Active Learning in Calculus Courses

Chairs/Leads Meeting
January 22, 2016

Jim Fowler
The Ohio State University
Department of Mathematics

Joint work

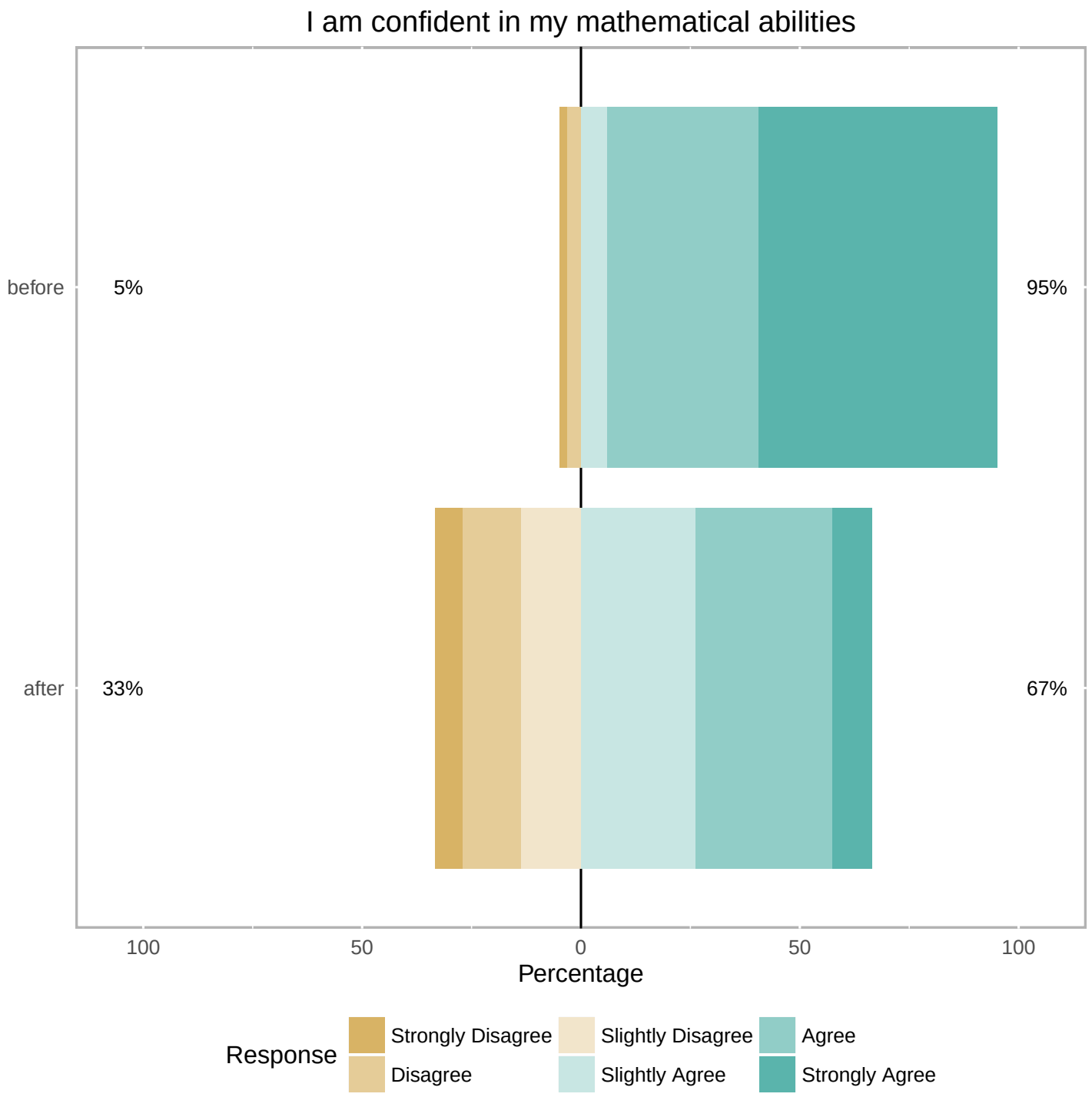
This is a **department-wide** project involving

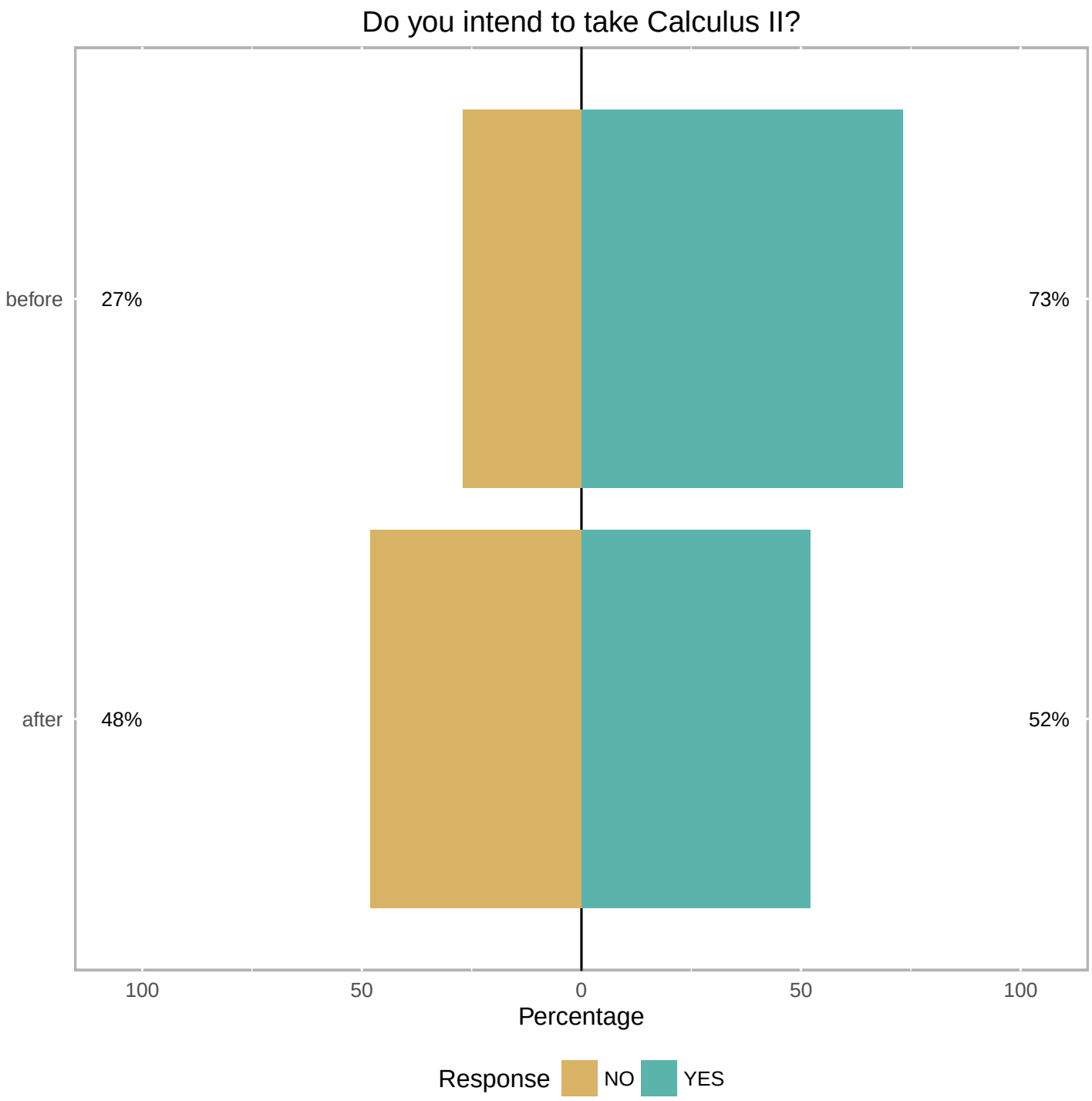
the *Calculus Design Coordinator* (John Johnson)
funded with support of Randy Smith
and the Office of Academic Affairs;

