Impacts on Student Achievement from Mastery Assessment and Course Redesign

P. Gavin LaRose

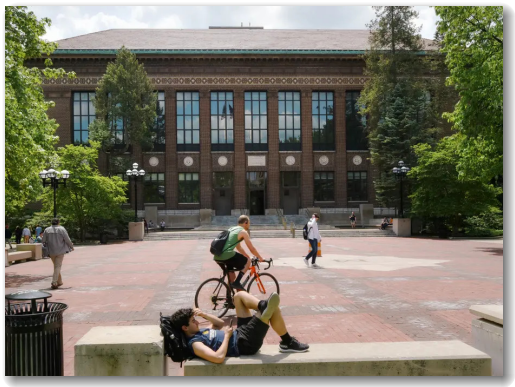
Department of Mathematics
University of Michigan
glarose@umich.edu

September 9, 2025

Motivation

"…but isn't that a weeder course?"

- Introductory math courses are seen as barriers, not accessible learning environments, in part defensibly:
  - Average DFW rates for Precalculus (2021, APLU data): 28%, 30% for women[1]
  - Average DFW rates for Calculus (2021, APLU data): 33%, 40% for URM[1]
    - DFWI (36 institutions, ∼13,000 students) in Calculus (2018, Gardner Inst): 34%, 48% for Black[2]
- U Michigan has a good reputation and track record in introductory math, but is not immune to these concerns.



U-M Diag, Hatcher Library

Local Context

- Student Achievement: overall not bad, but uneven
  - Course before Calculus ("Precalculus"):
    - (2018) DWF rate 19%; URM 27%
    - (2019) Performance relative to expectation (grade − GPA)
      White men, −0.5; Black men, −0.75
  - Calculus I
    - (2018) DWF rate 12%; URM 16%
    - (2018) Performance relative to expectation
      White men, −0.6; Black men, −0.8
  - Exam content study
    "if a student aces the exam, they definitely know the content, but. . . "
- *". . . do you have any ideas for what you want to do?"*

Course Redesign Group, 2019

Course Redesign: Context

- Introductory Courses at U-M: ("Precalculus," Calculus I & II; since calc reform in the 1990s)
  - Strong active learning component (and technology, originally calculators)
  - Small class sizes (24, or 32, or 18, or 24)
  - Strong conceptual focus
  - Highly coordinated course sections (content, assessment, teacher training)
  - Many new(ish) instructors (graduate students, post-docs)
- Assessment
  - Historically: 95%, exams; 5%, webhw
    Gateway tests (skills): grade penalty
    Issues with high-stakes testing and minority students[3]

Calculus class, 1990s

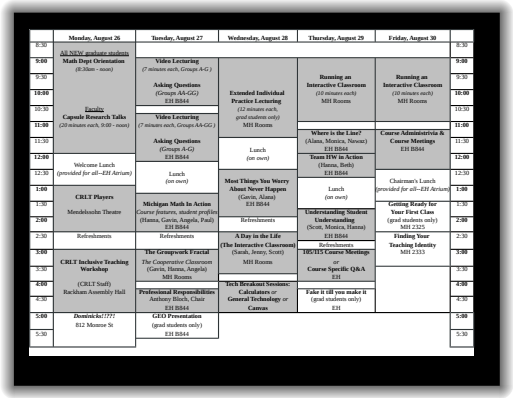
Course Redesign: Process

- Course Redesign: initially, “Precalculus”
  - “Foundational Course Initiative” at CRLT[4] (our Center for Research on Learning and Teaching)
    - “Course Design Institute”, consultants, some funding
    - 3 year process
  - Plus funding from the College, facilities upgrades
- Course Changes:
  - Focus on Instructors
    - (More) Equity Focused Training
    - More experienced teachers in this course
  - Mastery Assessment

Course Redesign Team, 2019

Course Redesign: Training & Instructors

- Department Training:
  - 1 week program
    - All new graduate students and post-docs
  - Added and improved equity-focused teaching content
- CRLT Graduate Student Instructor Training
  - Added CRLT session on equity-focused teaching
- Instructor Scheduling



