Case Study: U(M)'s Large Coordinated Courses Structure, Evolution and Equity, and Application

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intro program class

Outline

- Context: Course and Institutional
- Case Study: Coordinated Courses at Michigan
  - Coordination
  - Pedagogy
  - Assessment
  - Professional Development
- Development, Evolution, and Making Change: some history
- Program Assessment
- Implementing and Sustaining Change
- Conclusions

UM central campus

Introductory Program Courses and Demographics

- Our Introductory Program is:
  - Math 105: Data, Functions, and Graphs
  - Math 115: Calculus I
  - Math 116: Calculus II
- Demographics: largely traditional college students.

	1st gen	intntl	URM	women	major
Math 105	15%	3%	35%	58%	$>$75% undecl.
Math 115	8%	6%	18%	46%	$>$65% undecl. $\sim$8% engin
Math 116	8%	9%	16%	37%	$>$45% undecl. $>$35% engin
College	8%	6%	14%	55%	

[2019 data]

U(M)'s Introductory Program: Numbers and Structure

- Numbers (approximate averages):

	fall			winter		
course	#stu	#sec	#instr	#stu	#sec	#instr
105	450	30	20	110	8	6
115	1700	95	75	775	50	40
116	700	40	35	725	45	38

- Instructors are mostly
  - Math 105: graduate students & lecturers
  - Math 115, 116: graduate students, lecturers, and post-docs (occasionally, tenure-line faculty)
- All have a strong conceptual focus (texts are those by Hughes Hallett, et al.), active pedagogy, and are (very) uniform and highly structured

U(M)'s Introductory Program: Departmental Context

- Large, Research 1 Department of Mathematics
  - About 60 tenure-line faculty, 65 postdocs, 13 continuing non-tenure line faculty, 130 graduate students
  - About 600 mathematics majors (one of the largest in the College)
- Large, diverse (in level) undergraduate program
  - 5 two-year entry sequences (one standard, four honors)
  - Many undergraduate (and graduate) course options
  - Many program facets: IBL center and courses, "Emerging Scholars"-type program, Comprehensive Studies Program, Log(M) (Geometry/Research course), Math Learning Center

East Hall, Math Dept.

Current Coordination Structure

- Coordinators
  - Faculty course coordinator
    - Faculty course co-coordinator
      (Math 115 in fall)
  - Graduate student co-coordinator
    (All but math 105 in winter)
- Uniformity
  - Uniform daily schedules
  - Uniform exams and final, and grading
  - Uniform team homework, grading by common rubric
  - Uniform web homework
  - Uniform conceptual focus
  - Uniform course pedagogy (mostly)
    Lesson plans, instructor support
  - Uniform course meetings (mostly)
- Section work is managed by section instructors
  - With explicit expectations (e.g., quizzes)

Hanna B, Christina A, Gavin L, Paul K

Current Pedagogical Model

- Course instruction: student-centered, active learning
  - Sample class:

10:00–10:05am	Group work on introductory problem
10:05–10:15am	Announcements
10:10–10:20am	Summary of group work solutions
10:20–10:30am	Mini-lecture on new material
10:30–11:00am	Group work on new material
11:00–11:10am	Discussion of solution group wrote on board
11:10–11:15am	Group discussion
11:15–11:20am	Summary of remaining group work

  - Supported by: training, lesson plans, class layout

Paul K in class

Current Assessment Model

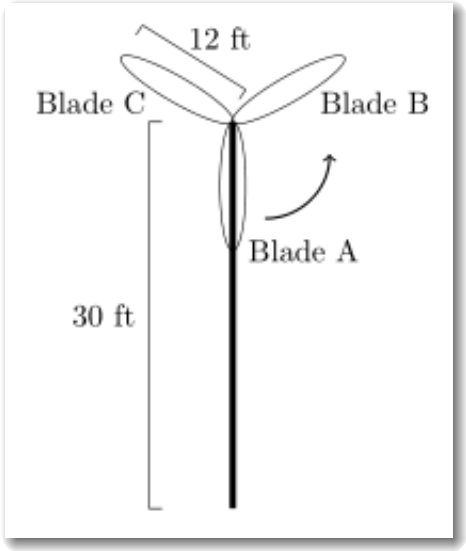
	2020–22	2022–
math 105	2 exams (30%) webhw (5%) teamhw (5%) quizzes (5%) 10 masteries (55%)[1]	3 exams (40%) webhw (5%) teamhw (5%) quizzes (5%) 6 masteries (45%)[1]
math 115	2 exams (50%) webhw (4%) teamhw (3%) quizzes (3%) prepwork (2%) 4 masteries (38%)	3 exams (55–65%) webhw (4%) teamhw (3%) quizzes (3%) prepwork (2%) 3–4 masteries (23–33%)