Ximera (NSF DUE–1245433); and

an ALX grant from Ohio State's
Office of Distance Education and eLearning.

The Problem


I am confident in my mathematical abilities
before
after
5%
95%
33%
67%
100
50
0
50
100
Percentage
Response
Strongly Disagree
Disagree
Slightly Disagree
Slightly Agree
Agree
Strongly Agree


Do you intend to take Calculus II?
before
27%
73%
after
48%
52%
100
50
0
50
100
Percentage
Response
NO
YES

Goals

Goals

Implement interventions so students

- learn more math, and
- don't leave STEM.

Metrics

Conceptual pre- and post-tests;

Surveys modeled after the *Characteristics of Successful Programs in College Calculus* (CSPCC) study; and

Traditional exams across all sections.

Five Interventions and Control

Traditional	180-student lecture and 32-student recitations
Ximera	an open-source text and homework system
Active	with peer instruction and clickers
Flipped	meeting twice/week and online
Class size	both large (Huge) and small (Epsilon)

Five Interventions and Control

Traditional	180-student lecture and 32-student recitations
Ximera	an open-source text and homework system
Active	with peer instruction and clickers
Flipped	meeting twice/week and online
Class size	both large (Huge) and small (Epsilon)
	384 students 32 students

Conclusions

Conclusions

Students notice.

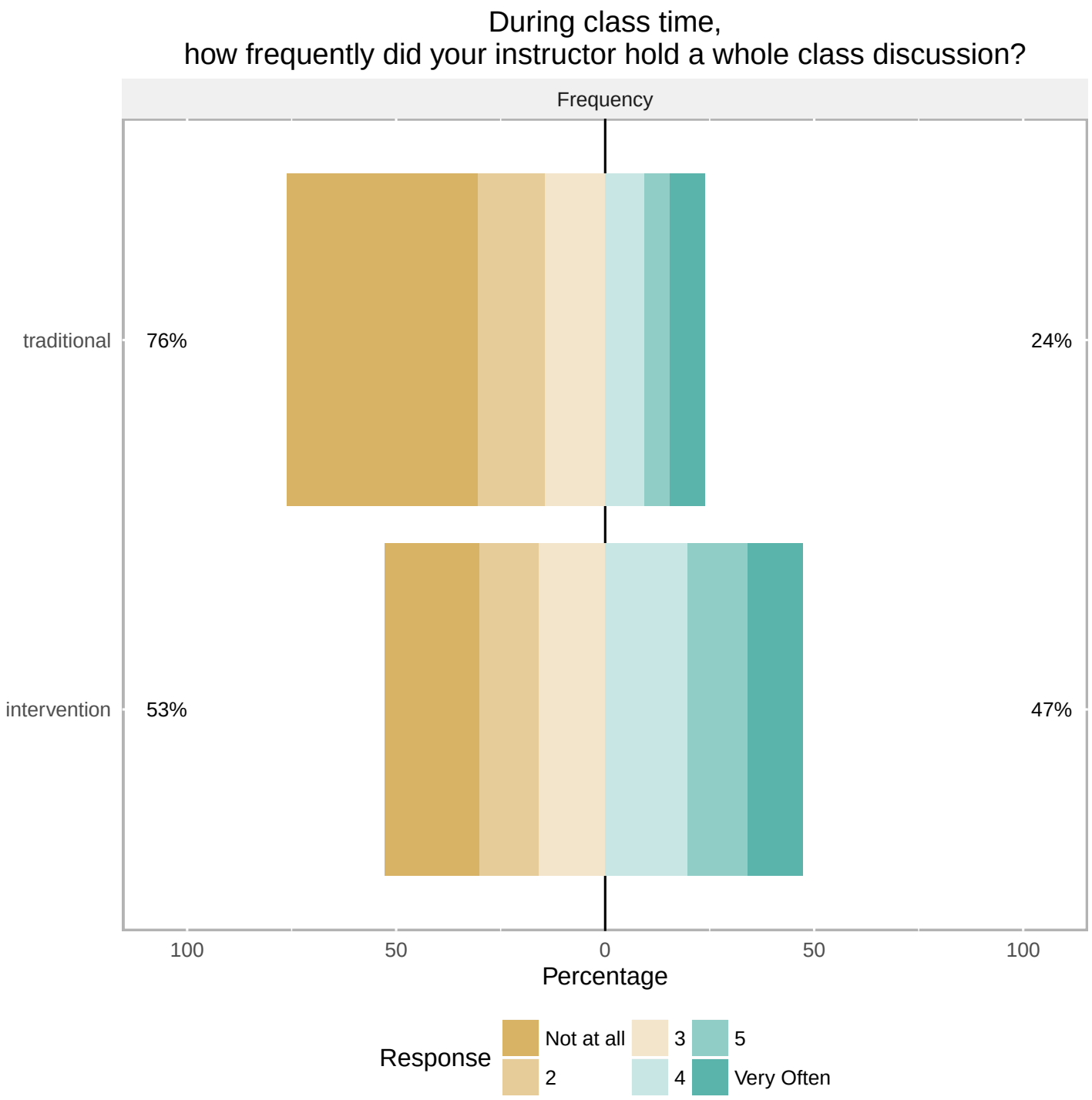
Certain formats are better for certain students.

