

PEDAGOGY AND RESULTS OF



The Math You Need, When You Need It
math tutorials for students in introductory geoscience

Eric Baer, Highline Community College and
Jennifer Wenner, University of Wisconsin Oshkosh

"MATHPATCH"

- Developed by Baer and Burn
- A separate 1 credit class taught first F2F, then online.
- Initial results showed 14% increase in retention, higher course grades, and increase in quantitative content for some faculty.
- Move to online was co-incident with sharp drop in use, even when required.



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PHASE 1: WEBSITE & PILOTS

Unit Conversions

http://serc.carleton.edu/mathyouneed/UnitConvExpl.html

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Math You Need > Unit Conversions

Math You Need
Calculating density
Graphing overview
Hypsometric Curve
Rearranging equations
Slopes
Trigonometry
Unit Conversions
Unit Conversions Practice Problems
Unit Conversions - Instructor

How do I change units on an number? Unit conversions in the geosciences


Introduction to unit conversions

In the geosciences, we think about how the Earth works on a variety of scales. For example, the San Fault that runs nearly the length of California's coastline is over 1200 km long. But we talk about the fault in terms of mm per year. So, we have to be able to think about thousands of km and a few talking about the same feature. In addition, a geoscientist who lives in the United States needs to be in terms of English and metric units - the public thinks in terms of English units (miles, gallon, etc.) a scientific community uses SI units (kilometers, liters, etc.). This may seem difficult at first, but it is anyone studying geosciences to be able to move easily from one unit to another (with a little calculation course). Luckily, there are some simple steps that, if followed, can help you complete unit conversion relative ease.

How do I do a unit conversion?

You can do any unit conversion if you follow a few simple steps. Although there is no single "right" way follow these steps, DO NOT SKIP ANY STEPS! Although it may seem tedious, working through unit conversion steps be followed so that you can be sure that you end up with what you want, especially when you do unit conversions.

Below, you can download and print some tables for your use when doing unit



• If you are converting from one metric unit to another, this [list of metric prefix](#) be useful.

• When converting from metric to imperial (sometimes called English) units (or [chart](#) (Acrobat (PDF) 28kB Apr10 08) might be helpful.

When you do any unit conversion, you should always know what units you start end up with. This is key to success at unit conversions.

[Show credits](#)

The Steps

The steps to successfully completing a unit conversion are outlined below. To illustrate the steps, lets Southern California, slip on the San Andreas Fault is on the order of 25 km/Myr. How many

- The structure of the websites provide a rich learning environment for students to build their quantitative skills.
- Each module/topic has three main parts:
 - instruction
 - practice
 - assessment



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INSTRUCTION


Each module:

- begins with an explanation
 - How does it fit in the geosciences?
 - Why should I?
- includes a step-by-step process for solving problems
- Ends with link/help

Rearranging equations

<http://serc.carleton.edu/mathyouneed/Equation.html>

Some simple steps for manipulating equations



Here are some simple steps for manipulating equations. Under each step you will find an example of how to do this with an example that uses the geologic context of [density](#) (a measure of mass per unit volume).

1. Assess what you have (which of the variables do you have values for?, what units are present?, etc.). **DO NOT plug in any numbers yet!**
▶ [Show me how to do this](#)
2. Determine which of the variables you want as your answer. (What is the question asking you to calculate? What is the unknown variable?)
▶ [Show me how to do this](#)
3. Rearrange the equation so that the unknown variable is by itself on one side of the equals sign (=) and all the other variables are on the other side. **RULE #1: you can add, subtract, multiply and divide by anything, as long as you do the same thing to both sides of the equals sign.**
▶ [Show me how to do this](#)
4. **NOW plug in the numbers!** Replace known variables with their values and *don't forget to keep track of units!*
▶ [Show me how to do this](#)
5. Determine the value of the unknown variable by performing the mathematical functions. That is, add, subtract, multiply and divide according to the equation you wrote for step 2.
▶ [Show me how to do this](#)
6. Ask yourself whether the answer is reasonable in the context of what you know about the geosciences and how much things should weigh.
▶ [Show me how to do this](#)

Next Steps

- [I'm ready to practice! \(These problems have worked answers.\)](#)
- [I still need more help!](#) (See the links below for more help with equations).

More help with equations

[Geomaths](#) at University College London has a [MathHelp page about equations and functions](#) ([more info](#)).

The [chemistry department at Texas A&M](#) has a [math review page](#) about [Algebraic Manipulation](#).

The [Economics and Business faculty at University of Sidney](#) has a page where you can practice your equation manipulation skills! Take the [algebraic manipulation quizzes!](#)

This page was written and compiled by Dr. Jennifer M. Wenner, Geology Department, University of Wisconsin Oshkosh and Dr. Eric M. Baer, Geology Program, Highline Community College,



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PRACTICE

Each practice page:

- has multiple contextual examples
 - reinforces importance
 - repetition promotes transfer
- Examples are solved using step-by-step instructions.
- Ends with link to quiz

Practice Rearranging Equations

http://serc.carleton.edu/mathyouneed/ManEqSP.html

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You Need > [Rearranging equations](#) > Practice Rearranging Equations

Math You Need

- Calculating density
- Graphing overview
- Hypsometric Curve
- Rearranging equations
- Practice Rearranging Equations**
- Rearranging equations - Instructor
- Topes
- Trigonometry
- Unit Conversions

Solving for any variable... Rearranging Equations - Sample Problems

Practice rearranging equations below using the "rules" that you have just learned. Answers are provided (but try doing them on your own before peeking!)

