Implementing Collaborative Learning through POGIL

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Context and Motivation

History of IBL at UChicago

- One section of Honors Calculus (Math majors, placement by invitation only)
- Collaborative Learning started in Chemistry → expanded to other departments

Target Course: Elementary Functions and Calculus (Math 130s)

- Students with weaker or nonexistent Calculus background
  - Mostly non-STEM majors
  - Approx 300 students/quarter
- Lectures (13 sections) --- mainly first-time Graduate Student Lecturers, coordinated by an IP
- Mandatory "tutorials" (2 per week) --- 26 undergraduate TAs
- Converted to Mastery-Based Grading
  - Exams and homework mostly assess lower-level Bloom's skills

Primary Goals

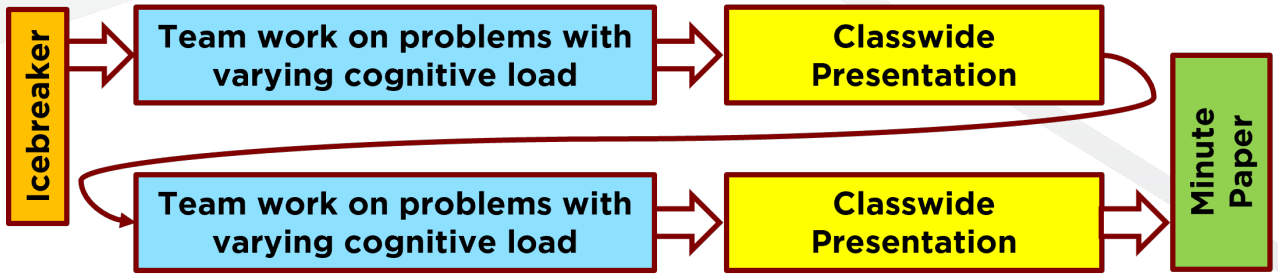
- Consistency in active learning and group work across sections
- Higher-level Bloom's skills ← relaxed time constraints

Solution

- Adapt POGIL → scalable model.
- Make tutorials collaborative and inquiry-based

Structure of Collaborative Learning

Structure of CL Tutorial



Manager

- Ensure that the team stays on task and is focused.
- Aims for equitable turn-taking.

Recorder

- Keeps a record of who plays what role in the team.
- Documents critical team insights for future reference.

Spokesperson

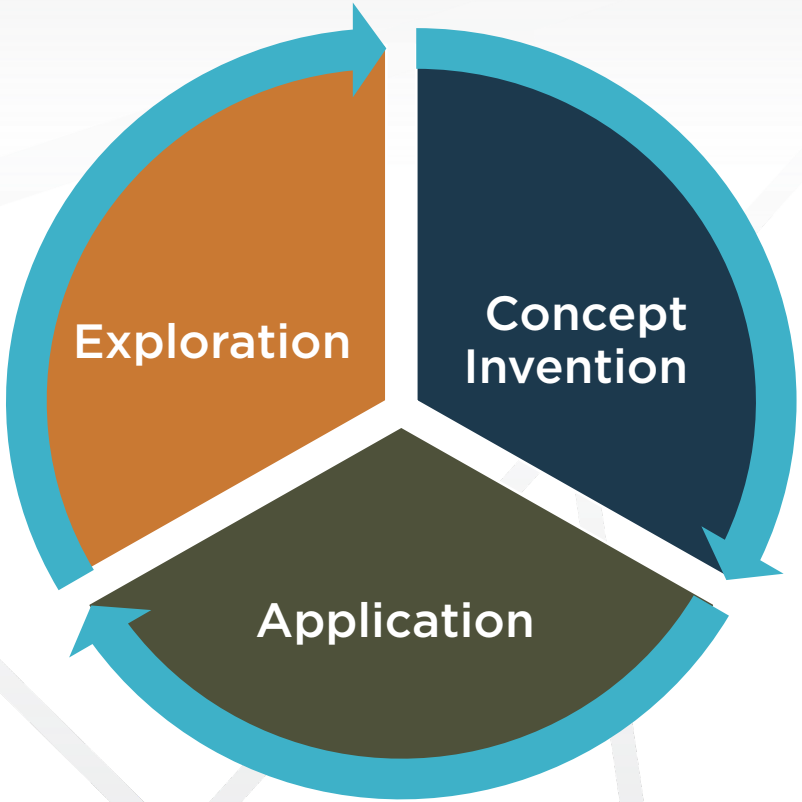
- Presents the team's ideas to the rest of the class.
- Relays the success/challenges to the UTA
- Must rely on the recorder's notes.