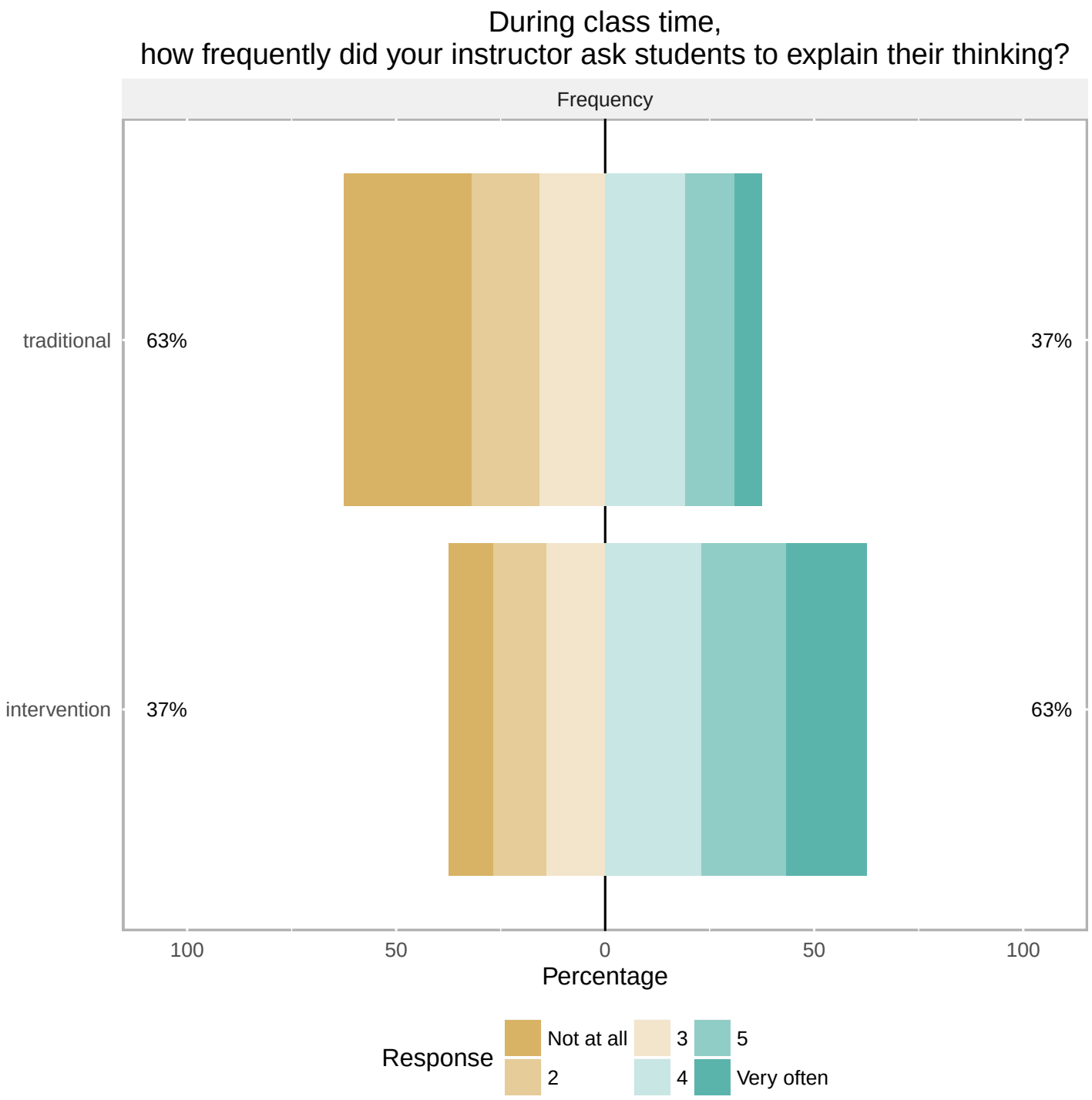
Open source textbooks can be equally good.

