the formal lab reports of two peers in a thoughtful, thorough, conscientious manner.

What should I include in the rubric?

Section	Components
Format	Complete, logical, and correct format of sections and labels
Intro	Concise background, research questions, objectives, hypothesis
Methods	Thorough explanation and justification
Results	Appropriate summary with tables/figures
Discussion	Interprets results in context of hypothesis and background, draws conclusions, addresses uncertainty, and poses new questions

What are the logistics?

- Students are provided a grading rubric.
- Students bring 2 copies of their lab reports for an in-class peer review activity that lasts about 1 hour.
- During lab class, students grade the formal lab reports of two of their classmates using the provided grading rubric.
- After receiving input and grades from their peers, students have time to incorporate revisions before turning in a final copy.

What are important considerations?

- We recommend the review be done in-class to avoid plagiarizing and so the instructor is available for clarification.
- A very clear and detailed grading rubric is necessary to avoid discrepancies between instructor and peer grading. For each portion we specified the components required for full, half, or no credit.

For more information, see complete design memos here: http://simple.onmason.com/

Active Learning in Undergraduate Civil Engineering Classrooms

Laura Kosoglu, Ph.D. and Anthony Battistini, Ph.D.
Sid and Reva Dewberry Department of Civil, Environmental, and Infrastructure Engineering

In-Class Exercises (ICE)

- Short engineering problems that students work on in pairs during class for 5-10 minutes.
- One group presents their work to the class for extra credit.
- Class discussion on the parts of the problem where the class struggled.

Why do I use ICE problems?

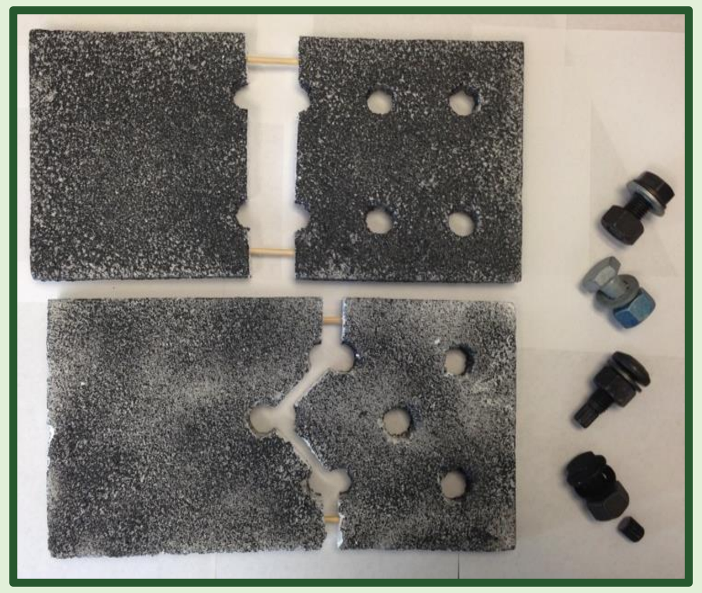
- Active student engagement vs. passive listening and watching.
- Students collaborate and learn from their mistakes in a no-risk environment.
- Students practice teaching and sharpen their presentation skills.
- Instructor can quickly learn what topics need better explanation.

Idea for Variation

- Provide the solution to the problem but with certain lines blanked out, to be completed by the students.

This example reinforces the principles of buoyancy, without requiring extensive calculations. A hint is provided to help the students start. The instructor can then build on this example to return back to lecture.

A wooden cube with 9 inch sides is inserted into water. The specific gravity of wood is 0.6. What force must be applied to the block to keep the block completely submerged? Hint: Draw a free body diagram to start the problem.



Being able to see typical sizes of steel connection details and the failure patterns required to be checked during design helps students understand the formulas used.

Students often struggle with correlating the required structural design loads to a physical representation. In this ICD, the instructor taped off a 4 ft x 4 ft square and kept adding students to the box until the design load was obtained.

In-Class Demonstrations (ICDs)

- Physical models or materials used to increase students' ability to apply engineering principles to real-world problems.
- Students are involved in demonstration.
- Student volunteers receive reward (engineering trinket) for participation.

Why do I use ICDs?

- Many engineering students learn visually.
- Complex theories can be easily observed.
- Students seem to better remember concepts when associated to an activity or physical model.
- Varies the style of the lecture- students are eager to see ICDs and can formulate his/her own understanding of behavior.

Ideas for Improvement

- Include follow-up questions on homework.
- Develop enough ICDs to have <u>*at least one every class period*</u>.

Interactive lecture videos in a distance-learning course: Biostatistics for Biology Majors

Marieke Kester, Environmental Science and Policy Department

This project is supported by the National Science Foundation, Division of Undergraduate Education, under Grant No. 1347675.

Making distance learning lectures interactive

- 60 lecture videos for semester-long course
- Lecture videos were on average 13.5min long (± 5.6min) with 1 – 3 activities each
- Intro to activity slide: "It's your turn. Pause the video and try the following activity"
- Presentation of activity
- Follow-up slide: "Did you really try the activity? Pause the video and try it. Warning: Answers coming next"
- Video presentation discussing conceptual answers or solving for numeric answer

Why use embedded activities?

- Lecture videos can be passive and boring and students lose focus

- Embedding review questions in the video engages students with the content better
- Adds active learning component into distance learning course
- Attention is drawn to important concepts
- Students are asked to solve problems independently right after learning material
- Follow independent attempt directly with step-by-step process and answer

What are the logistics?

- Activities were designed to be completed independently to fit life style of distance learning student
- Activities take variable amount of time – 5sec (simple recall) to 20min (full hypothesis test)
- Correct answer and step-by-step solving process always presented directly after student attempt
- Students self-check answers
- Activities were the first practice session of a given topic and thus were not graded

Example embedded activity

It's your turn…
PAUSE THE VIDEO

Use the formula for probability to calculate $Pr(E_3)$

Where E_3 = rolling a 7 with 2 dice

→

Did you really try the activity?
If not, PAUSE THE VIDEO AND TRY IT

WARNING: Answers coming next!

→

Video presentation showing, step-by-step how to solving for answer and explaining any difficulties.

What are important considerations?

- Creating engaging digital lecture content is very time-consuming
- Embedding review questions as video content is created is efficient
- Most students reported doing the lecture activities but there is no easy way to verify

Hot Seats: Large Classroom Engagement through Measurable Participation

Chris Kauffman, Dept. of Computer Science, GMU

This project is supported by the National Science Foundation, Division of Undergraduate Education, under Grant No. 1347675.