Strategy Analyst

- Observes team dynamics and guides the consensus-building process.
- Initiates a discussion of bolded prompts and records the reasoning behind decisions.

Process Oriented Guided Inquiry Learning

- Teamwork
- Critical Thinking
- Management
- Problem Solving
- Self+Peer Assessment
- Communication
- Information Processing
- Metacognition



Training Program for UTAs

Pedagogy Training – 50 minutes

- Practice strategies for motivating students, managing group dynamics, and facilitating without lecturing
- LMS Course with reading and journaling assignment

Lead a tutorial – twice a week

- Time management sheet
- Peer observation report

Content Analysis Training – 120 minutes

- Learning Goals ← Bloom's and Cognitive Demand
- Prior knowledge ← probing questions
- Possible misconceptions ← leading questions
- metacognitive question
  - slow down teams
  - confirm main takeaway

Pedagogy Training Topics by Quarter

Autumn: Collaborative Facilitation Strategies

- Utilizing Roles to balance contribution, manage time, and handle disruptive behavior
- Effective Communication
- Evidence-Based Observation
- Questioning Strategies
- Operant Conditioning

Winter: Science of Learning

- Cognitive Demand Framework
- SMART Goals
- Establishing Authority
- Perry's Scheme
- Welcoming and equal participation
- Process Skills
- Leveraging Feedback

Spring: Knowledge Creation

- Backward Design
- Integrating Styles and Modes of Learning
- Understanding Student Thinking
- Conceptual AND/OR Procedural Knowledge
- Creating a Handbook for the future

Designing Tutorial Problem Sets: Vision vs. Labor

Philosophy

- ❑ promote positive interdependence and promotive interaction
- ❑ scaffolding conceptual tasks
- ❑ discovery-based learning
- ❑ encourage exploration, risk-taking, and productive struggle

Challenges

- ❑ varying task types
- ❑ estimating cognitive load and student perception
- ❑ framing authentic contexts so students see why a problem matters
- ❑ writing metacognitive follow-ups that go deeper than additional applications.

Let's consider the following "if-then" statement

$$\text{If } |x-2|<3, \text{ then } |3x-6|<9.$$

We should interpret it using words as follows:

If we choose an x such that it satisfies $|x-2|<3$, then that same x will also satisfy $|3x-6|<9$.

(a) Your team's initial goal is to demonstrate that the above statement is true. Here is an outline for your team to follow. Compile the outlined steps into a complete, coherent argument.

(i) Start by discussing how we show an "if-then" claim is true. If none of you remember how to do this, stop and check the problems from the last tutorial.

(ii) Consider the set of all x that satisfies the inequality $|x-2|<3$. Discuss what we mean by the "solution set" of the inequality. Can you write the set as an interval?

(iii) Now, if the feasible values of x are chosen from this interval, what are the attainable values of $3x$? Write your answer as an interval.

(iv) Are those values within distance 9 from the real number 6 on the number line?

(v) What can your team conclude from all the observations so far?

(b) Suppose $\delta>0$ is a positive real number and consider the following statement:

$$\text{If } |x-2|<\delta, \text{ then } |3x-6|<9.$$

While the statement is true for $\delta=3$ (as seen above), it might also be true for other values of δ.

(i) Consider the cases $\delta=2$ and $\delta=4$. In each case, determine whether the claim is true or find possible value(s) of x for which the claim is false (i.e., produce a counterexample).

(ii) Discuss what other values can be chosen for δ for which the claim is true. **Write down the set of all such δ as an interval.**

(c) Suppose $\varepsilon>0$ is a positive real number and consider the following statement:

$$\text{If } |x-2|<3, \text{ then } |3x-6|<\varepsilon.$$

Again, while the statement is true for $\varepsilon=9$ (as seen in part (a)), it might also be true for other values of ε.

(i) Consider the cases $\varepsilon=6$ and $\varepsilon=12$. In each case, determine whether the claim is true or find possible value(s) of x for which the claim is false (i.e., produce a counterexample).

(ii) Discuss what other values can be chosen for ε for which the claim is true. **Write down the set of all such ε as an interval.**

Sample Problems

During the lecture, we learned about the inverse trigonometric functions $\arcsin(x)$, $\arccos(x)$, and $\arctan(x)$. In this exercise, we will review those briefly and look into some of their applications.

(a) Before we begin, discuss the following claim. If your team members disagree with each other or with other teams, have a quick class-wide discussion on this.

Since $\sin:\mathbb{R}\to\mathbb{R}$ is not an invertible function, the function $\arcsin(x)$ is not an inverse of $\sin(x)$.

(b) What is the largest interval containing zero on which $f(x)=\sin x$ is one-to-one? What does it have to do with $\arcsin(x)$?