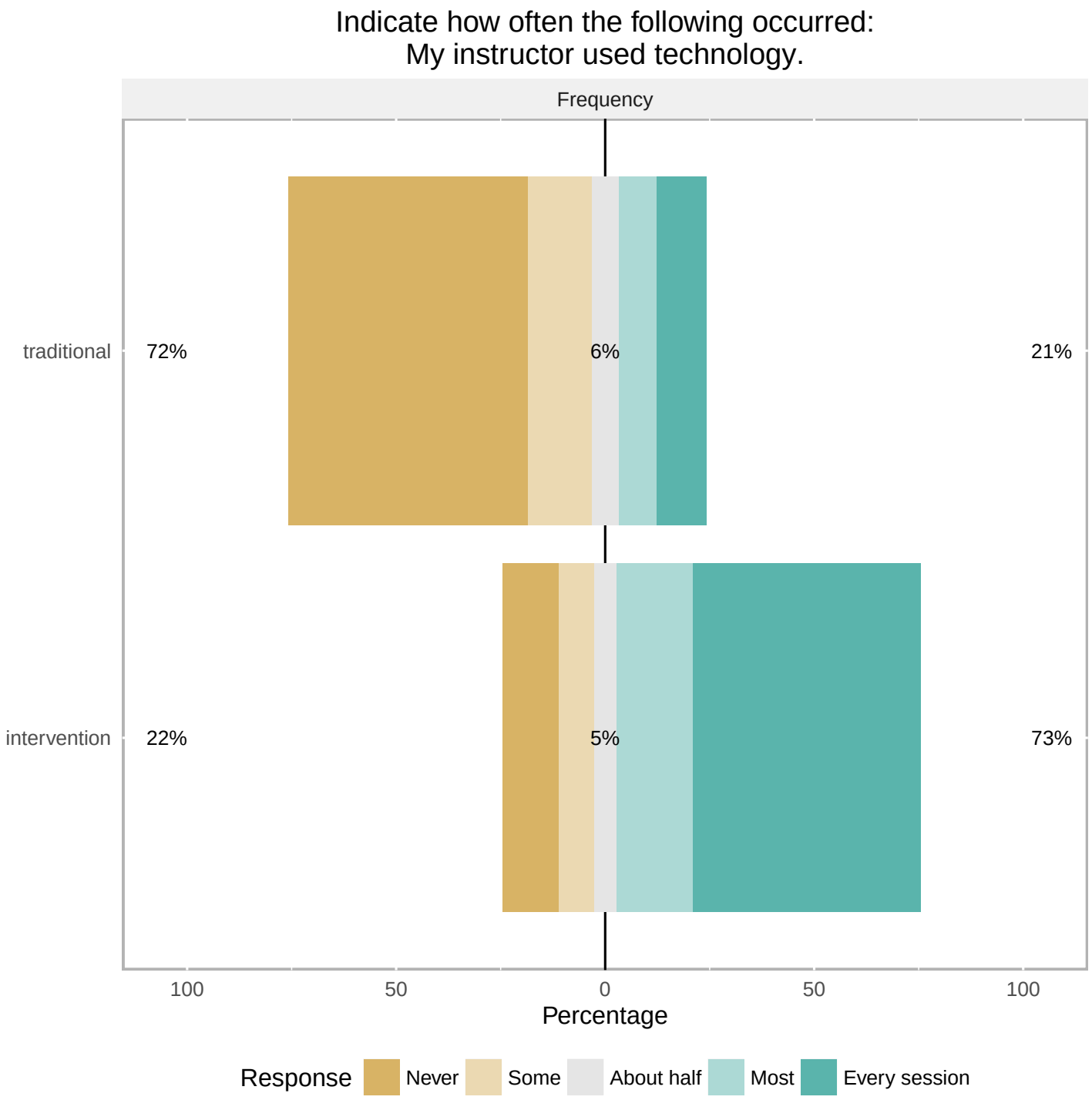
An “active” classroom shifts the emphasis.

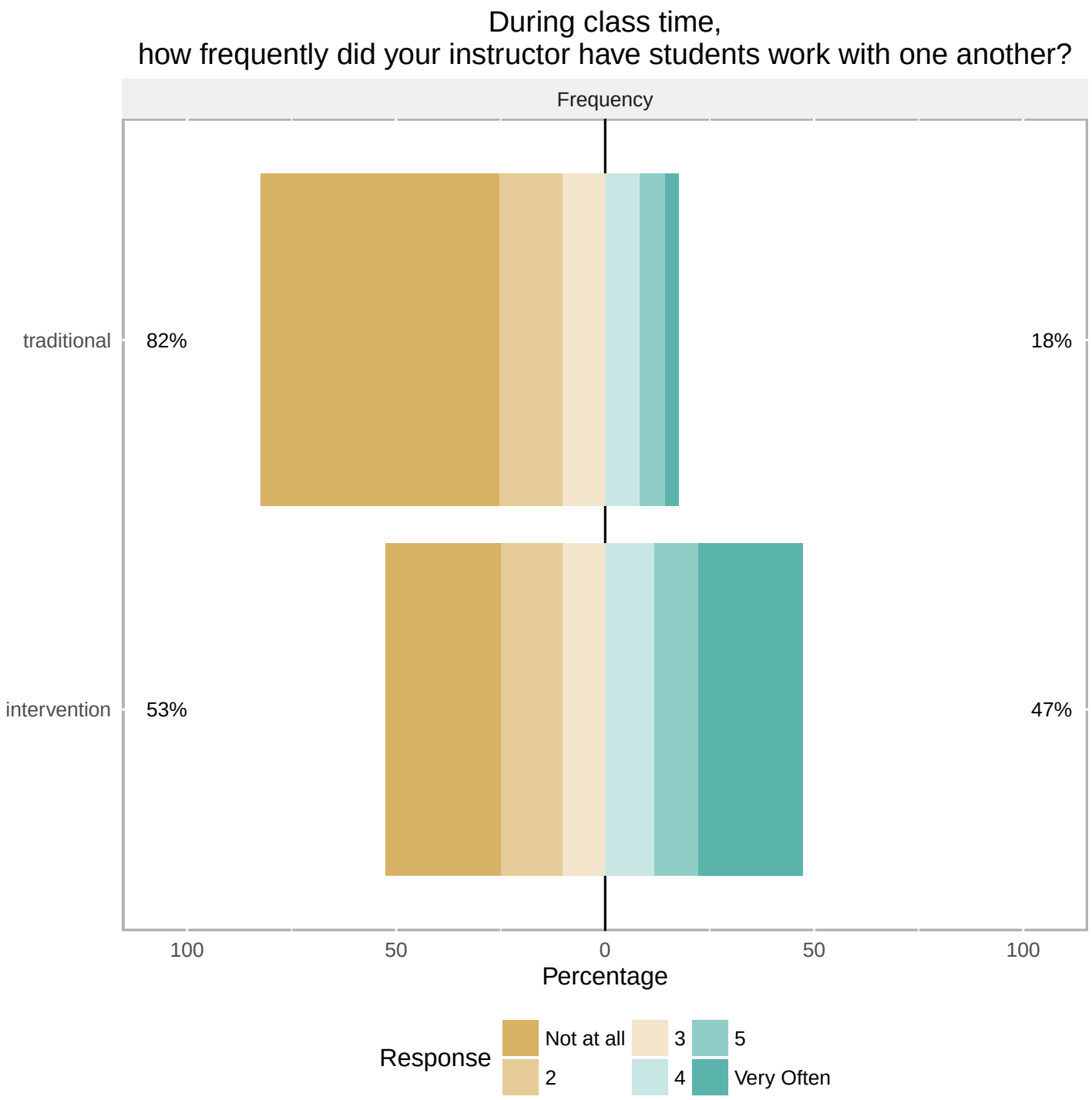
Community matters.