- Math 105 (Data, Functions, and Graphs) and 115 (Calculus I) have undergone significant reform in the past three years
- Math 116 (Calculus II) is waiting. . . its assessment structure is still our "Calculus Reform" structure (greater emphasis on exams)

[1] *math 105 has also a ceiling grade based on mastery points*

Assessment Sample: Exam Problems

- [Winter 2019] A wind turbine, spinning counterclockwise at a constant rate, stands 30 feet tall... It has three equally spaced blades, each 12 feet long. At exactly 1:00 pm, an engineer sees that Blade A is pointing straight toward the ground as shown. It takes 1.5 seconds to return to this downward position. Let $A(t)$ be the height from the ground, in feet, of the outermost tip of Blade A, t seconds after 1:00 pm.



  - Find a formula for the trigonometric function $A(t)$
  - The height $C(t)$ of the outermost tip of Blade C, in feet above the ground can be given as a transformation of $A(t)$. Circle all correct transformations:
    $C(t) = A(t - 0.5)$; $C(t) = A(t - 2\pi/3)$; $C(t) = A(t) + 18$...
- [Fall 2021] For each part below, sketch the graph of a function that satisfies the given properties, or, if there is no function satisfying all the properties in that part, write DNE instead. Any graphs you draw should have axes like those shown to the right. Make sure your graphs are clear and unambiguous, with any important values marked on the axes.
  - A function $f(x)$ that satisfies $\lim_{x \to 1^-} f(x) = f(1)$ but that is not continuous at $x = 1$.
  - A function $g(x)$ that is positive on $-2 < x < 2$ and such that $g'(x)$ is negative on $-2 < x < 2$.

Assessment Sample: Team Homework

- Students have the roles Editor, Clarifier, Reporter, and Manager
- Solutions are written out in full sentences, with explanations
  - Coulomb's law describes the electrical force, $F(d)$ (in Newtons) between two electrically charged objects a distance d (in cm) apart
    - What is a reasonable domain for $F(d)$?
    - Given experimental data for $(d, F(d))$: $(1, 5)$, $(4, .31)$, $(6, .139)$, $(10, .05)$, determine the type of function F could be
    - Given two data points, could you tell what type of function it is?
  - Let $h(t)$ represent the height in inches of a toy airplane above the ground at time t seconds. Below is a table of values for $h(t)$ and $h'(t)$.

t	0	1	2	3	4
$h(t)$	7	12	14	10	11
$h'(t)$	5	3	-1	-2	1

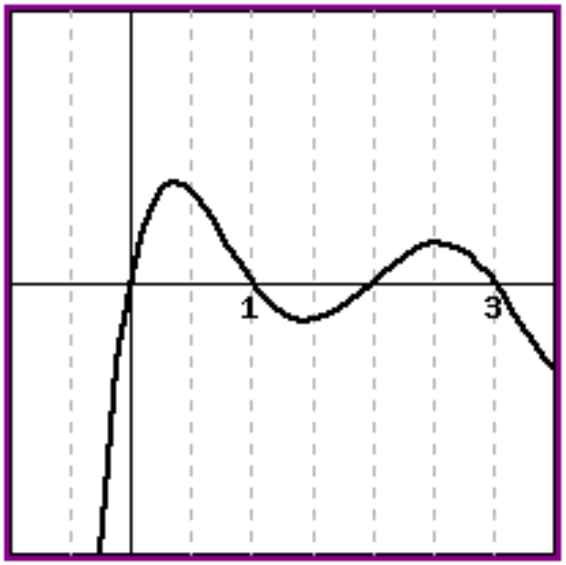
    - Note that $h'(2) = -1$. Give a practical interpretation of that value.
    - Find a formula for the linear approximation $K(t)$ to the function $h(t)$ at $t = 2$.
    - Find $K(2.2)$. Give a practical interpretation of this value.
    - Compare the previous and first answers. How are they related? Do they provide the same information?

Assessment Sample: Web Homework

- Web Homework: Twice weekly, largely drawn from the (conceptual) textbook. Administered with WeBWorK.