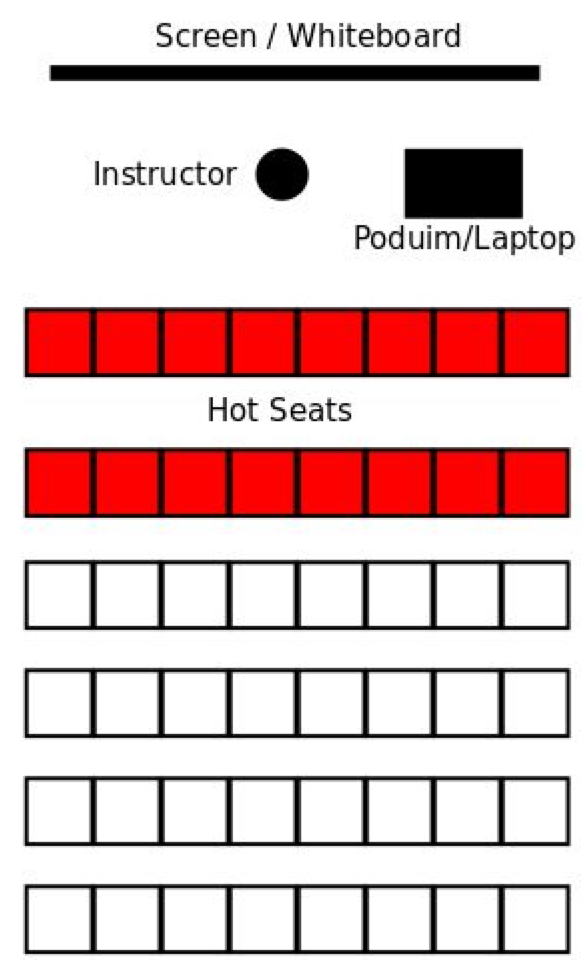
Typical Large Classroom Problems

- Initiating Proper interactive discussion is difficult: many students prefer anonymity of silence
- Invisible wall between instructor/class
- Gauging student understanding difficult without feedback through discussion
- In the absence of technology (clickers) measuring participation in large classes is difficult, tedious, or both
- Single student may attempt to dominate discussion

Hot Seats Help Solve these Problems

- No major technology required
- Incentivizes optional participation or provides easy accounting of required participation
- Creates an atmosphere of discussion rather than lecture

Typical Lecture Setup



Playing cards are a readily available and inexpensive token to hand out as students answer questions. I use souvenir cards from trips/museums.

Sample Adaptations

Situation	Variation
Very large class	Rotate hot seats by last name: A-K, in lecture 1, L-Z in lecture 2
Participation Required	Notify students they must reach a certain total by end of semester
Participation Optional	Top token-earner gets a 3% bonus, others get propotional bonuses
Single dominant student	Rotate who gets to answer to spread tokens around

What are the logistics?

- Hot Seats are seats close to the front of the room students may elect to sit there
- During discussion, questions are directed at students in hot seats
- Effort and answers are rewarded with a “token” physically given to participant
- Unprompted questions from any part of the room also nets a token
- At the end of class students return tokens and record how many they received on a sheet of paper at the front of the room
- Works well with in-class activities: rewards for contributing answers after 10-minute work period
- Instructor tallies total participation over the course of the semester: quantifiable participation based on token count
- Frequent Q&A shows temperature of the room; can speed up or slow down presentation based on answer quality
- Emphasis on discussion encourages all students to ask questions

Scaffolding Strategies in Lesson about Food Security in a Social Determinants of Health Course

Diana Karczmarczyk PhD, MPH, MCHES
Department of Global and Community Health

What are Scaffolding strategies?

- These are strategies that break up a complex topic into smaller pieces
- Students are asked to reflect on their own personal experiences
- Students share experiences with each other in small groups
- Students have visual aids to explore
- Students may be unfamiliar with the food items that are a part of the activity

Why do I use scaffolding?

- Food security is a complex topic
- This strategy encourages students to reflect on their own experience
- Using this strategy encourages evaluation of the topic through a variety of lessons

What are possible small group discussion questions?

- What is the name of the food items?
- Are you familiar with this food item?
- Have you eaten this food before?
- Did you like the taste of it?
- How do you prepare this food?
- Develop a recipe with this food
- Name your recipe
- Swap foods with another group & repeat.

Class discussion-- How does this activity relate to food security?

Lessons Learned from the Activity

- We generally eat foods that we know
- We buy foods that are available to us
- There are different ways to prepare and eat foods
- There are systems in place that can impact what foods are sold in our communities
- Recipes and beliefs about food are shared

What are the logistics?

- Purchase a variety of fresh fruits and vegetables for the activity
- Consider items of various sizes, colors
- Using the letters of the name of the item, swap the letters around to rename each food item
- Develop appropriate questions related to the food topic in the class

What are important considerations?

- A safe environment in the classroom needs to be built and cultivated prior to this type of activity so that students feel that their contributions to the discussion will be well received
- Make sure to develop a key/legend with the correct name of each food
- Have recipes available for the foods new to most students

Concept Maps for Formative Assessment and Student Reflection in a General Education Astronomy Course

Rebecca Ericson, Department of Physics and Astronomy

Why concept maps?

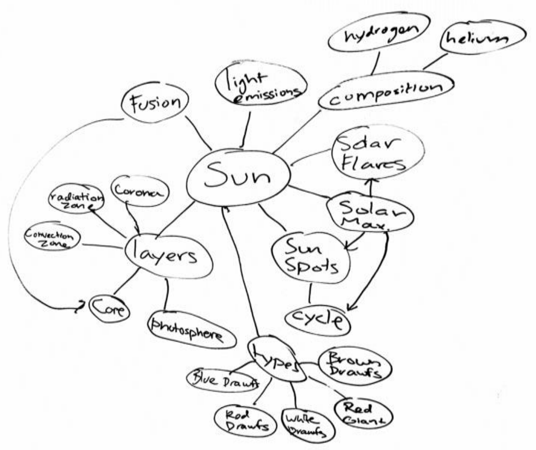
- Concept maps provide a way to see deeper into student learning of science than traditional multiple choice tests or even problems.
- Connections are a key part of the map, forcing students beyond basic facts
- Evidence that these support critical thinking.
- Students usually enjoy creating them, and find them challenging but thought provoking.

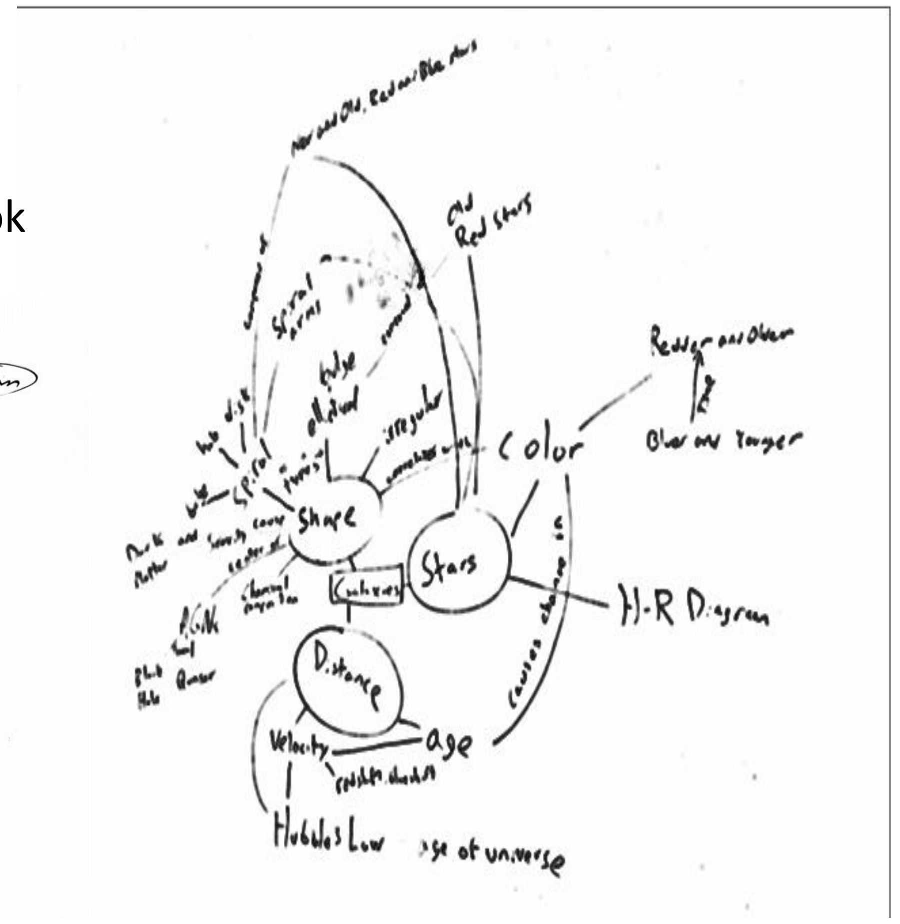
How could faculty use them?