Students Notice


During class time,
how frequently did your instructor hold a whole class discussion?
Frequency
traditional
76%
24%
intervention
53%
47%
100
50
0
50
100
Percentage
Response
Not at all
2
3
4
5
Very Often


During class time,
how frequently did your instructor ask students to explain their thinking?
Frequency
traditional
63%
37%
intervention
37%
63%
100
50
0
50
100
Percentage
Response
Not at all
2
3
4
5
Very often

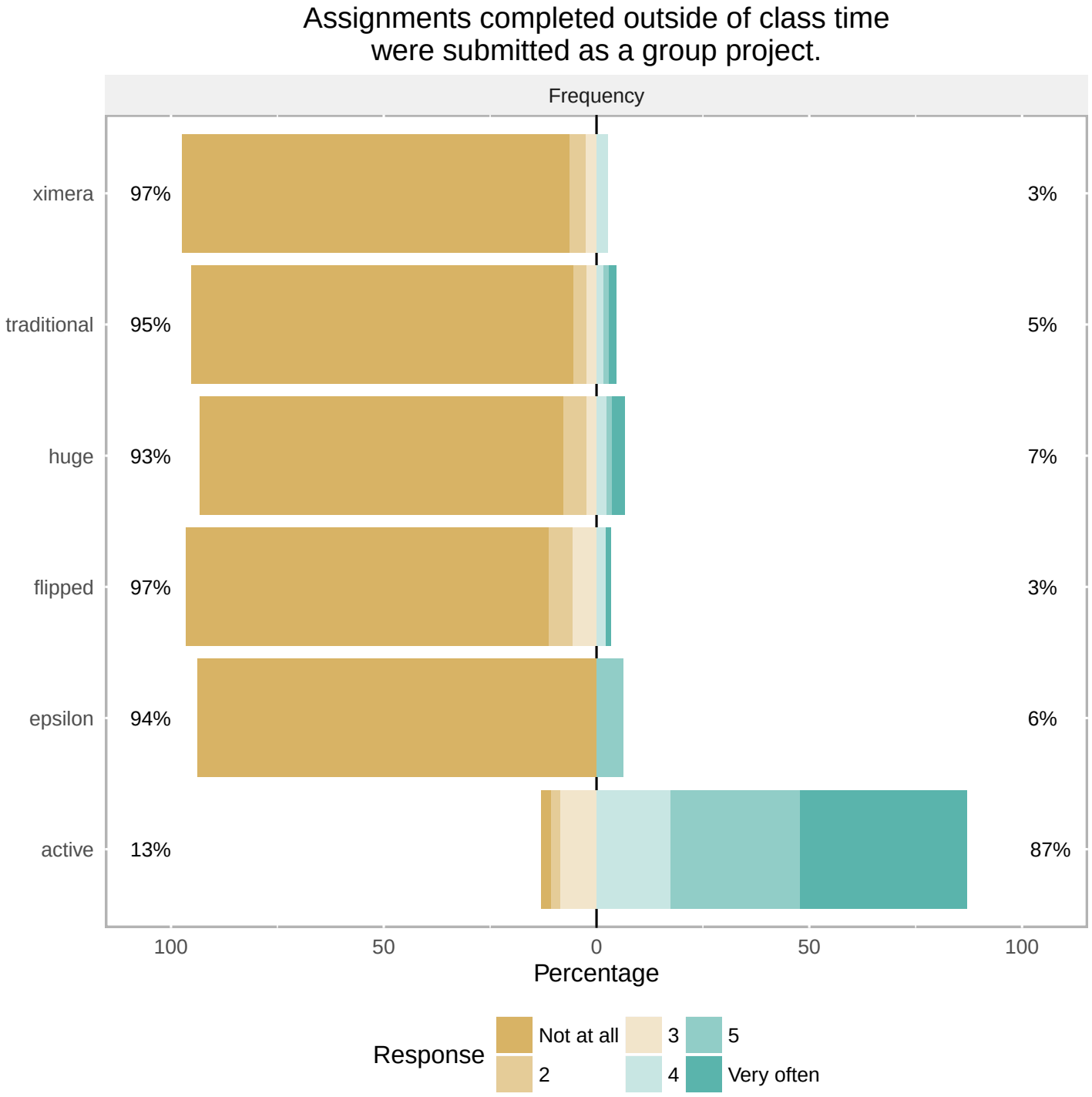

Indicate how often the following occurred:
My instructor used technology.
Frequency
traditional
intervention
72%
6%
21%
22%
5%
73%
100
50
0
50
100
Percentage
Response
Never
Some
About half
Most
Every session