(1 pt) **../../../problembanks/svcalc/Chap2Sec2/Q09.pg**

Consider the function $y = f(x)$ graphed below.



Give the x-coordinate of a point where:

A. the derivative of the function is negative: $x =$

B. the value of the function is negative: $x =$

C. the derivative of the function is smallest: $x =$

web homework sample problem

Assessment Sample: 105 Mastery

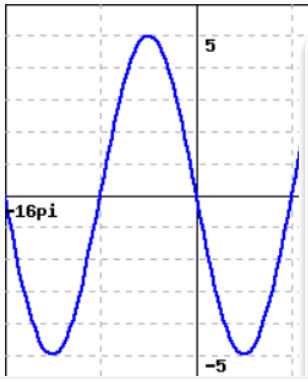
- Mastery 3: Previews of transformations, concavity, and quadratic functions
  - Suppose the function $f(x)$ has the domain $[-7, -2]$ and range $[-12, 14]$. Let $g(x) = f(x + 4) + 5$.
    (a) What is the domain of $g(x)$? (b) What is the range of $g(x)$?
    (c) If the point $(0, 6)$ is on the graph of $f(x)$, what point must be on the graph of $g(x)$?
  - Suppose a quadratic function $f(x)$ has its vertex at $x = 0.5$. Values of $f(x)$ are:

x	-2	1	2
$f(x)$	-4	2	0

    (a) What are the zeros of $f(x)$? (b) What is $f(-5)$? (c) Find the y-coordinate of the vertex of $f(x)$
  - Suppose harvesting m pounds of wheat produces $h(m)$ pounds of white flour, and a pounds of white flour produces $r(a)$ slices of white bread. For each of the following give a mathematical expression for the quantity (possibly involving h and/or r):
    (a) The number of slices of bread that can be produced from 4 pounds of flour is [____] slices. (b) The number of slices of bread that can be produced from 35 pounds of wheat (made into white flour) is [____] slices. (c) The weight of wheat, in pounds, needed to produce 95 pounds of white flour is [____] lbs.
  - (Plus two more.)

Assessment Sample: 115 Mastery

Problem 1.



Find a fo

$f(x$

Problem 2.

Let $C = f(q) = 300 + 0.2q$ give the cost in dollars to manufacture q kg of a chemical.

a. a) Which of the following statement(s) correctly explain(s) the meaning of $f^{-1}(C)$? Check

- **A.** The cost of manufacturing C kgs. the chemical.
- **B.** The cost of manufactur
- **C.** The number of kg of ch
- **D.** The number of kg of th

kg of the

ove

Problem 3.

Let $f(x) = \sqrt{7 - 8x}$.

Which of the following decompositions of $f(x) = p(q(x))$ into a pair of functions $p(x)$ ((the inside function) is

- **A.** $p(x) = 7 - 8$
- **B.** $p(x) = \sqrt{7 -$
- **C.** $p(x) = \sqrt{x}$ ar
- **D.** $p(x) = \sqrt{-8x}$
- **E.** None of the abo

Problem 4.

Glaciers in most of the world are shrinking. Suppose that for glaciers in one park, the area cover 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

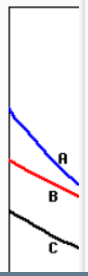
b. Find and explain the meaning of the A-intercept. Which statement best explains its significa

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

Problem 5.

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

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



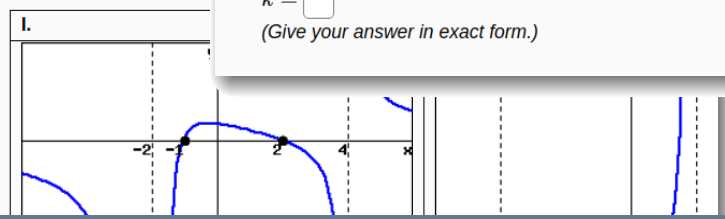
Problem 6.

Match each of the rational function

a. $f(x) = \dfrac{4(x+2)^2(x-1)}{(x-2)^2(x+4)^2}$

b. $g(x) = \dfrac{4(x+2)(x-1)}{(x-2)^2(x+4)}$

with one of the graphs below. In ea with vertical dashed lines.



Problem 7.