Velocity, distance and time

Many problems in the geosciences deal with the concept of velocity, from stream flow to plate motion. Being able to manipulate the equation for velocity ($v = d/t$) gives you a powerful tool for understanding the world around you. And there are two other equations that you can get by rearranging the equation that you probably already know for velocity (also rate)!

Problem 1: Generally, we know the equation for velocity (a rate) to be:

$$v = \frac{d}{t}$$

Where v = velocity, d = distance and t = time.

This equation can be rearranged so that you have an equation for distance (d) and time (t).

1. **Rearrange the velocity equation to create an equation for distance (d).**
► [Show me how](#)
2. **Rearrange the velocity equation to create an equation for time (t).**
► [Show me how](#)

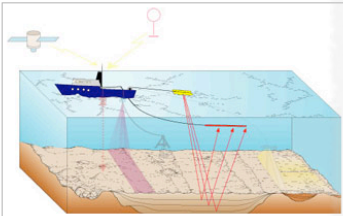

Use the equations that you manipulated above to solve the following problems:

Problem 2: A wave traveling downward from the surface of the ocean at 1.5 km/sec takes six seconds to reflect off the ocean floor. How deep is the ocean at that site?
► [Show me how to calculate the depth](#)

Problem 3: Imagine that you are working with Ms. Homeowner to understand the groundwater flow in her area. She is particularly interested in an underground tank that is located 2.6 km from her home. You have measured the velocity of the groundwater to be 0.033 km/day. About how long will it take any contaminants leaking from the tank to reach Ms. Homeowner's well?
► [Show me how to calculate how long](#)

Density

Density plays an important role in our understanding of the physical properties of Earth materials. The equation for density is similar to that for velocity and, as such, it can be manipulated so that you can



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ASSESSMENT

Link from practice page:

- WAMAP
 - designed for mathematics
- Wide variety of options for quizzes (students can get feedback after due date)
- Self grades

Practice Rearranging Equations

<http://serc.carleton.edu/mathyouneed/ManEqSP.html>

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You Need > **Rearranging equations** > Practice Rearranging Equations

**Solving for any variable...
Rearranging Equations - Sample Problems**

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► [Show me how](#)
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► [Show me how](#)

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INSTRUCTOR PAGE

The screenshot shows a web browser window with the URL <http://serc.carleton.edu/mathyouneed/ManEqInstructor.html>. The page title is "Rearranging equations - Instructor". The main heading is "The Math You Need, When You Need It" with the subtitle "math tutorials for students in introductory geoscience". A sidebar on the left lists various topics: Math You Need, Calculating density, Graphing overview, Hypsometric Curve, Rearranging equations, Practice Rearranging Equations, Rearranging equations - Instructor (highlighted), Slopes, Trigonometry, and Unit Conversions. The main content area is titled "Guiding students through rearranging equations" and "An instructor's guide to Manipulating Equations". It includes a byline: "by Dr. Jennifer M. Wenner, University of WI Oshkosh Geology, and Dr. Eric M. Baer, Highline Community College Geology." Below this, there are links: "Jump down to: [Student struggles](#) | [What we left out](#) | [Resources](#)". The text states: "Many instructors find themselves struggling to get students to remember how to rearrange simple equations (like the one for velocity). There are many reasons that students need review: they may be math phobic, or have forgotten their algebra skills, or maybe they just never learned it. Nonetheless, the [Manipulating Equations](#) unit is designed to help your students catch up so that they can remember how to rearrange any equation." A section titled "What should the student get out of this page?" follows, stating: "This module is designed to address faculty concern that many students do not know how to manipulate equations to solve for another variable. By the time they finish this page, students should know:" followed by a numbered list: 1. the steps essential to manipulating equations, 2. that manipulating equations before plugging in numbers is easier (and more powerful) than inserting numbers immediately, 3. rules for manipulating equations (i.e., performing the same operation on both sides of an equation). An image shows hands working with a calculator and a ruler. Below this, it says: "The manipulating equations page should help students gain a bit more confidence in their abilities to use math to solve problems that are common in introductory geoscience." Another section titled "Why is it hard for students?" follows, stating: "Students struggle with equation manipulation for a variety of reasons:" followed by a numbered list: 1. As with many topics covered on this website, one obstacle to learning how to manipulate equations is math phobia - many students believe that they can't "do math". This belief is so strong that they generate a mental block and are often unwilling to even consider trying to manipulate an equation. Giving students support in building their math skills may help some of them to overcome this problem. 2. Many students have the impression that there is "magic" in numbers. Thus, they immediately plug in numbers and try to rearrange the equation with the numbers. Sometimes this works but often, they cannot see their way to isolating the unknown variable when there are numbers in the way. This can also lead to problems with units if they don't keep track of what units go with what number! 3. In addition to the "magic numbers" problem, some students are intimidated by the idea of manipulating equations with only "variables" in them. This may be because they feel more comfortable performing an operation on a number (e.g., multiplying by 8 or 42) than on a letter (m or v). This is compounded even further if there is a Greek letter like ρ or θ involved in the equation. 4. Students think they should just be able to use the formula that they memorized (e.g., rate =

- What you should expect from this module
- why it's hard for students
- what we left out
- outside resources



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PILOT RESULTS

School/Course	Semester/quarter offered	number of students	post-test attempts	completion rate	Average pre-post change
UWO Physical Geology	Fall sem 2008	154	1	90%	28
UWO Physical Geology	Spring sem 2009	166	unlim.	95%	42
UWO Physical Geology	Spring sem 2010	164	unlim.	84%	28
UWO Environmental Geology	Fall sem 2008 §	180	1	67%	19
HCC Physical Geology	Fall qtr 2008 §	5	1	40%	-33
HCC Physical Geology	Spring qtr 2009	10	1	80%	18
HCC Physical Geology	Fall qtr 2009	5	1	60%	-13
HCC Physical Geology	Spring qtr 2010	19	1	83%	-13



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PHASE II EXPANSION

Phase I
(2006-9)

Highline Community College

University of Wisconsin Oshkosh

2009/10

Adams State

Fort Lewis College

McHenry County College

2010/11

Rochester
CTC

Illinois
Valley CC

Hofstra
University

SUNY
Geneseo

Trinity
College

Boston
University

Cal Poly
Pomona

2011/12

California
Univ. (PA)

Patrick
Henry CC

Fitchburg
State

Wake Tech
C.C.