- See more quickly what is missing in instruction
- See student prior conceptions and misconceptions
- Adjust teaching accordingly!

What is an example of the task?

Sun (below)and Galaxies (left) in same portfolio. This set shows increasing ability to connect and look for relationships.





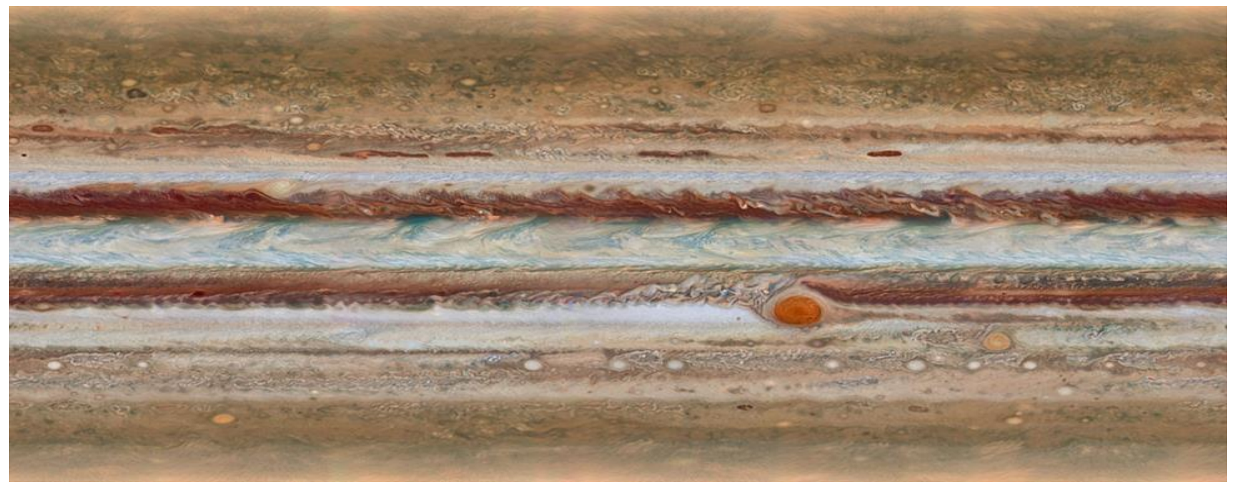
Perceived difficulties with concept maps

Difficulty	Overcome by
Difficult to construct even for expert	Realizing it can be enlightening to struggle alongside students!
Difficult to grade	Skipping the grading! Instead find "holes" in instruction or use for student reflection
Time consuming to teach	Realizing when they are worth the time and effort
They are messy!	Seeing how they reflect learning in all its chaos!

How do the students use these?

- Groups of 3 create on white board
- Groups submit a photo of the map on Blackboard
- Students compare their sequence of maps and note where they see evidence of their own learning
- Students create the maps with different small groups each time.
- Students recreate one of the maps to demonstrate increasing mastery of concepts

Value for learning



Just as clouds on Jupiter (above) are linked to hidden processes and parameters below the cloud tops, so student surface understanding has underlying drivers that are hard to identify. Concept maps can probe deeper for instructor and student alike.

Using Interactive PhET Simulations in University Physics Recitations, Summer Session 2016

Anne Crowell, Dept. of Physics and Astronomy

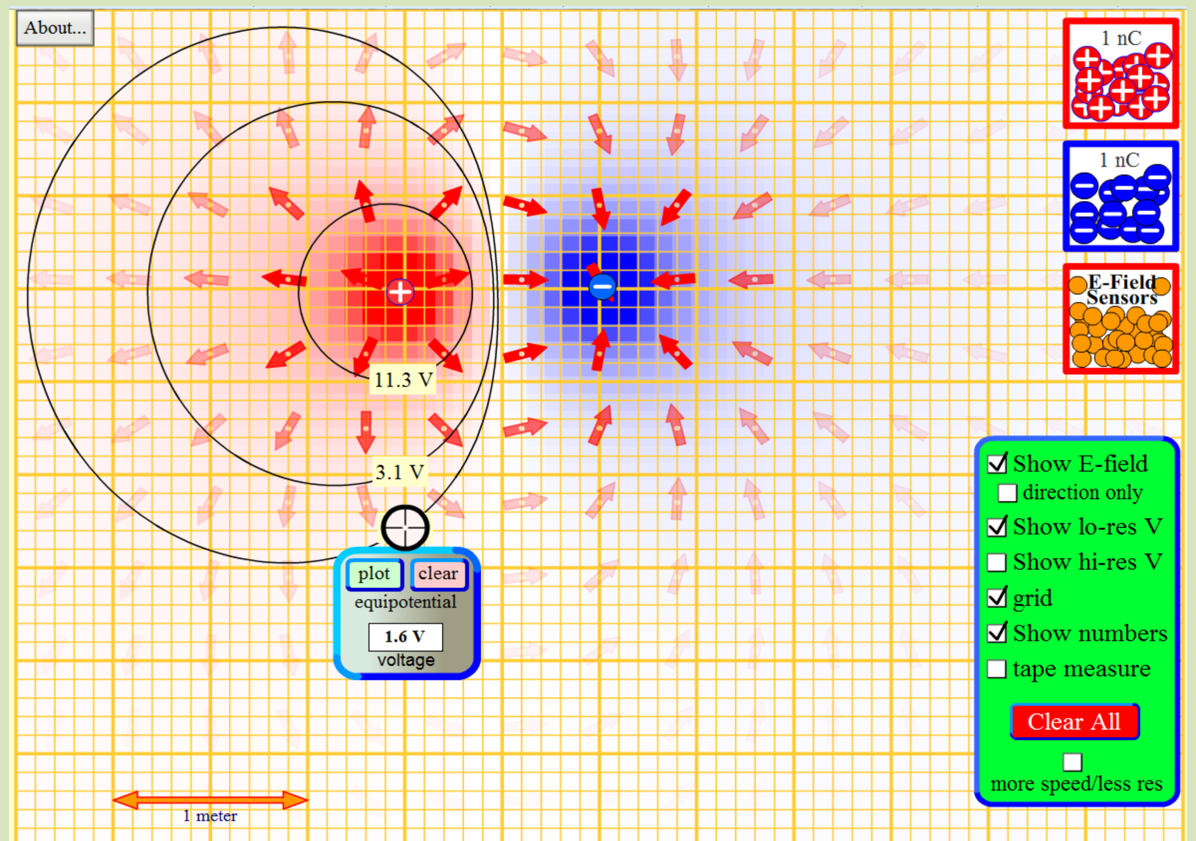


Figure 1: PhET Electric Field simulation.