Find the continuous growth rate of an exponential function that passes through the points $(-1,$

$k =$ ☐

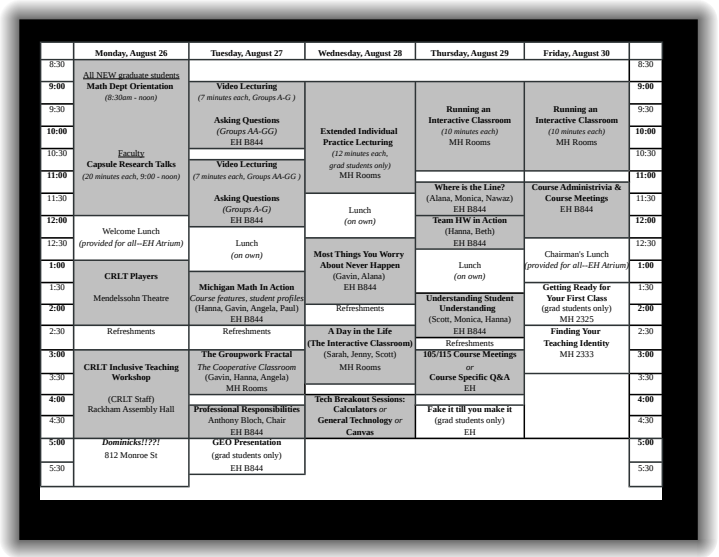
(Give your answer in exact form.)

Professional Development

- *Note 1*: Effective pedagogy requires instructor, and student, buy-in

  Note 2: Effective use of active learning, and equity-focused instruction, requires training and practice

- New instructor training program
  (Most instructors are grad students and post-docs)
  - One week before fall term: Goals
  - Prepare new instructors to teach inclusively with active learning
    - Build community and buy in from instructors
    - Facilitate creation of buy in from students
    - Give scripts/outlines for first week
    - Give teaching tools and practice to implement active learning
    - Provide background on course structure and goals