Ursinus

Linn-Benton
CC

U. Maine
Farmington

Austin
CC

SUNY
Oneonta

Los
Angeles
Valley CC

North
Hennepin
CC

Bergen
CC

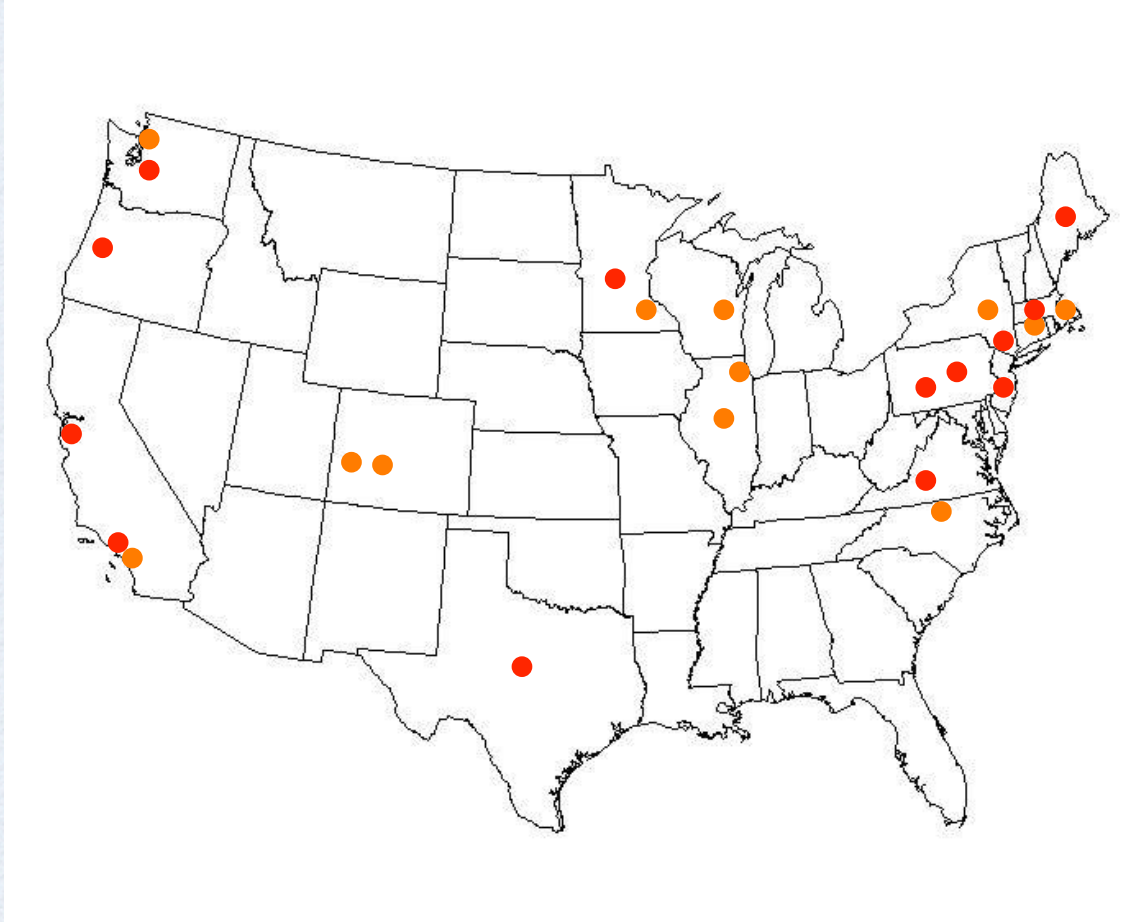
CSU East
Bay

Central
Wyoming
Coll.



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PHASE II EXPANSION (2011/12)