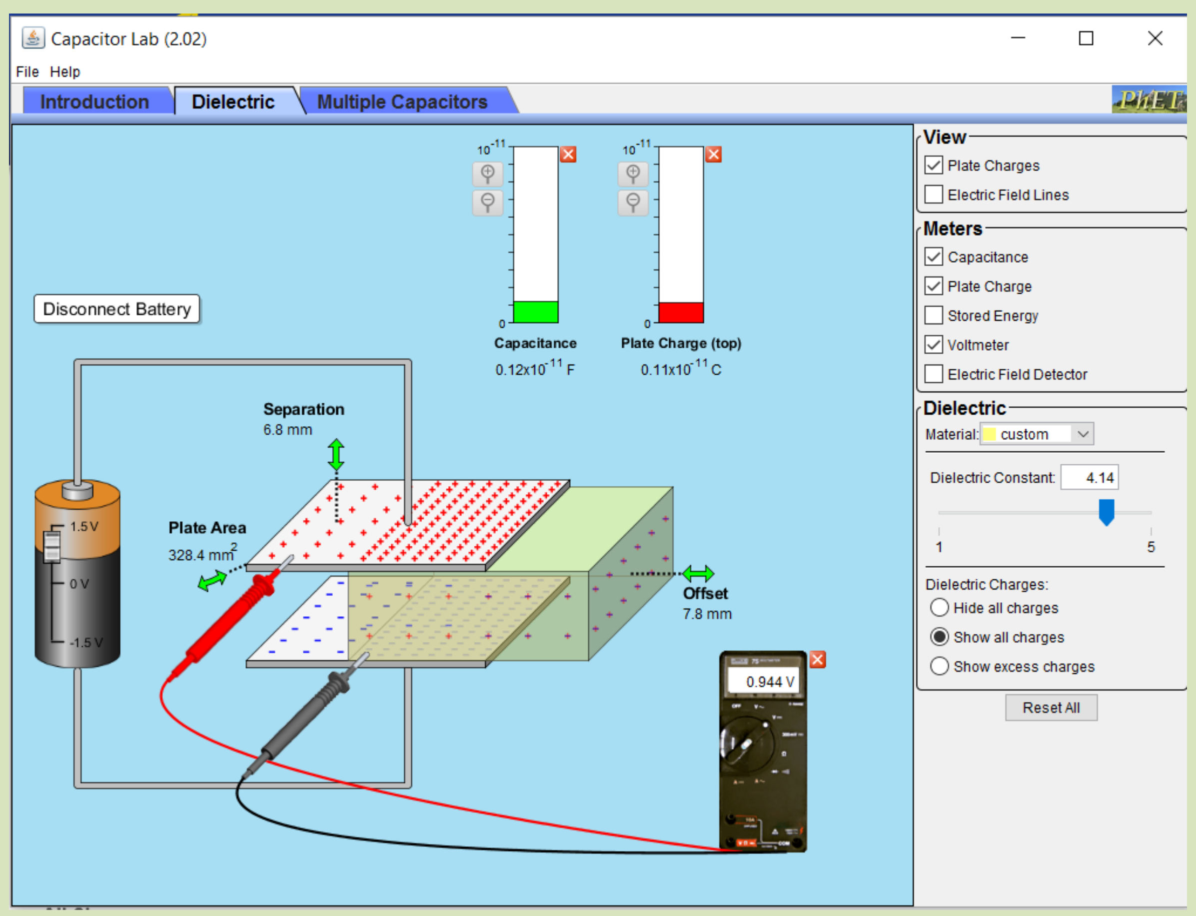


Figure 2: PhET Capacitor Lab simulation.

Reference

https://phet.colorado.edu/

Introduction

Second semester University Physics is a rigorous calculus based class in electricity and magnetism. The course is required for physics and engineering majors. The class is full of topics that are new and unfamiliar to students. As a result, the course requires a considerable time expenditure, and is difficult for students when taken during a regular 15 week term. Taking the course over the shortened summer term, (5 weeks), presents additional learning challenges to students. Student frustration level is generally very high when taking this course. PhET interactive simulations were utilized during a portion of the recitation sessions. The goals of integrating PhET simulations into the curriculum were:

1) **To speed up learning and retention of new concepts.**
2) **To reduce frustration levels .**

Inquiry based simulation guides were provided to students. Two were chosen from those available for download on the PhET website. One was designed by the instructor . Simulations used were: **"Charges and Fields", "Circuit Construction Kit AC/DC", and "The Capacitor-Lab"**

Logistics

1) Students were asked to bring their laptops to recitation. Inquiry based guides were available on Blackboard.
2) Exercises were designed to be completed during recitation.
3) Students were encouraged to work with a partner and discuss what they learned.
4) Activities counted towards the students' participation grade.
5) Most students responded favorably to the exercises. One student commented: *"I am a visual learner, and I found the simulations helpful."*

Suggestions

Don't over use the sims. Students expect the recitations to focus on solving problems from the text.

Student Response Systems in Large-Enrollment Technical Courses

Mark Snyder, Department of Computer Science

This project is supported by the National Science Foundation, Division of Undergraduate Education, under Grant No. 1347675.

What is a Student Response System (SRS)?

- An SRS is a tool that lets you poll students for answers in real time during class. "Clickers" are a common example of the technology, but many web-enabled systems allow for far more than just multiple-choice questions.
- Students must be present, and must send in their answers in the small window of time allowed; the class can then view aggregated (and anonymous) results immediately afterwards, and discuss.
- They need to use their own web-enabled devices, which may induce extra cost.

What is an example usage?

- After introducing a new concept, present students with a batch of 3-5 short answer questions, akin to drills.
- Let students discuss the questions together, try out calculations, and submit their answers.
- After a short period of time, begin discussing the questions and their answers. Look for common wrong answers to drive additional discussion.

What are the logistics?

Make questions to test basic concepts and common corner cases. Suggestions:

- open-ended questions, e.g. with numeric answers. There's a single correct answer, but students have to generate it on their own. "what is the final value of variable x?"
- multi-answer multiple choice: ask students to consider a property and match it to all candidates. "select all of the following that…"

Give ~5 minutes for students to discuss/answer. Close submissions and discuss solutions.

Why should you use an SRS?

- Students get immediate practice and feedback during lecture. It's interactive.
- Professors immediately see where students struggle, and can address the issue directly.
- It is an effective way to encourage class participation (and measure it for a grade).

Managing Students' Expectations

- If students feel they are being tested on brand new material, they may get anxious.
- Recommendation: give them full credit for answering, and extra credit for correct answers. Example: 2% of semester grade for any answers (class participation); up to 1% bonus for correct answers. Also, drop some number of questions in case they have connectivity issues or miss a day.

What are important considerations?

- The room needs to have good wifi for the class size – check your classroom ahead of time for access points (@GMU, these look like white square devices with blue/green lights on them).
- This partially flips your classroom. It *will* take away time from lecturing, so plan accordingly.
- Consider how you will accommodate students with disabilities. Alternate assignments might be needed.

The Geology Teaching Development Group

JULIA ANN NORD Geology Program, Department of Atmospheric, Oceanic and Earth Sciences, STEM Accelerator Faculty. George Mason University (Mason)
And the Geology SIMPLE Team

Learning Assistance Alliance

- The University of Colorado at Boulder Learning Assistant (LA) program has been shown to be very successful in increasing grades and engaging students in large lecture classes, increasing retention in sciences and also increasing confidence and GPA's for the undergraduate LA's.
- "Learning Assistants are undergraduate students who, with the guidance of course instructors, provide academic support to their peers in lectures, labs and recitations, strengthening their own understanding of the course material in the process."