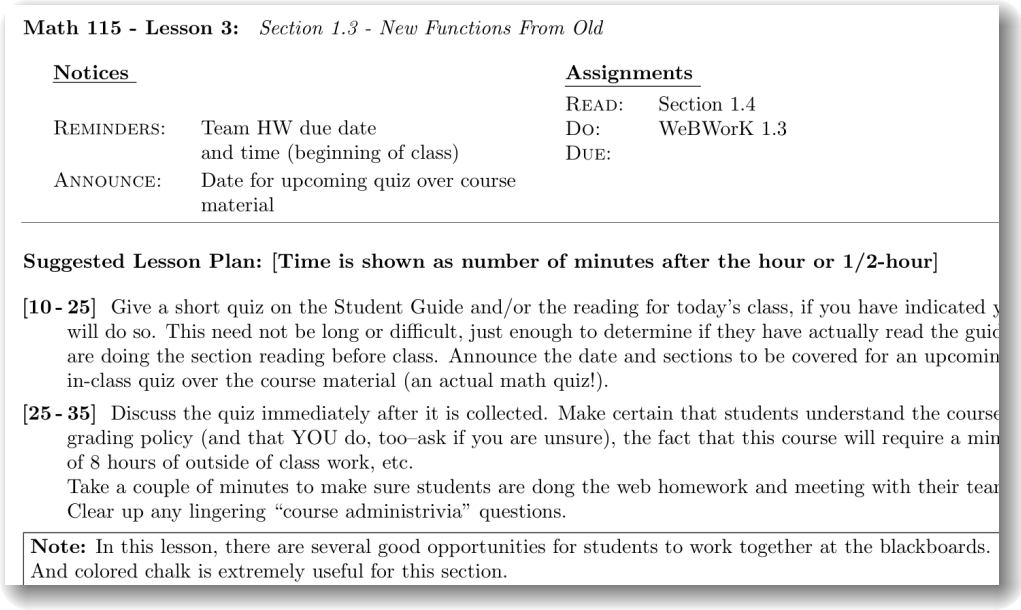


	Monday, August 26	Tuesday, August 27	Wednesday, August 28	Thursday, August 29	Friday, August 30	
8:30	All NEW graduate students					8:30
9:00	**Math Dept Orientation** *(8:30am - noon)*	**Video Lecturing** *(7 minutes each, Groups A-G)*	**Extended Individual Practice Lecturing** *(12 minutes each, grad students only)* MH Rooms	**Running an Interactive Classroom** *(10 minutes each)* MH Rooms	**Running an Interactive Classroom** *(10 minutes each)* MH Rooms	9:00
9:30		**Asking Questions** *(Groups AA-GG)* EH B844				9:30
10:00	Faculty **Capsule Research Talks** *(20 minutes each, 9:00 - noon)*	**Video Lecturing** *(7 minutes each, Groups AA-GG)*		**Where is the Line?** (Alana, Monica, Nawaz) EH B844	**Course Administrivia & Course Meetings** EH B844	10:00
10:30		**Asking Questions** *(Groups A-G)* EH B844	Lunch *(on own)*	**Team HW in Action** (Hanna, Beth) EH B844		10:30
11:00						11:00
11:30				Lunch *(on own)*	Chairman's Lunch *(provided for all--EH Atrium)*	11:30
12:00	Welcome Lunch *(provided for all--EH Atrium)*	Lunch *(on own)*	**Most Things You Worry About Never Happen** (Gavin, Alana) EH B844	**Understanding Student Understanding** (Scott, Monica, Hanna) EH B844	**Getting Ready for Your First Class** (grad students only) MH 2325	12:00
12:30						12:30
1:00	**CRLT Players** Mendelssohn Theatre	**Michigan Math In Action** *Course features, student profiles* (Hanna, Gavin, Angela, Paul) EH B844	Refreshments	Refreshments	**Finding Your Teaching Identity** MH 2333	1:00
1:30			**A Day in the Life (The Interactive Classroom)** (Sarah, Jenny, Scott) MH Rooms	**105/115 Course Meetings** *or* **Course Specific Q&A** EH		1:30
2:00	Refreshments	Refreshments				2:00
2:30						2:30
3:00	**CRLT Inclusive Teaching Workshop** (CRLT Staff) Rackham Assembly Hall	**The Groupwork Fractal** *The Cooperative Classroom* (Gavin, Hanna, Angela) MH Rooms	**Tech Breakout Sessions: Calculators** *or* **General Technology** *or* **Canvas**	**Fake it till you make it** (grad students only) EH		3:00
3:30		**Professional Responsibilities** Anthony Bloch, Chair EH B844				3:30
4:00						4:00
4:30						4:30
5:00	***Dominicks!!!!*** 812 Monroe St	**GEO Presentation** (grad students only) EH B844				5:00
5:30						5:30

training week schedule

Ongoing Professional Development

- Course meetings
  - Course guidance, logistics
  - Instructional support, workshops
- Sample lesson plans and worksheets
- Class visits
  - For all new instructors, early in semester
  - For some, a second visit, or a visit in the second semester
- Midterm evaluations
- Informal mentoring



Math 115 - Lesson 3: *Section 1.3 - New Functions From Old*

Notices

REMINDERS:	Team HW due date and time (beginning of class)
ANNOUNCE:	Date for upcoming quiz over course material

Assignments

READ:	Section 1.4
DO:	WeBWorK 1.3
DUE:	

Suggested Lesson Plan: [Time is shown as number of minutes after the hour or 1/2-hour]

[10 - 25] Give a short quiz on the Student Guide and/or the reading for today's class, if you have indicated y will do so. This need not be long or difficult, just enough to determine if they have actually read the guic are doing the section reading before class. Announce the date and sections to be covered for an upcomin in-class quiz over the course material (an actual math quiz!).

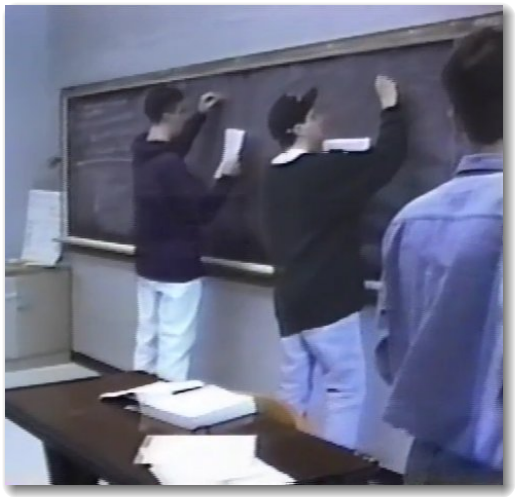
[25 - 35] Discuss the quiz immediately after it is collected. Make certain that students understand the course grading policy (and that YOU do, too–ask if you are unsure), the fact that this course will require a min of 8 hours of outside of class work, etc.
Take a couple of minutes to make sure students are dong the web homework and meeting with their tea Clear up any lingering "course administrivia" questions.