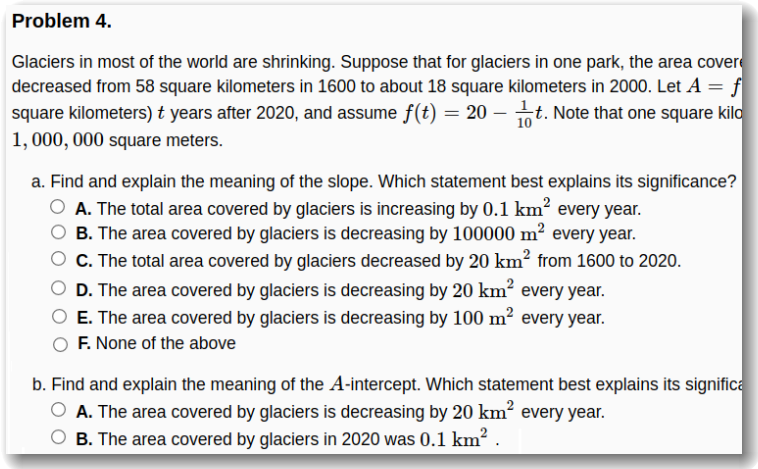
	Monday, August 26	Tuesday, August 27	Wednesday, August 28	Thursday, August 29	Friday, August 30
8:30	All NEW graduate students				
9:00	**Math Dept Orientation** (8:30am - noon)	**Video Lecturing** *(7 minutes each, Groups A-G)*			
9:30		**Asking Questions** *(Groups AA-GG)* EH B844	**Extended Individual Practice Lecturing** *(12 minutes each, grad students only)* MH Rooms	**Running an Interactive Classroom** *(10 minutes each)* MH Rooms	**Running an Interactive Classroom** *(10 minutes each)* MH Rooms
10:00	Faculty **Capsule Research Talks** *(20 minutes each, 9:00 - noon)*	**Video Lecturing** *(7 minutes each, Groups AA-GG)*			
10:30		**Asking Questions** *(Groups A-G)* EH B844	Lunch *(on own)*	**Where is the Line?** (Alana, Monica, Nevaan) EH B844	**Course Administrivia & Course Meetings** EH B844
11:00				**Team ITW in Action** (Hanna, Beth) EH B844	
11:30	Welcome Lunch *(provided for all--EH Atrium)*	Lunch *(on own)*	**Most Things You Worry About Never Happen** (Gavin, Alana) EH B844	Lunch *(on own)*	Chairman's Lunch *(provided for all--EH Atrium)*
12:00					
12:30		**Michigan Math In Action** *Course features, student profiles* (Hanna, Gavin, Angela, Paul) EH B844	Refreshments	**Understanding Student Understanding** (Scott, Monica, Hanna) EH B844	**Getting Ready for Your First Class** (grad students only) MH 2325
1:00	**CRLT Players** Mendelssohn Theatre				
1:30				Refreshments	
2:00	Refreshments	Refreshments	**A Day in the Life (The Interactive Classroom)** (Sarah, Jenny, Scott) MH Rooms	**105/115 Course Meetings** or **Course Specific Q&A** EH	**Finding Your Teaching Identity** MH 2333
2:30		**The Groupwork Fractal** *The Cooperative Classroom* (Gavin, Hanna, Angela) MH Rooms			
3:00	**CRLT Inclusive Teaching Workshop** (CRLT Staff) Rackham Assembly Hall		**Tech Breakout Sessions: Calculators** or **General Technology** or **Canvas**	**Fake it till you make it** (grad students only) EH	
3:30		**Professional Responsibilities** Anthony Bloch, Chair EH B844			
4:00					
4:30		**GEO Presentation** (grad students only) EH B844			
5:00	**Dominicks!!!??** B12 Monroe St				
5:30					

Training Schedule, 2019

Dept Training Session

Course Redesign: Mastery Assessment

- "Precalculus" Assessment Model
  - Exams: 50%
  - Learning component (homework, quizzes, etc.) 15%
  - 5 Mastery Assessments: 35%
- Calculus I Assessment Model *. . . is in flux*
  - Exams: 50%
  - WebHW: 10%
  - Section component (participation, quizzes, etc.): 5%
  - 4 Mastery Assessments: 35%
    - including "Derivative Procedures Mastery"



Problem 4.