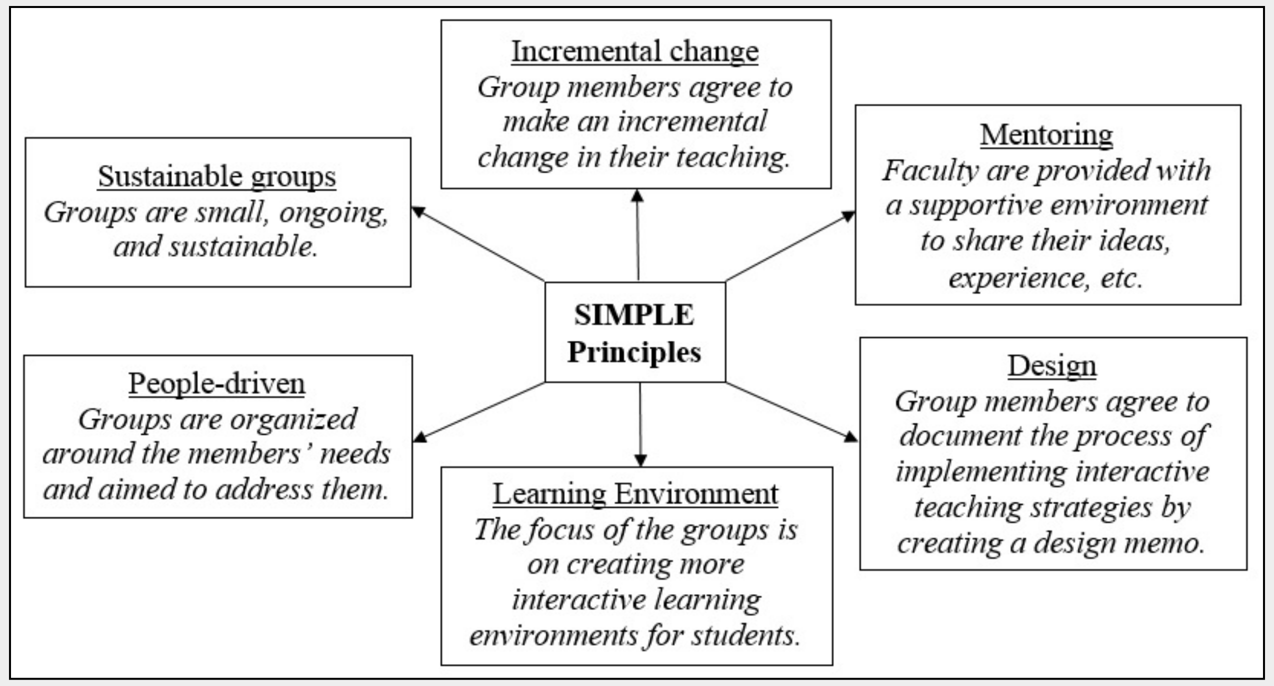
https://laa.colorado.edu/about.php

Geology 101: Physical Geology Mason Core

- Physical geology is different from most courses with LA's as it does not work with math-based problems.
- In spring 2015 we used an LA in an active learning with technology classroom with 58 students. About ten percent of students were documented as attending out of class tutoring hours with LA's.
- In Fall 2015 we had the four LA's attend lecture, a few labs and conduct office/tutoring hours. Forty-Seven students out of 223 respondents reported that they worked with a LA, and stated that the LA helped. However, participation out-of-class was low with only 2-5 students going to office hours per week, except for lecture test review days.

SIMPLE MODEL

A Mason working group (NSF grant) to encourage active learning in STEM classrooms



We hypothesized that students with an LA in lab will
1. have higher grades in lecture,
2. have more confidence in their knowledge,
3. have greater enthusiasm for the subject and
4. be more likely to go on to other geology classes.

VARIABLES

Pedagogy **Personality** **Access**

Two professors

Ten Lab Instructors

Fourteen Lab Classes

Four LA's in Seven Labs

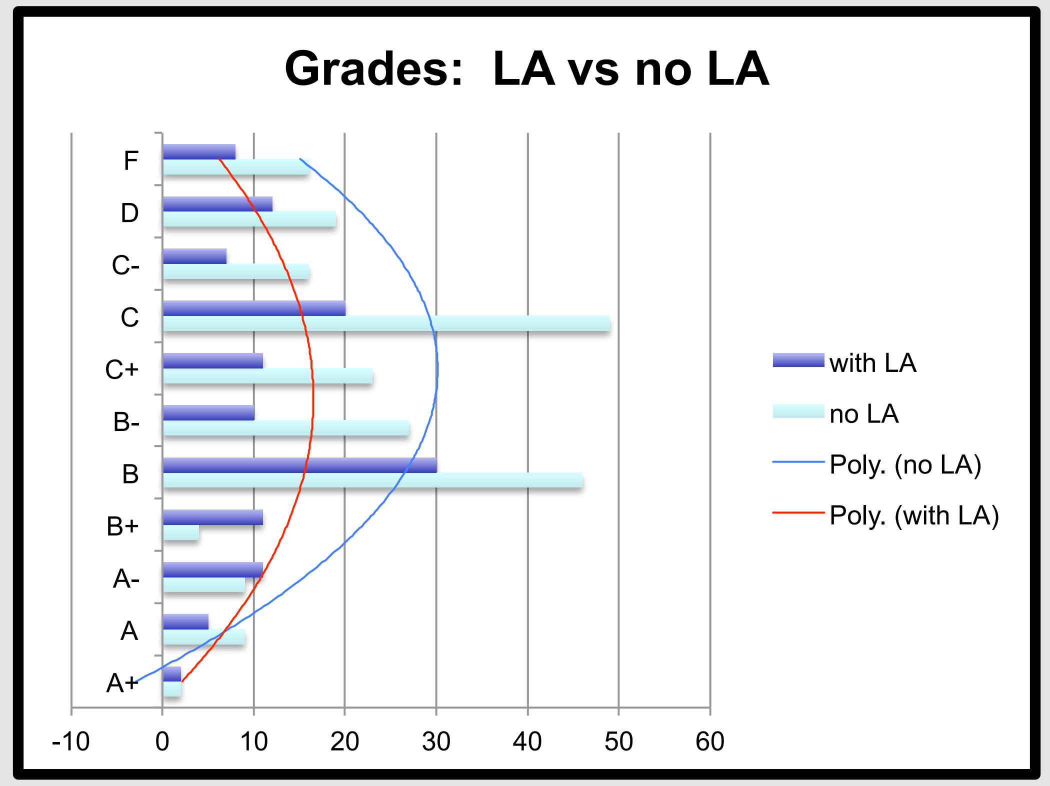
Grade composition

50 or 75% - multiple choice lecture exams
0-25% - participation & graded assignments in lecture
Level of questions?
Curving? 25 point curve?