Note: In this lesson, there are several good opportunities for students to work together at the blackboards. And colored chalk is extremely useful for this section.

sample lesson plan

How We Got Here: Change and Implementation

- 1990s: NSF Calculus Reform
  - Goals and motivation:
    - Improve student learning
    - Improve student affect
  - Reform:
    - Class sections to ~~24~~ 32 students
    - Active learning, conceptual focus: skills assessed by "gateway" tests
    - Updated professional development program



calc class, 1990s

and calculators. . .

  - Evolution: Faculty Expansion Program (2015)
    - Class sections to 18 students
    - 15 post-docs, 7(?) lecturers, 2 tenure-line faculty added

Program Structure: 1990–2020

- Exams: 2 midterms, 1 final = 95% of course grade
  Web homework: daily, 5% of course grade
- Team homework: 6–10 assignments
- Mastery Assessment = Gateway Test
  - Math 105: Entrance (algebra, functions)
  - Math 115: Differentiation
  - Math 116: Entrance (differentiation), Integration

  Gateways are a *grade penalty* at the end of the semester if not passed
- Section work, team homework, quizzes: factors as a grade adjustment at the end of the semester

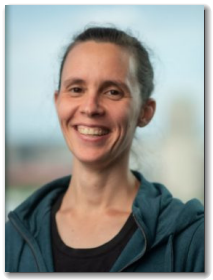
proctored gateway lab

. . . also, current math 116 structure

Reform 2.0: Process and Motivation

- Process
  - Exam analysis: are exams harder now?
  - Contacts and Vision: what comes of equity work?
  - Projects:
    - CRLT and the Foundational Course Initiative (3 year program, consultants, $10,000/year; for both 105 and 115)
    - 2 College Grants (2 years, $65,000+ each)
    - College and university facilities support
- Goals:
  - Improved quality of instruction
  - Increased transparency
  - Explicit focus on equity
  - Improved student affect

. . . still



Elaine Lande

Hanna Bennett

A Note About Assessment of Deep Learning

- "Novel," non-formulaic problems are better at assessing students' deep/conceptual learning
  - What is "novel" is a moving target
    - *Find the derivative of* $y = \frac{\sqrt{x}+x}{x^2}$. Simplify your answer. (Non-UM exam)
    - *There's dust on my guitar! The total amount of dust after* t *days is given by* $g(t)$*. I know that* $g(30) = 270$ *mg, and that* $g'(30) = 5$*. (a) Estimate* $g(32)$*. (b) What are the units of* $g'(t)$*?* (UM exam, 1994)
    - *Kimoi wants to make and provide free carrot juice to her customers using carrots from her garden.*
      - *Let* $c(w)$ *be the amount of carrots, measured in pounds, that grow when she gives her carrot garden* w *gallons of water during the growing season.*
      - *Let* $j(v)$ *be the amount of carrot juice, measured in gallons, that she can make from* v *pounds of carrots.*

      (a) Write a complete sentence that gives a practical interpretation of the equation $c^{-1}(38) = 620$*... (d) Pick the one sentence below that gives a valid interpretation of the equation* $(j^{-1})'(10) = 18$*.* (UM exam, 2020)
- This has implications for transparency, equity, and affect.

A Note: Inclusive to Equity-Focused Teaching

- *"**Inclusive teaching** deliberately cultivate[s] a learning environment where all students are treated equitably, have equal access to learning, and feel valued and supported in their learning. Such teaching. . . change[s] the ways systemic inequities shape dynamics in teaching-learning spaces, affect individuals' experiences of those spaces, and influence course and curriculum design."*
  - Is intentional and systemic: a guiding intent
  - Is characterized by transparency, academic belonging, and structured interactions
- *"**Equity-focused teaching** is a corrective tool that moves beyond inclusion. . . , allows instructors to acknowledge and disrupt historical and contemporary patterns of educational disenfranchisement that often negatively impact marginalized and minoritized students. It recognizes that systemic inequities shape all students' individual and group-based experiences of social identity and produce vastly different relationships of power in and outside of the classroom, which impact students' learning and success."*
  - Is an ongoing commitment that develops across a teaching career
  - Deliberately cultivates a learning environment where students have equal access to learning, feel valued and supported, experience parity in course success, and share responsibility for equity