Glaciers in most of the world are shrinking. Suppose that for glaciers in one park, the area covere decreased from 58 square kilometers in 1600 to about 18 square kilometers in 2000. Let $A = f$ square kilometers) t years after 2020, and assume $f(t) = 20 - \frac{1}{10}t$. Note that one square kilo $1,000,000$ square meters.

a. Find and explain the meaning of the slope. Which statement best explains its significance?

- **A.** The total area covered by glaciers is increasing by $0.1\ \text{km}^2$ every year.
- **B.** The area covered by glaciers is decreasing by $100000\ \text{m}^2$ every year.
- **C.** The total area covered by glaciers decreased by $20\ \text{km}^2$ from 1600 to 2020.
- **D.** The area covered by glaciers is decreasing by $20\ \text{km}^2$ every year.
- **E.** The area covered by glaciers is decreasing by $100\ \text{m}^2$ every year.
- **F.** None of the above

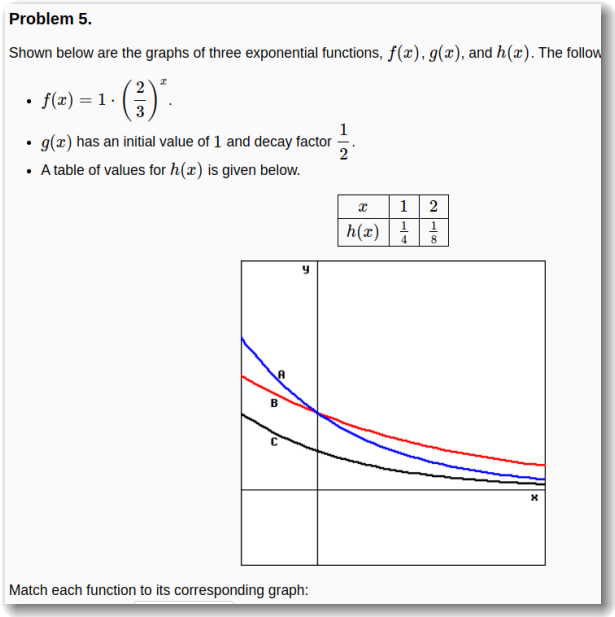
b. Find and explain the meaning of the A-intercept. Which statement best explains its significa

- **A.** The area covered by glaciers is decreasing by $20\ \text{km}^2$ every year.
- **B.** The area covered by glaciers in 2020 was $0.1\ \text{km}^2$.

Sample Mastery Problem

Mastery Assessments: A Definition

- Repeatable
  - Practice anytime, anywhere
  - Proctored for credit: take 2/day in proctored lab
  - Are available for 1 week
    (practice available before and after)
  - Plus Reopen Tokens
    (reopen a mastery for an extra day)
- Cover Course Learning Objectives
  - Cover conceptual course material
  - Cover 1–2 chapters of material each
- Are Mastery Based
  - Require 6/7 to get credit, 7/7 for full


Problem 5.

Shown below are the graphs of three exponential functions, $f(x)$, $g(x)$, and $h(x)$. The follow

- $f(x) = 1 \cdot \left(\frac{2}{3}\right)^x$.
- $g(x)$ has an initial value of 1 and decay factor $\frac{1}{2}$.
- A table of values for $h(x)$ is given below.

x	1	2
$h(x)$	$\frac{1}{4}$	$\frac{1}{8}$

Match each function to its corresponding graph:

Sample Mastery Problem

Mastery Logistics

- Mastery/Gateway Assessment is now in over 7 courses in the department
- In 2024: we gave over 42,000 proctored tests
- Facilities:
  - 4 Testing Labs (Math Dept., $\sim$ 100 seats) open 56 hours/week
  - 1 Testing Lab (Engineering campus, 28 seats) open 30 hours/week (. . . mostly)
- Proctors:
  - $\sim$45 undergraduates, managed by our Math Learning Center Director