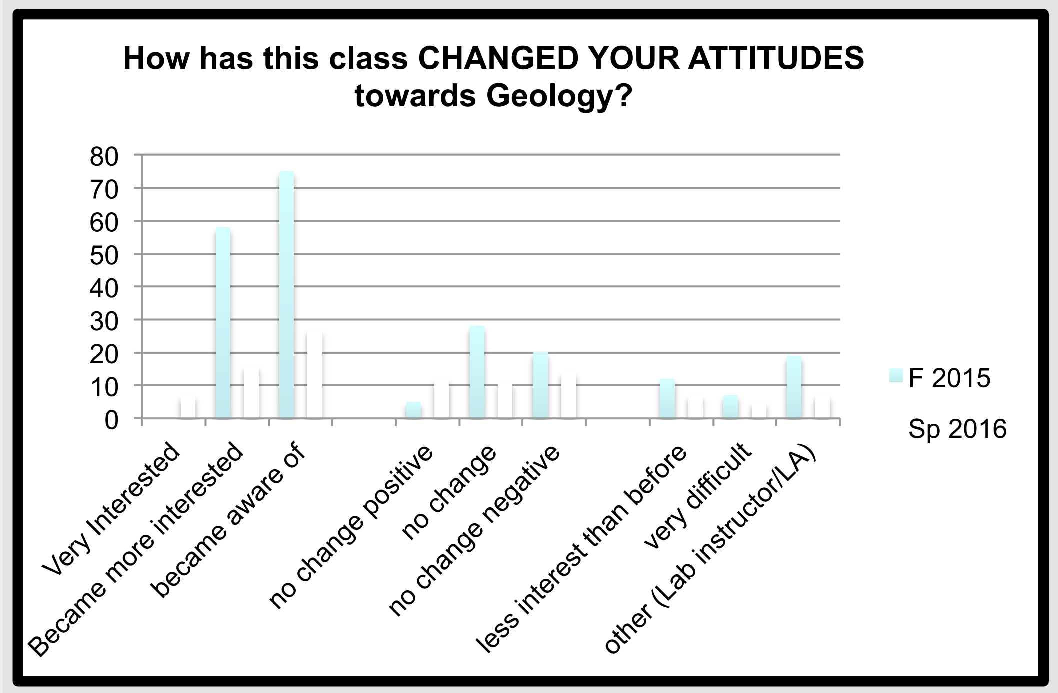
SALG ASSESSMENT: Student Assessment of their Learning Gains

The SALG website is a **free course-evaluation tool** that allows college-level instructors to gather **learning-focused** feedback from students. **http://salgsite.org/**

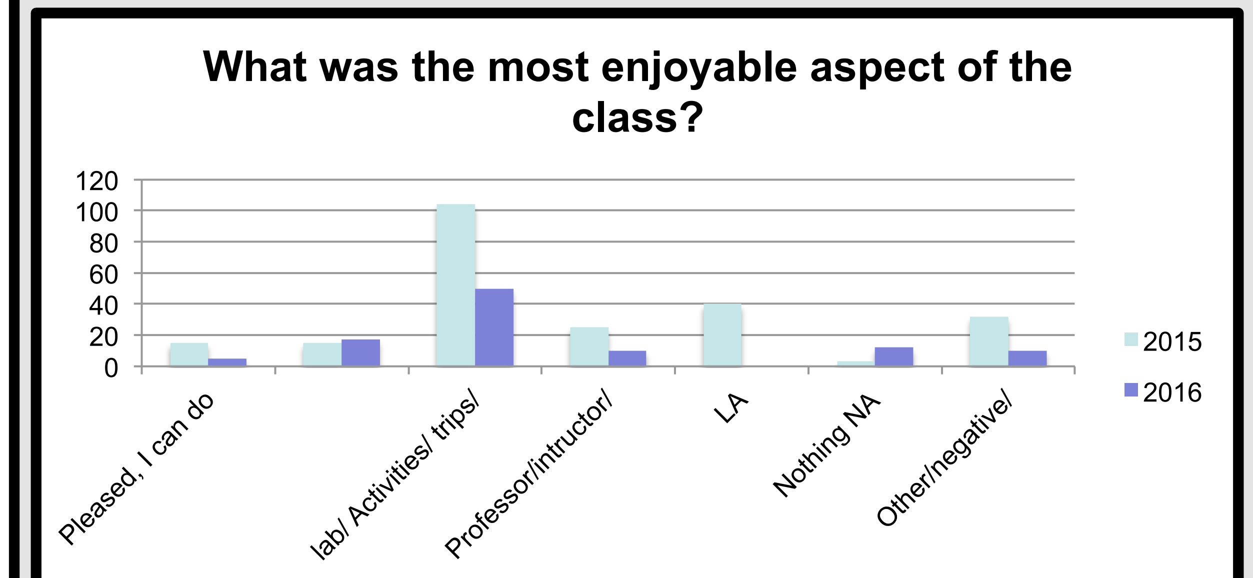
RESULTS

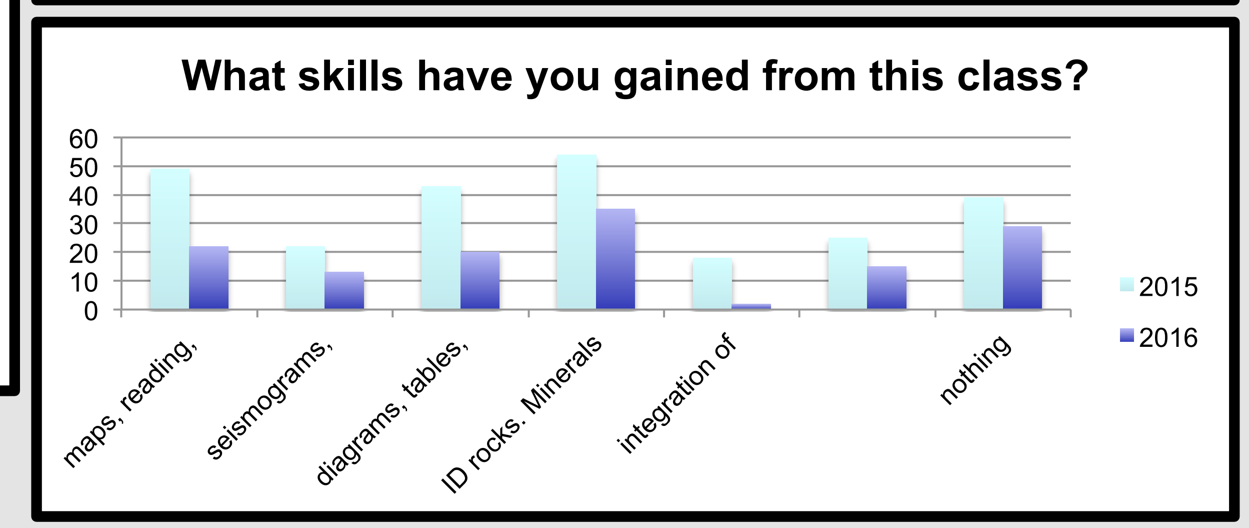


Grades follow a normal distribution. Grades seem to be slightly higher where students had a LA in lab. Fewer students were in classes with LA's.
LA's were added to labs after most enrollment ended.



"My lab professor and LA made it kind of interesting and actually related [phenomenon] like volcanoes to real life situations."





NEXT STEPS

- From this preliminary study it is impossible to understand cause and effect.
- Students appear to have a slight increase in grade with an LA in the lab class.
- Statistics show the highest correlation between grade attained and lecture professor (0.106, $p<0.05$).
- Lecture is 75% of the grade, so maybe we are better going back to using LA's to add active learning in the classroom.