All from UM's CRLT

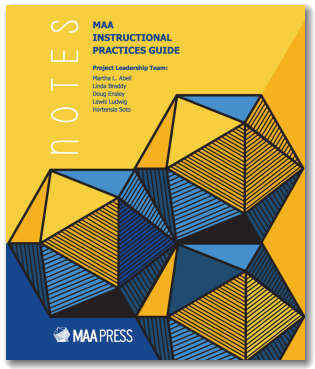
`https://crlt.umich.edu/equity-focused-teaching`

Instructional Practice and Equity

- Working on systemic change is imperative:

> *"Teaching and learning are forces for social change. . . We owe it to our discipline, to ourselves, and to society to disseminate mathematical knowledge in ways that increase individuals' access to the opportunities that come with mathematical understanding."*
>
> *—IP Guide, p.viii*

- And design principles for equity include
  - Access to mathematical ideas, teaching and learning spaces
  - Achievement on assessments, in courses, and in majors
  - Identities, understanding those of our students and the resources and ways of knowing available to them thereby
  - Power differences between instructor/student, between students, and between student/mathematics



IP Guide

—Gutiérrez, 2009; IP Guide

Equity and Mastery Assessment Development

- Start from learning goals: (transparency) *e.g.*,
  - Given any representation for a function, evaluate it at a given input value or find input values that give a particular output. (§§1.1, 2.1)...
  - Given a real-world context, interpret the meaning of expressions and equations involving inverses, compositions, and combinations. (§§10.1-10.3)
- Mastery Assessments: move away from high-stakes testing
  - Administered through WeBWorK
  - Each (2020–2022) is 5 questions (math 105) or 7 questions (math 115) long
  - Math 105: score of 5 = 5pts; 4 = 4pts; <4 = 0pts
  - "Infinite" practice, credit for scores in proctored lab
- Sample...

FCI course design

Changes to Professional Development

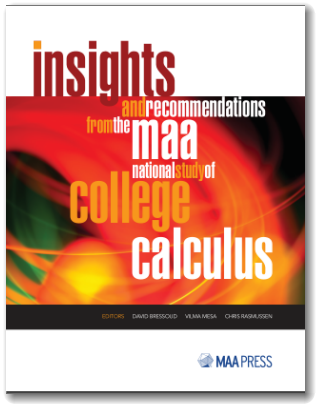
- Training: Goal to “Raise the floor” for instruction
  - Pedagogy: evolution of training week
  - Equity-focused instruction
    - CRLT workshop on equity-focused instruction
    - Increased focus on equity throughout training week
    - Emphasis on active learning and inclusive instruction
    - Session on equity-focused instruction
- Support
  - Course meetings, with evolution
  - IBL Community and training
  - Department and graduate student Learning Community on Inclusive Teaching (LCIT)

LCIT book group

- Staffing changes
  - Only experienced, equity-focused instructors in math 105
  - All new instructors now teach math 115

Program Assessment

- Direct assessment: we appear to be doing pretty well
  - 1990–2010: Site visits, Calculus Concept Inventory, Study of Calculus II
  - 2010–2020: MAA's study of calculus programs
  - Empirical measures: DWF rate, institutional buy-in
- Indirect assessment: we appear to be doing the right things
  - Pedagogy and learning: Active learning improves student understanding and disposition, performance, and success; especially for URM students
  - Equity and retention: Are essential focal points; active learning can help address inclusion
  - Characteristics of successful programs: effective placement; coordination with uniform text, assessments, and course meetings; challenging and engaging course content; active pedagogy; professional development; student support



MAA Calculus Study

Implementing and Sustaining Change

- Implementation and program design are context specific
  - Institution, course, section characteristics must inform program design.
  - Common features of successful programs (education, inclusion):
    - Active learning
    - High standards
    - Coordination structure
    - Cultivation of academic belonging
    - Transparency of expectations

Don Lewis

- (Implementation of and) Sustaining change requires
  - Internal and institutional support
  - Internal champions
  - Assessment and program evolution
    - Change should be ongoing
    - Assessment provides signposts for what to do next, and support for continuation

Pat Shure

Conclusions

- Michigan math is one case study for a large, coordinated course structure
  - With a strong focus on active learning
  - And great uniformity between sections
- This requires a lot of structure and leadership
  - Professional development and instructor support is essential
  - Especially for new instructors, but also in general
- Integration of effective equity-focused, and student-centered, pedagogy is essential—but takes a lot of time and effort
- Programs can and must change

class, 1990s

class, 2010s