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STUDENTS USING TMYN



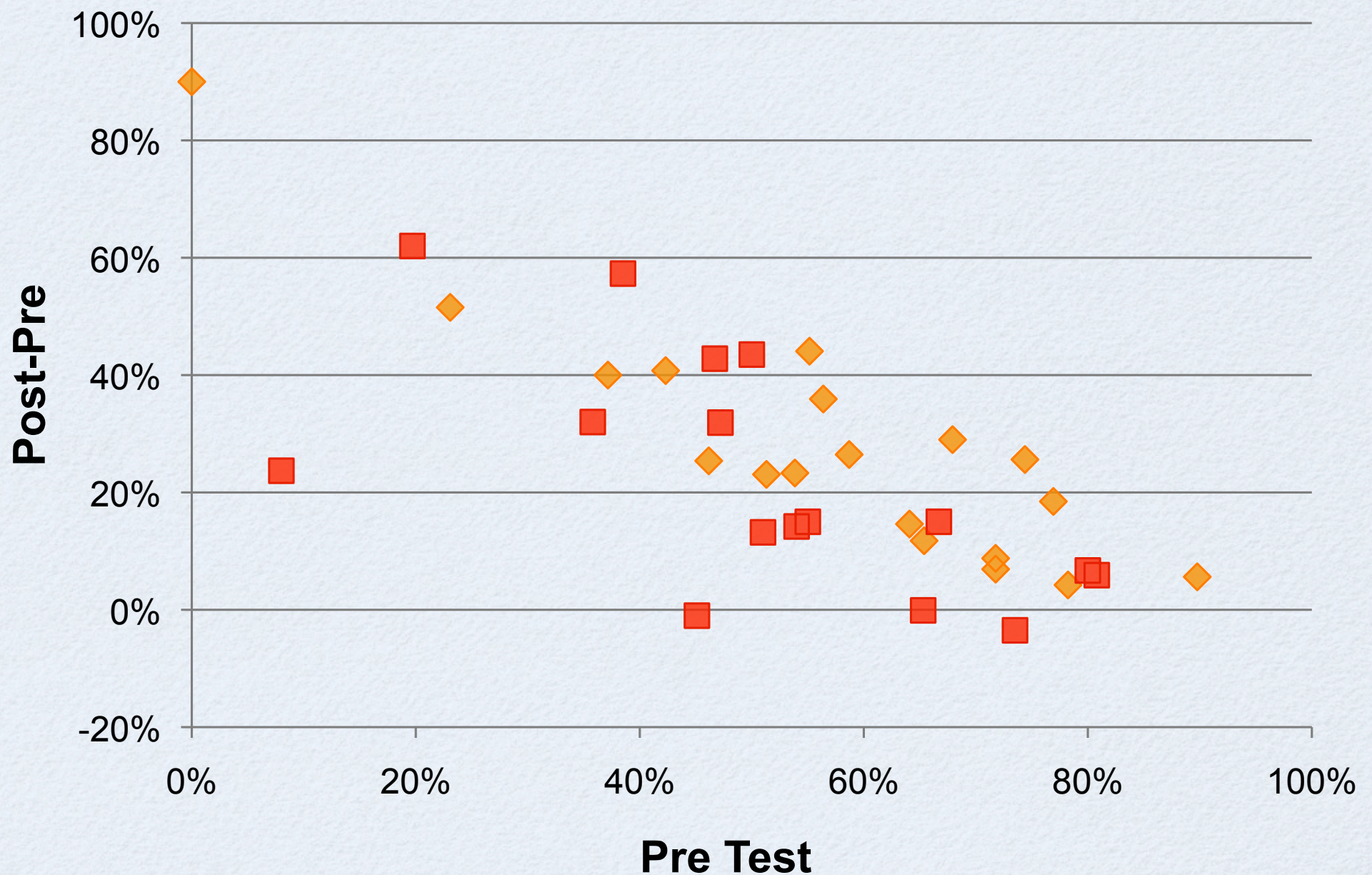
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WHO ARE WE HELPING?

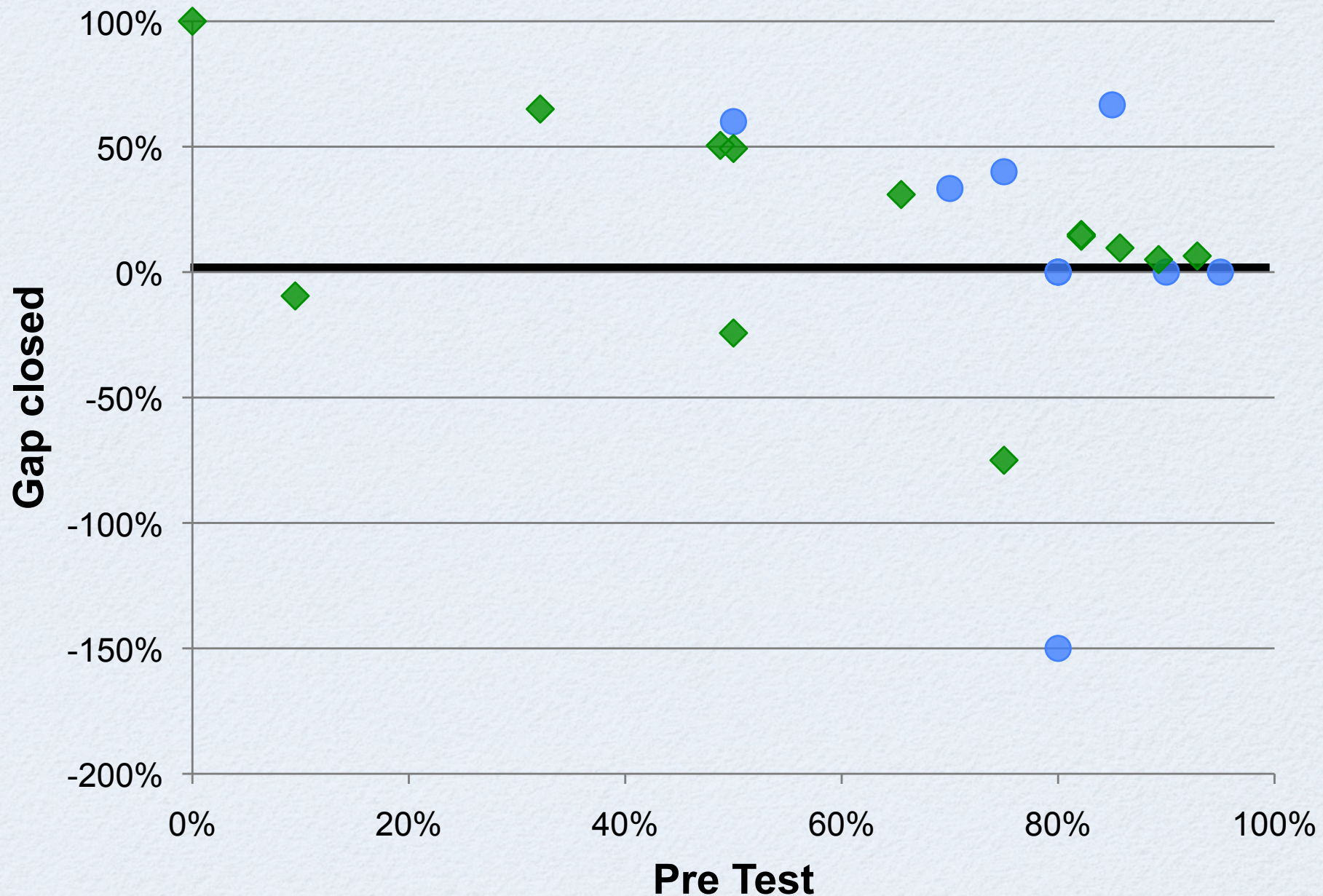
- The most underprepared students?
- The students on the borderline?
- Students who would pass but not excel?
- Students at the top of the class?
- No one?