Towards Guided Reinvention of the Fundamental Theorem of Calculus

Bob Sachs, George Mason University

Why Focus on Riemann Sums of Products and the Fundamental Theorem of Integral Calculus (FTIC)

- The topic is central, linking derivatives to integrals, and is valuable for later use of calculus in theory and applications
- The RUME literature demonstrates known student issues
- Ending the course with guided reinvention of a major result is an empowering experience

Why Guided Reinvention

- Educational advantages when successful on a challenging but achievable task for students
- Approach towards ``thinking like a mathematician'' on a genuine problem (Realistic Math Education), building on a problematic situation for students (Intellectual Need – Harel)
- Productive struggle/failure for students aids in understanding even if unsuccessful on tasks initially
- With the framing of averaging, students can do two important things (not always successful, but the key goals): conjecture the FTIC; see the local version (derivative in moving endpoint) as a limiting case of the global version.

Known Student Issues

- Product structure and the meaning and use of Riemann sum approximation is not clear
- Many students view FTIC only as an evaluation statement and miss its use as a tool for creating an antiderivative
- Variable endpoints often come first in a textbook proof and are not motivated by student intellectual need (Harel)
- Area under a graph is a model of summed multiplications but as the dominant image, area leads to confusion when integrating a cross-sectional area, a negative quantity or reversed endpoints
- Using integration to create quantities or solve differential equations occurs often in applications but is difficult for students to connect to their notion of having a known antiderivative used to evaluate a particular integral

Integration As Averaging

- Relevant to applications, especially average values of rates, densities, continuous data
- Context for Riemann sums is then as (weighted) averaging of subaverages to get the global average
- Works naturally in multivariable calculus as opposed to accumulation concept image for integration
- The global form of FTIC as average leads to a difference quotient expressing the average rate of change for the primitive function, which motivates students to propose the limiting case of a shrinking interval, the local form of FTIC!
- We can use equal signs, since students find it hard to be precise about ``approximately equal''

Fundamental Theorem with a Twist

$$\int_a^b f(x)dx = F(b) - F(a) \text{ where } F'(x) = f(x)$$

$$\frac{1}{b-a}\int_a^b f(x)dx = \frac{F(b)-F(a)}{b-a} \text{ where } F'(x) = f(x)$$

The fundamental theorem in global form relates the average rate of change of a given function F(x) on an interval to the average of the instantaneous rate of change, F'(x) and ties to Riemann sums using the MVT for derivatives:

$$\frac{F(b)-F(a)}{b-a} = \sum_{j=1}^{n} \frac{F(x_j)-F(x_{j-1})}{x_j - x_{j-1}} \frac{x_j - x_{j-1}}{b-a}$$

$$= \sum_{j=1}^{n} F'(\bar{x}_j)\frac{x_j - x_{j-1}}{b-a}$$

From Global to Local:

We move from global to local as follows:

$$\lim_{b\to a}\frac{1}{b-a}\int_a^b f(x)dx = f(a) = \lim_{b\to a}\frac{F(b)-F(a)}{b-a} = F'(a)$$

Three Sets of Tasks

1) **Building a robust understanding of average rates of change and the discrete problem of combining average rates of change on subintervals in context** – leads to weighted averaging using size of subintervals. Examples use distance vs. time; earnings over time with different rates of pay; cost of cell phone data plans with variable cost based on usage; road building cost varying with location; car mileage per gallon of gas based on various types of driving. Seek to have students describe some properties of averages and to pose the issue of how to use instantaneous rates to estimate.

2) **Expressing average rate of change as a difference quotient and then writing out the general process.** Recalling the mean value theorem, this is a sum of products (Riemann) using a derivative value and then framing the problem of estimation using some value of the derivative rather that the special one from MVT. Aiming student conjecturing the global version of FTIC.

3) **Formulating both the FTIC on a given interval with a given integrand and then in a general form**. Having an opportunity to notice a difference quotient for average global rate of change and thereby expressing FTIC as a statement that the average of the instantaneous rate of change is the average rate of change. Trying to prove that. Hoping this will prompt a limit process to find the local version of FTIC, using the idea that for continuous functions the limit of the average of the function will be the value of the function at the limiting point.

Ongoing work: refining the tasks, using new version this fall, doing student debriefs and interviews, measuring effectiveness in later courses (math and others), writing up the revised tasks for publication.

Contact Info: rsachs@gmu.edu

Inquiry-based Physics 261 Laboratory Instruction

Assessing Impact on Students' Perceptions & Learning Gains

Tracy Cator-Lee, GMU BS Physics 2015, Dr. Mary Ewell, & Ayabavi Tounouvi,
Department of Physics and Astronomy, George Mason University

Inquiry-based vs. Traditional

- Traditional (T) physics lab instruction implements a set procedure with known results.
- Inquiry-based (IB) labs offer students freedom to generate questions and experiment to find answers.
- Students may find it difficult to enjoy a T setting (i.e. become bored) however the IB method requires more work.
- There are Pro's and Con's to both IB and T methods, but which one maximizes overall student enjoyment and conceptual understanding?

Learning Gains & Knowledge Retention

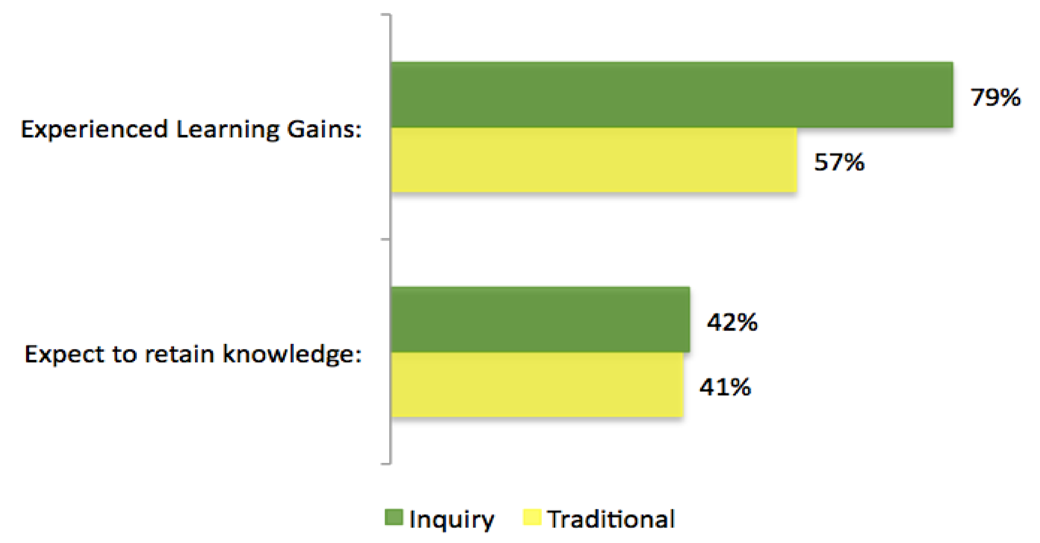


Figure 1: Percentage of students who experienced learning gains and expect to retain what they have learned.