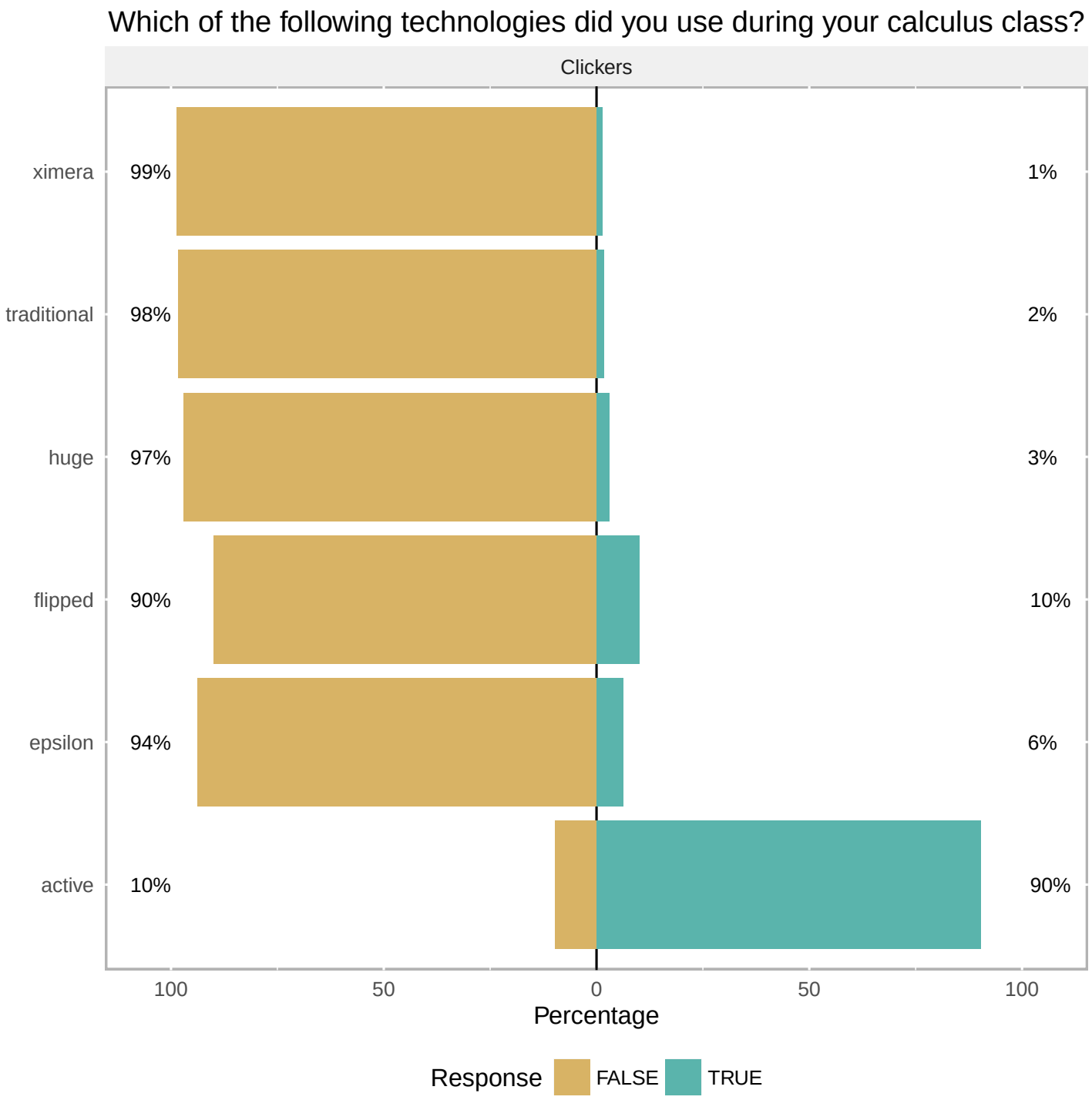

During class time,
how frequently did your instructor have students work with one another?
Frequency
traditional
82%
18%
intervention
53%
47%
100
50
0
50
100
Percentage
Response
Not at all
2
3
4
5
Very Often

A day in ACTIVE

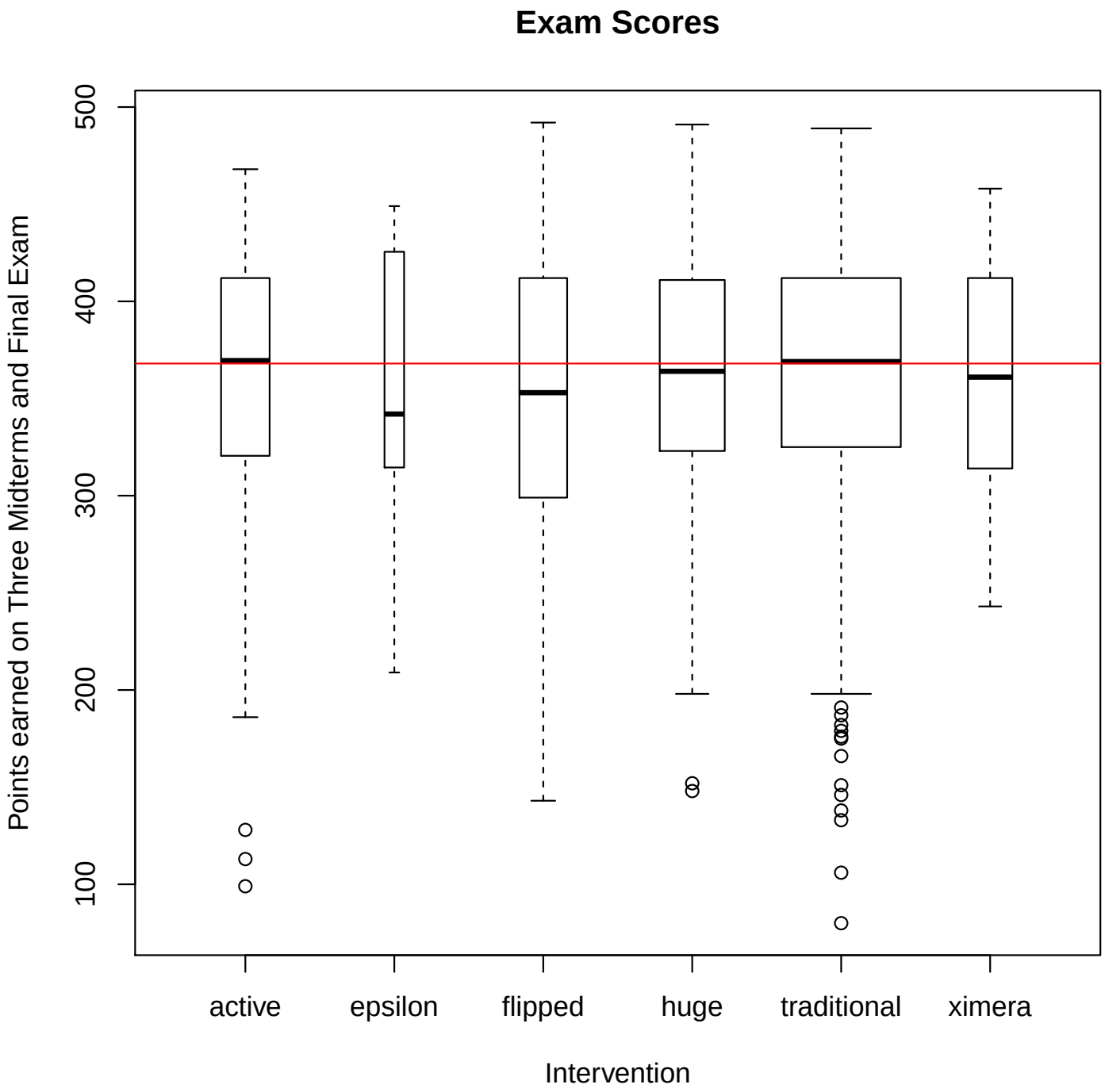
Class consists of a short (10–15 minutes) lecture,
a question presented via Top Hat,
peer instruction and discussion of responses,
a whole class discussion,
a summary of the correct response,
and repeat.