(c) Let's define $f(x)=\sin(\arcsin x)$.

(i) What is the natural domain of $f(x)$? Let's call it $\mathscr{S}$.

(ii) Draw the graph of $f(x)$.

(iii) Is $f(x)$ the same as x for every $x\in\mathscr{S}$? **If you believe yes, explain why this is the case. If you do not believe so, find a real number $c\in\mathscr{S}$ such that $f(c)\neq c$.**

(d) Next, let's define $g(x)=\arcsin(\sin x)$.

(i) What is the natural domain of $g(x)$? Let's call it $\mathscr{T}$.

(ii) Explain why $\arcsin(\sin x))=\pi-x$ for $x\in[\pi/2,3\pi/2]$.

(iii) Draw the graph of $g(x)$. Try not to use DESMOS. Or, if you sneakily do it anyway, explain what's going on with the graph. Why does it look like the way it does?

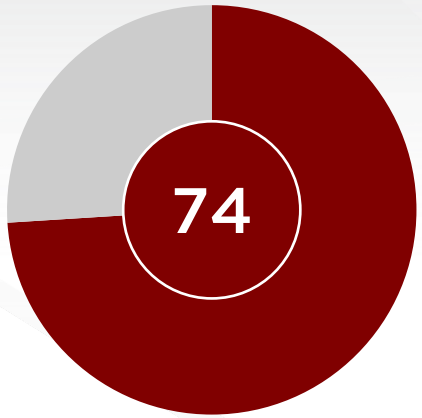
(iv) Is $g(x)$ the same as x for every $x\in\mathscr{T}$? **If you believe yes, explain why this is the case. If you do not believe so, find a real number $c\in\mathscr{T}$ such that $g(c)\neq c$.**

(e) Use the graph of $g(x)$ your team found in the previous part to sketch a graph of $g'(x)$.

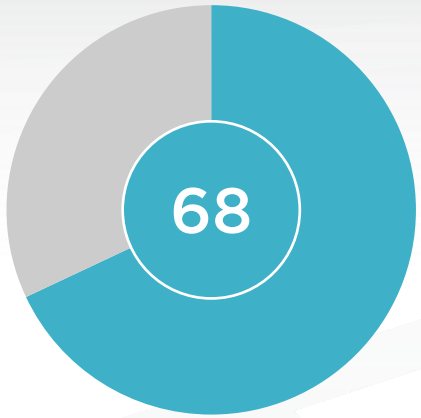
(i) Write down the intervals where $g'(x)\geq 0$ and where $g'(x)\leq 0$.

(ii) Use your observations to explain why we can write $g'(x)=\dfrac{\cos x}{|\cos x|}$.

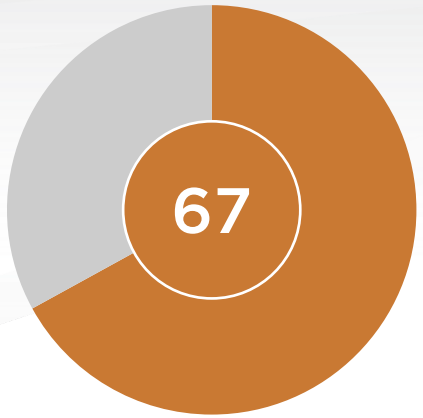
Student Survey and Reflection



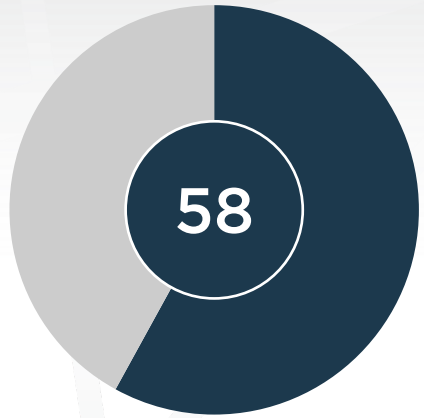
Enhanced Teamwork and Accountability



Improved Critical Thinking and Problem-Solving Ability



Established Community and Belonging



Listening to Peers majorly contributed to learning

- 47% stated the tutorials 'Enhanced' or 'Significantly enhanced' their learning (38% neutral, 15% negative)
- 'Minute Paper' was rated as one of the least effective components for learning

Future Revisions

Redesign `Minute Paper'	Stronger messaging	Balance difficulty level	Enforce Role accountability
• around half online check-ins via Canvas. For the other half, provide exact question instead of having the tutors come up with ideas.	• not designed to be practice for their exam or homework, and assess a different skill set.	• Boost student confidence • Replace with procedural questions before exams	• Concrete deliverables for each individual

Thank you for listening!

Questions?

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