Overall Enjoyment

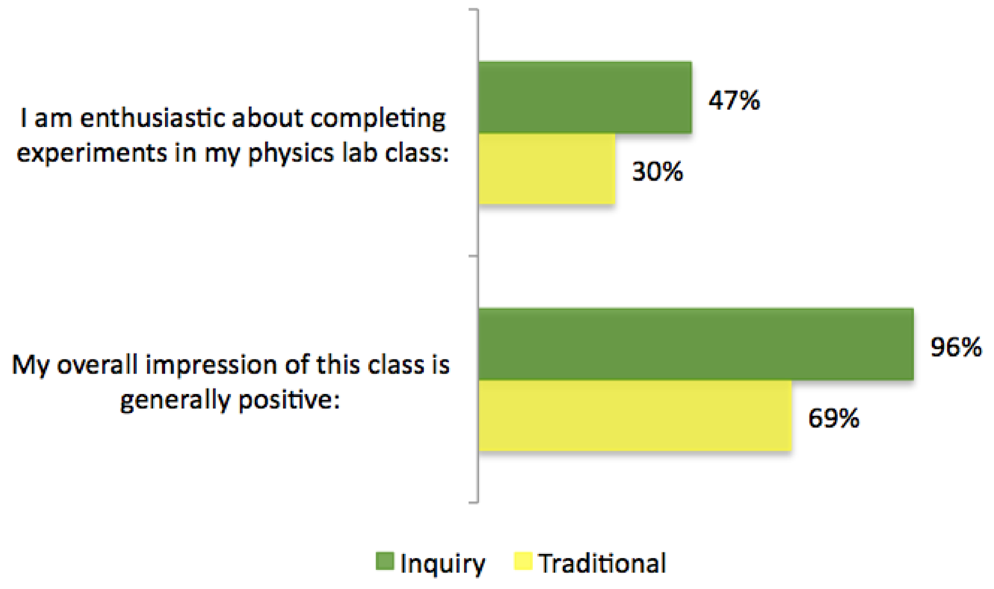


Figure 2: Percentage of students who were enthusiastic about experimentation and whose overall impression was generally positive.

Student Self Assessment

- During the Fall 2014 semester the SALG (Student Assessment of Their Learning Gains, Seymour et. al, 2000) website was implemented to assess physics 261 lab students on a weekly basis.
- In Spring 2015 in an effort to increase participation a custom paper survey that reflected the SALG format was created and administered once mid-semester.
- The survey consisted of 17 questions, most of which were Likert sale 1-6 and was completed by 117 students.

A Brief Electricity & Magnetism Assessment (BEMA)

- This comprehensive electricity and magnetism assessment (Ding et. al, 2006) is widely used in educational research.
- The assessment consists of 31 questions and has a maximum score of 30 (there are two questions that together count as 1 point).
- In the post assessment 4 of the questions were omitted; 7 and 8 for lack of clarity, and 13 and 30 in the interest of brevity.

Results & Analysis

- Student Self-Assessment answers were divided into two groups *generally positive* (Likert scale 4-6) and *generally negative* (Likert scale 1-3).
- As demonstrated by the graphs in figures 1 & 2 IB classes had a more positive impression of physics 261.
- Pre and Post BEMA scores were only available for 32 IB and 21 T students, since both scores are needed to calculate gain factors (g= (post – Pre)/(100%-pre), Bao 2006) results are limited (figure 3, negative gains not displayed).
- Further analysis was performed on all 98 Post BEMA scores and again found to be consistently low with high standard deviations.
- For detailed analysis see: Innovations in Physics Education: Impact of Inquiry-based Laboratory Format on Student perceptions and Learning Gains, Tracy Cator-Lee and Mary Ewell (2016).

Positive Gain Factors

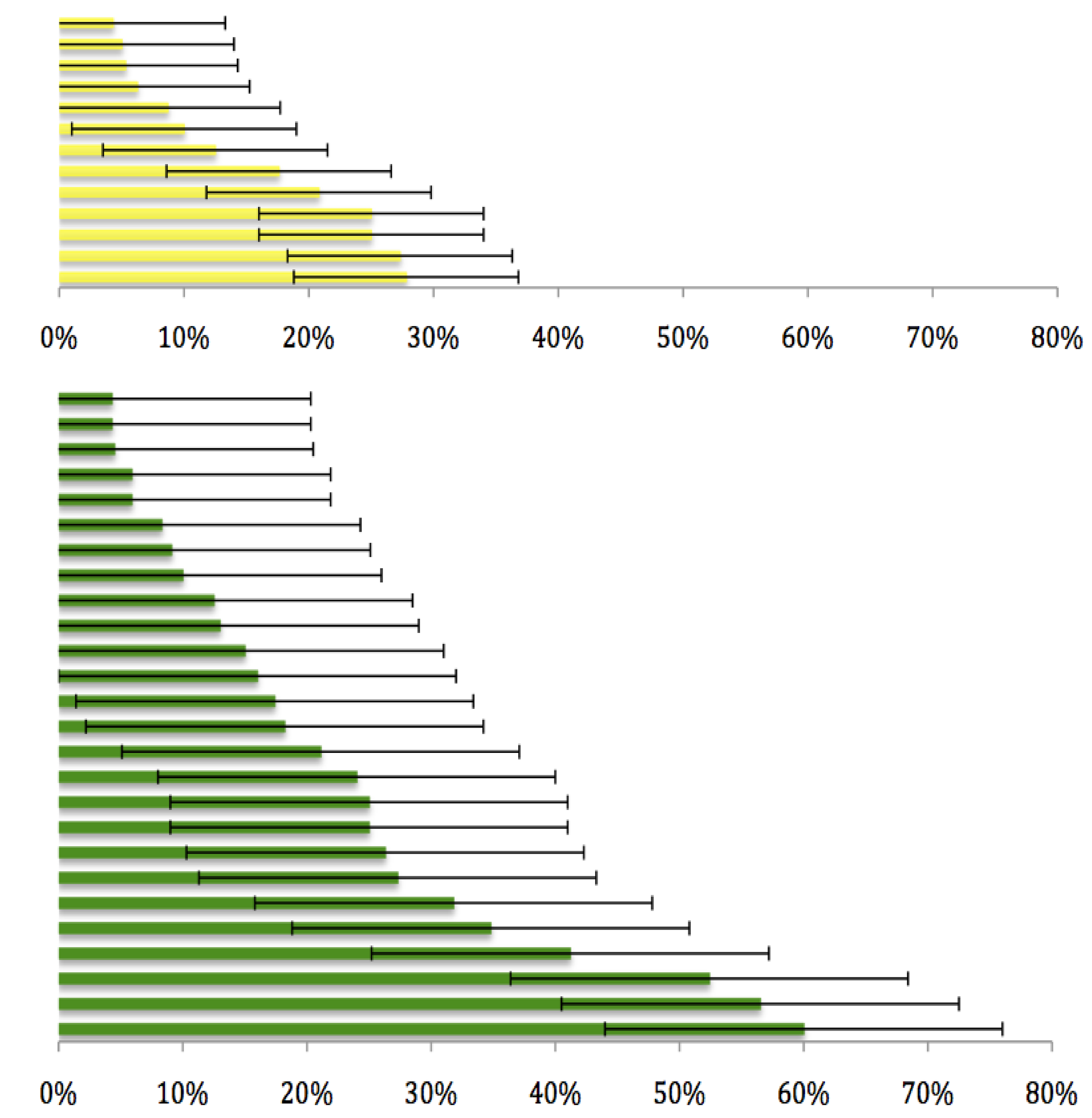


Figure 3: Positive Gain Factors for BEMA, T (yellow) n=13 and IB (green) n=26.

Conclusion

- Results suggest that students prefer the IB format to the T, however further study is needed.
- It is likely that a a hybrid between the T & IB methods will prove the most effective instructional format.
- BEMA scores were low and further research should explore additional assessment options including a new custom test.

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