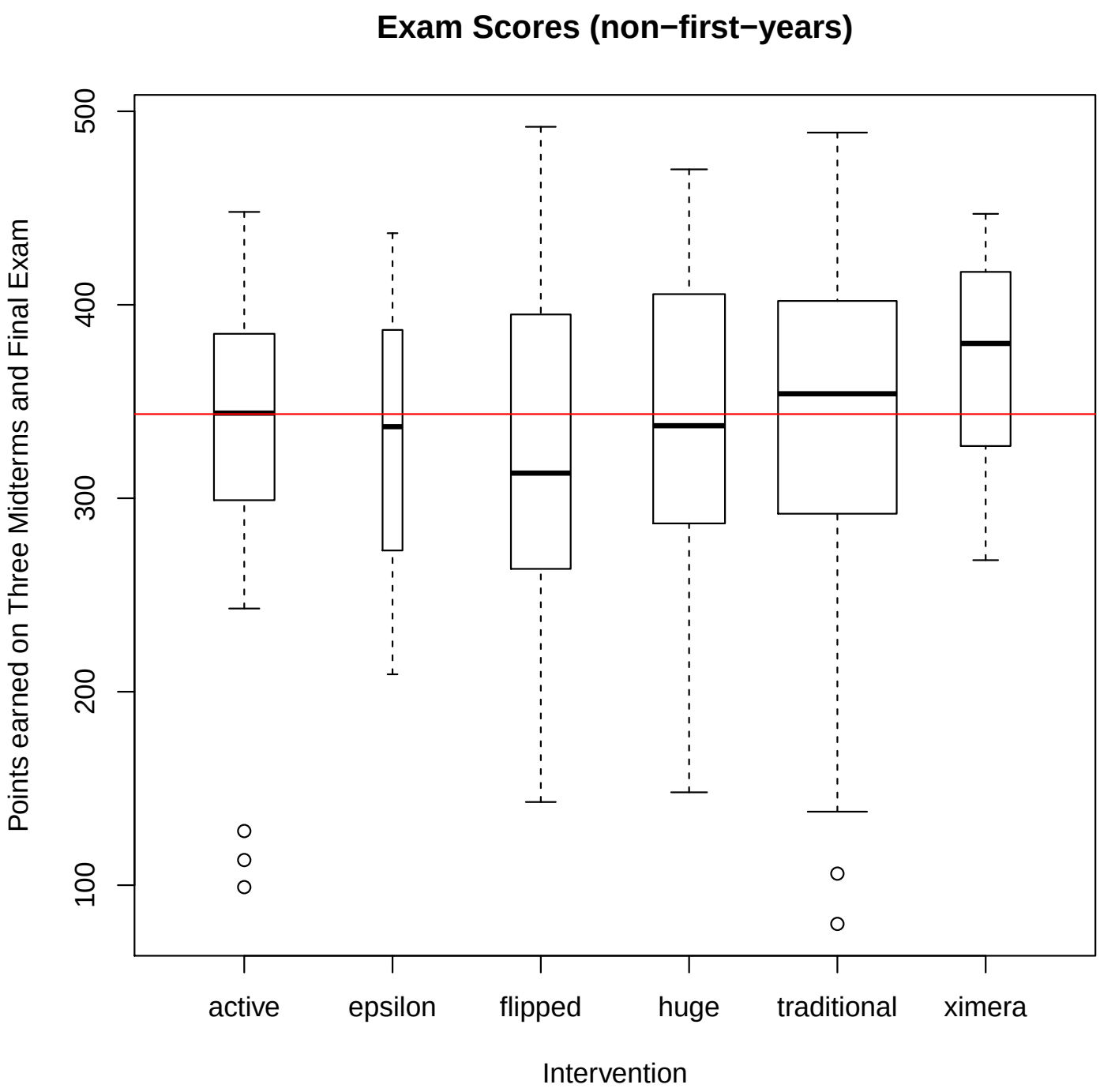
Recitations consist of students
working in small groups on worksheets,
followed by whole class discussions.


Assignments completed outside of class time
were submitted as a group project.
Frequency
ximera
traditional
huge
flipped
epsilon
active
97%
95%
93%
97%
94%
13%
3%
5%
7%
3%
6%
87%
100
50
0
50
100
Percentage
Response
Not at all
2
3
4
5
Very often


Which of the following technologies did you use during your calculus class?
Clickers
ximera
traditional
huge
flipped
epsilon
active
99%
98%
97%
90%
94%
10%
1%
2%
3%
10%
6%
90%
100
50
0
50
100
Percentage
Response
FALSE
TRUE

Exam Results


Exam Scores
Points earned on Three Midterms and Final Exam
500
400
300
200
100
active
epsilon
flipped
huge
traditional
ximera
Intervention


Exam Scores (non−first−years)
Points earned on Three Midterms and Final Exam
100
200
300
400
500
active
epsilon
flipped
huge
traditional
ximera
Intervention

Open Source Textbook

Open source textbook

Ohio State's math department

- started with an open source calculus text
  - written in the 1990s
- and has edited it
  - collaboratively via GitHub.

Open source textbook

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Structured as a **non-inferiority study.**

Functions, limits, and continuity

Understanding functions

Same or different? Two young mathematicians examine one (or two!) functions.

For each input, exactly one output We define the concept of a function.