New Testing Lab

Outcomes 1

- Pilot in “Precalculus” was in winter 2020
  - All students who fully participated earned a passing grade
  - Instructor observation: *[These] students were particularly likely to be hard hit by the challenges associated with COVID, and the new grading system made it extremely easy to be flexible… The fact that assessments were repeatable and the grading scale was published in advance also helped to reduce student concerns about cheating, because they knew that a classmate cheating wasn’t going to negatively impact their grade.*

The Michigan Daily

ONE HUNDRED AND TWENTY-NINE YEARS OF EDITORIAL FREEDOM

Ann Arbor, Michigan — Thursday, March 12, 2020 — michigandaily.com

CLASS CANCELED

2 DAYS OFF, COURSES MOVED ONLINE AMID COVID-19 OUTBREAK

DOMINICK SOKOTOFF/Daily

ADMINISTRATION

Philbert removed from role as provost

Since late January, he has been on paid leave due to multiple sexual misconduct allegations

1 of 2 confirmed coronavirus patients being treated at Michigan Medicine

Risk for employees and visitors remains low as individual receives treatment in isolation while situation closely monitored, according to statement from hospital

RESEARCH

Students, professors worried by COVID-19

Experts discuss ability to respond to pandemic locally, campus confused about status of programs

Michigan Daily, 12 March, 2020

Outcomes 2

Preliminary, not well checked data

- Fall 2018 Course GPAs (“Precalculus”)
  - Overall: 2.39
  - First-Generation: 2.33 (-3%)
  - URM: 2.11 (-11%)
  - First-Gen, URM: 2.08 (-13%)
- Fall 2024 Course GPAs (“Precalculus”)
  - Overall: 2.87
  - First-Generation: 2.73 (-5%)
  - URM: 2.66 (-7%)
  - First-Gen, URM: 2.59 (-10%)

Students in “Precalculus”

Outcomes 3

Not Quite So Preliminary, slightly better checked data

- Fall 2018 DWF rates (“Precalculus”):
  - Overall: 19%
  - First-Generation: 22% (+14%)
  - URM: 27% (+44%)
  - First-Gen, URM: 30% (+56%)
- Fall 2024 DWF rates (“Precalculus”):
  - Overall: 12%
  - First-Generation: 15% (+22%)
  - URM: 16% (+29%)
  - First-Gen, URM: 18% (+50%)

Another “Precalculus” Class

Conclusions and Next Steps

- Curricular Reform, with Mastery Assessment
  - Works!, or, at least, appears to be having a positive impact. Maybe
  - Is possible at scale, at least, with some dedicated faculty/staff time and resources
- Implementation and Assessment
  - Calculus I is still being iteratively updated
    - Assessment is not well formulated yet
  - Calculus II is in planning stages
- More Training and Instructor Support
  - New Graduate Student Instructors in "group rooms"
    - 4–5 class sections in team-learning room
    - With an additional, experienced instructor
  - Shows promise!

Team Learning Classroom

References

1. K. Michaels & J. Milner (2021). Powered by Publics Learning Memo: The Big Ten Academic Alliance Cluster Exploring Foundational Course DFW Rates, Equit Gaps, and Progress to Degree. APLU.
2. A.K. Koch & B.M. Drake (2018). Digging into the Disciplines: The Impact of Gateway Courses in Accounting, Calculus, and Chemistry on Student Success. John N. Gardner Institute for Excellence in Undergraduate Education Report. https://umaine.edu/provost/wp-content/uploads/sites/14/2018/11/Gardner-Institute-Digging-into-the-Disciplines-The-Impact-of-Gateway-Courses-in-Accounting-Calculus-and-Chemistry-on-Student-Success-.pdf, accessed 2025-09-08.
3. G.F. Madeaus & M. Clarke (2001). The adverse impact of high-stakes testing on minority students: Evidence from one hundred years of test data. In G. Orfield & M.L. Kornhaber (eds.) *Raising Standards or Raising Barriers? Inequality and High-Stakes Testing in Public Education*, pp.85–106. New York, NY:Century Foundation Press.
4. Foundational Course Initiative. https://crlt.umich.edu/fci, accessed 2025-09-08.