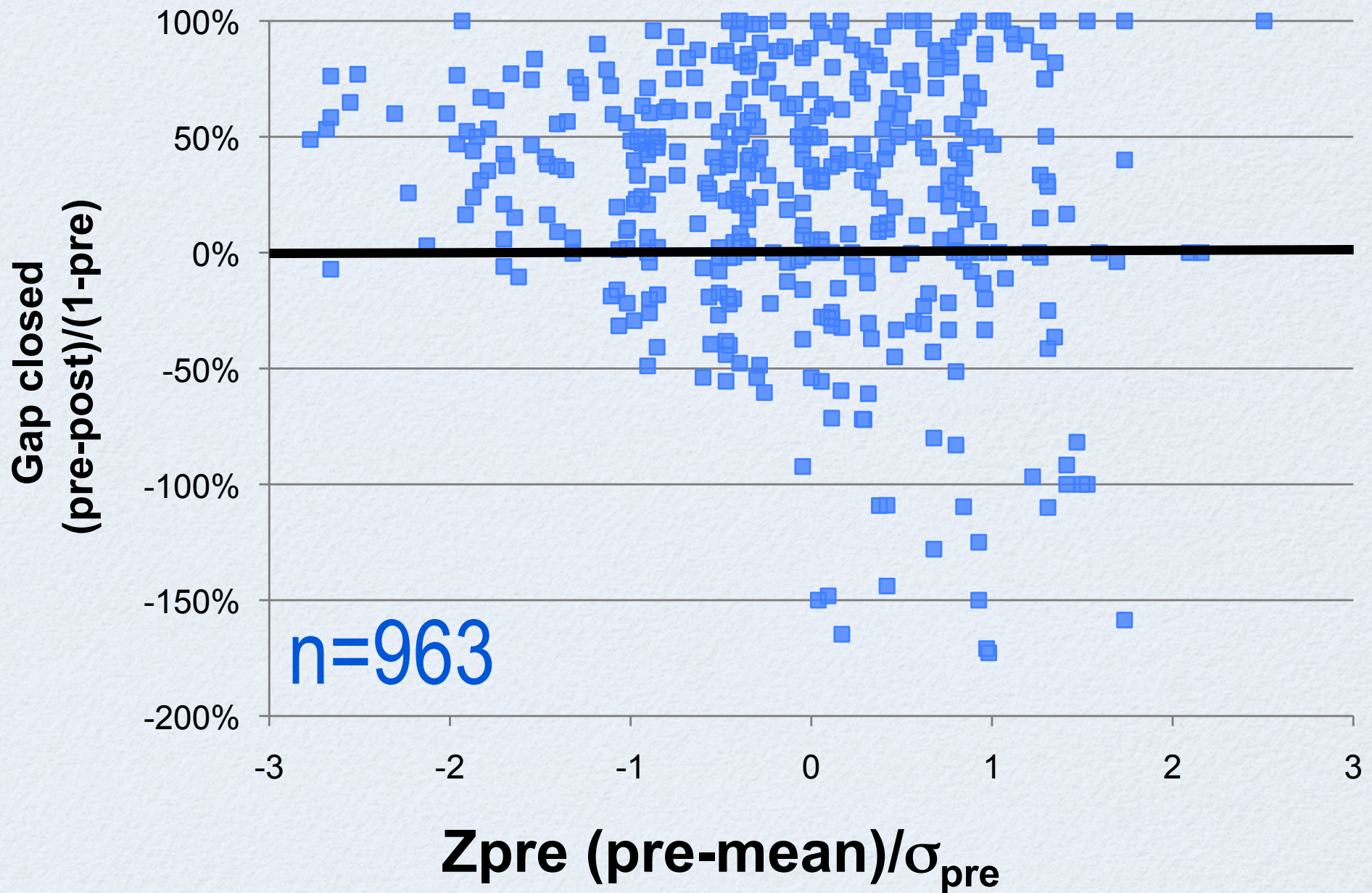
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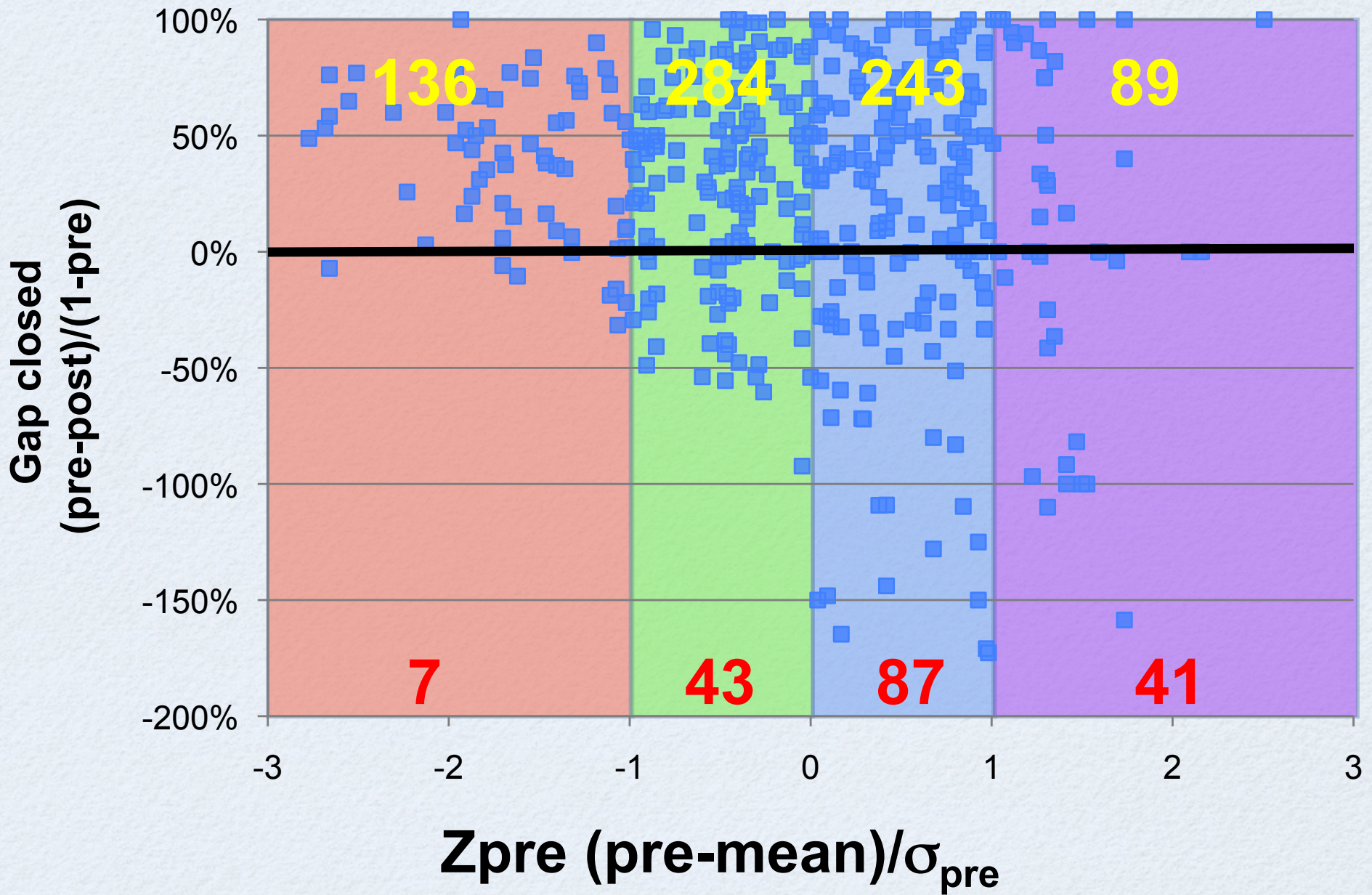
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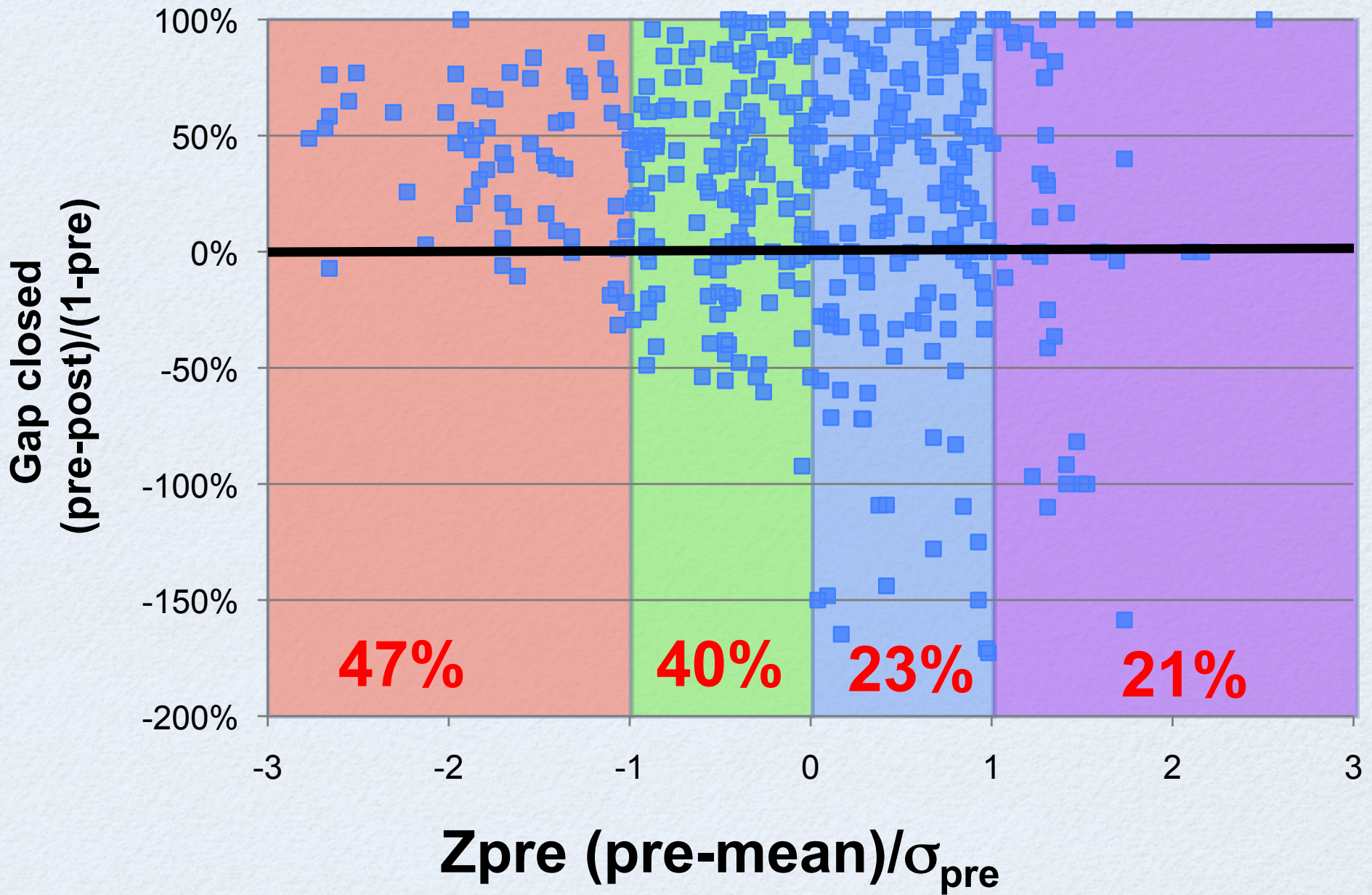
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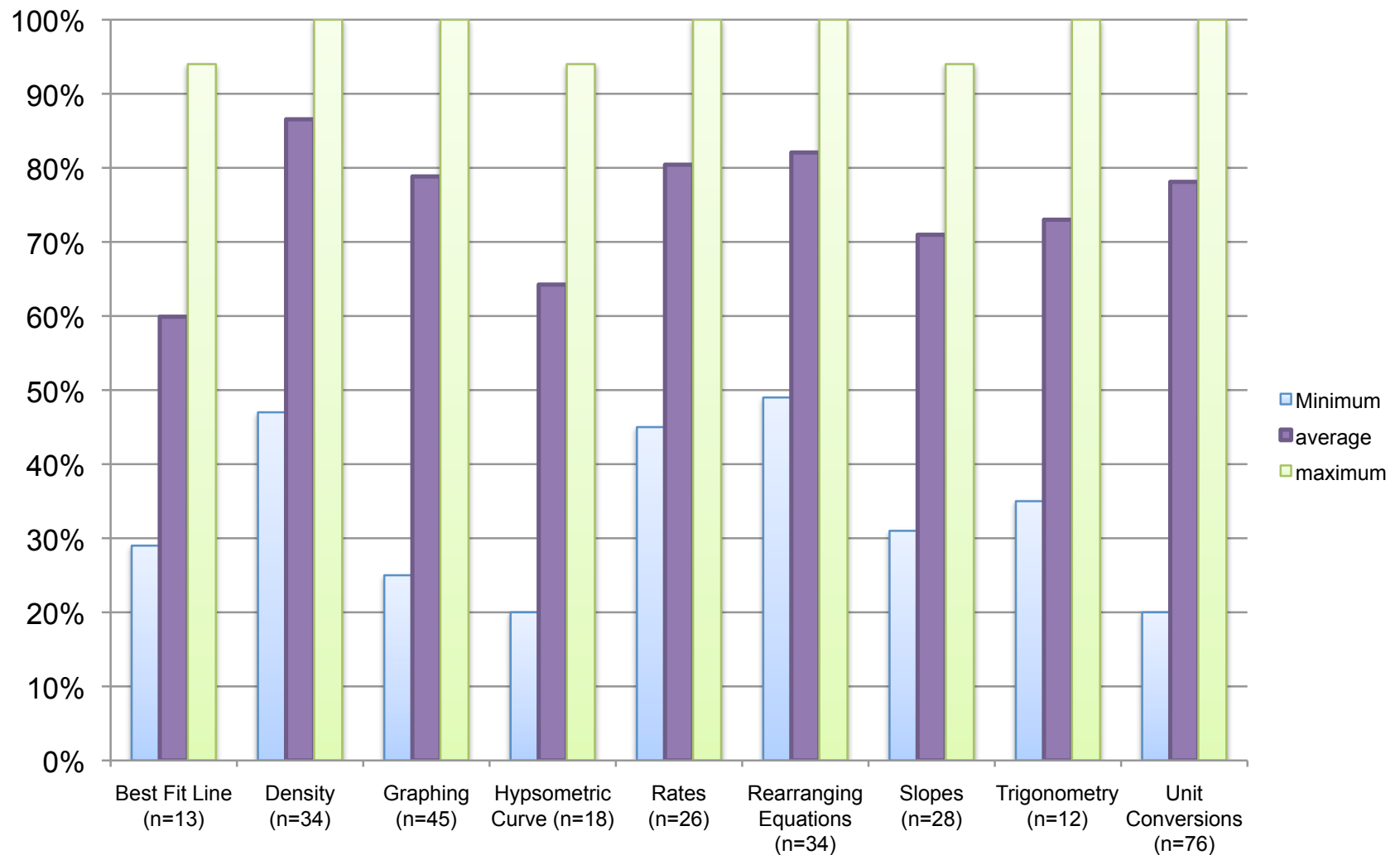


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I found this module helpful

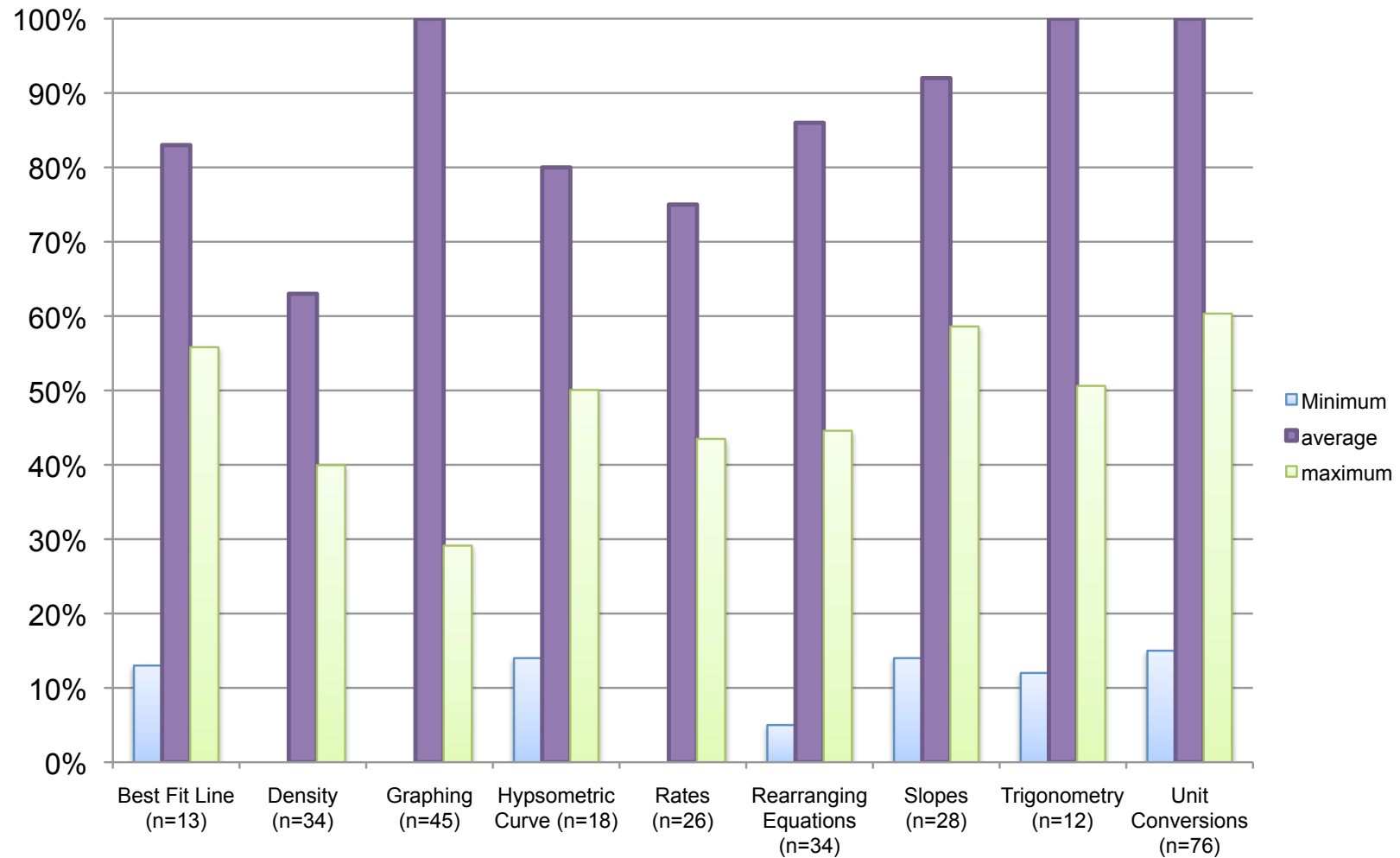


HELPFULNESS



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I found this module difficult



DIFFICULTY



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*Students...struggle
with manipulating trig
equations and dealing
with mapscales...
despite pre-calculus
being a pre-requisite
for the course.*

I was enthusiastic about being able to return to SOME numbers work, which I had largely dropped from my course...having a WIDELY varied student population meant that I would spend a large portion of lab time helping some students with simple calculations, not geoscience.

The course is focused on collecting, plotting, analyzing and interpreting data...In discussing challenges...it became apparent...that some were struggling...because they had not mastered basic quantitative skills. Their unfamiliarity...with basic operations and quantitative skills was preventing them from completing assignments that they understood conceptually and/or geologically.

RESPONSES TO WHY TMYN IS NEEDED...

Absolutely. [S]tudents did much better on mass balance calculations and... human impacts due to development and pollution. I have not been able to address these concepts in a quantitative way in the past. But... rely[ing] on students to work through math basics on their own outside of class time gave us more flexibility to address these interesting and valuable topics [in class].

Yes. In past years I have largely glossed over all math except for reading graphs and calculating density. Having students calculate rates added significantly to [the topics of] mass wasting and tectonics.

I don't think I increased the quantitative aspect, but using the modules allowed me to maintain it at the level I wanted rather than reducing the quantitative part of it.

DID YOU INCREASE THE QUANTITATIVE CONTENT OF YOUR COURSE?

CONCLUSIONS

- Students use it
- Students learn
- Students like it
- Faculty like it!



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THIS WORKSHOP

- Learn about what works
- Talk about strategies with like minded folks
- Design your own implementation
- Choose appropriate modules for your course
- Leave here ready to use it in your class



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