Compositions of functions We discuss compositions of functions.

Inverses of functions Here we "undo" functions.

Review of famous functions

How crazy could it be? Two young mathematicians think about the plots of functions.

Polynomial functions Polynomials are some of our favorite functions.

Rational functions Rational functions are functions defined by fractions of polynomials.

Trigonometric functions We review trigonometric functions.

Exponential and logarithmetic functions Exponential and logarithmic functions illuminated.

What is a limit?

Stars and functions Two young mathematicians discuss stars and functions.

What is a limit? We introduce limits.

Limit laws

Equal or not? Here we see a dialogue where students discuss combining limits with arithmetic.

Continuity Continuity is defined by limits.

The limit laws We give basic laws for working with limits.

The squeeze theorem The Squeeze theorem allows us to exchange difficult functions for easy functions.

(In)determinate forms

Could it be anything? Two young mathematicians investigate the arithmetic of large and small numbers.

Limits of the form zero over zero We want to evaluate limits where the Limit Laws do not directly apply.

Limits of the form nonzero over zero We want to solve limits that have the form nonzero over zero.

Using limits to detect asymptotes

Zoom out Two young mathematicians discuss what curves look like when one "zooms out."

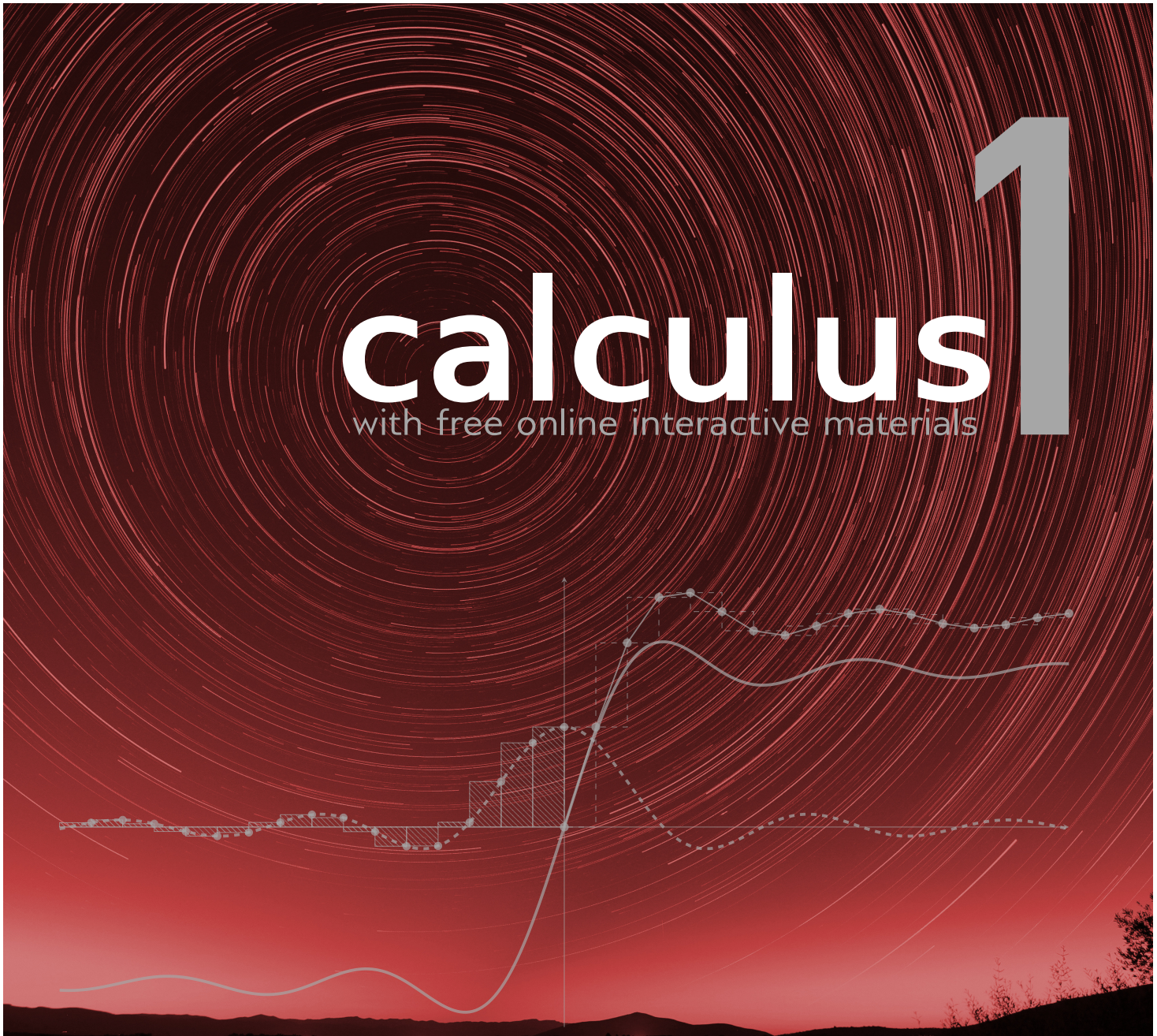
Vertical asymptotes We explore functions that "shoot to infinity" at certain points in their domain.

Horizontal asymptotes We explore functions that behave like horizontal lines as the input grows without bound.

Slant asymptotes We explore functions that "shoot to infinity" at certain points in their domain.

calculus 1

with free online interactive materials



developed in **XIMERA**

then $\lim_{x\to a} f(x) = L$.

Question. I'm thinking of a function f. I know that for all x

$$0 \leq f(x) \leq x^2.$$

What is $\lim_{x\to 0} f(x)$?

$f(x)$
$f(0)$
0
impossible to say

? Check work

Example. Consider the function

$$f(x) = \begin{cases} \sqrt[5]{x}\sin\left(\frac{1}{x}\right) & \text{if } x \neq 0, \\ 0 & \text{if } x = 0, \end{cases}$$

Building on the question above, it is not difficult to see that each of the hypothesis of the Intermediate Value Theorem are necessary.

Let's see the Intermediate Value Theorem in action.

Example. Explain why the function $f(x) = x^3 + 3x^2 + x - 2$ has a root between 0 and 1.

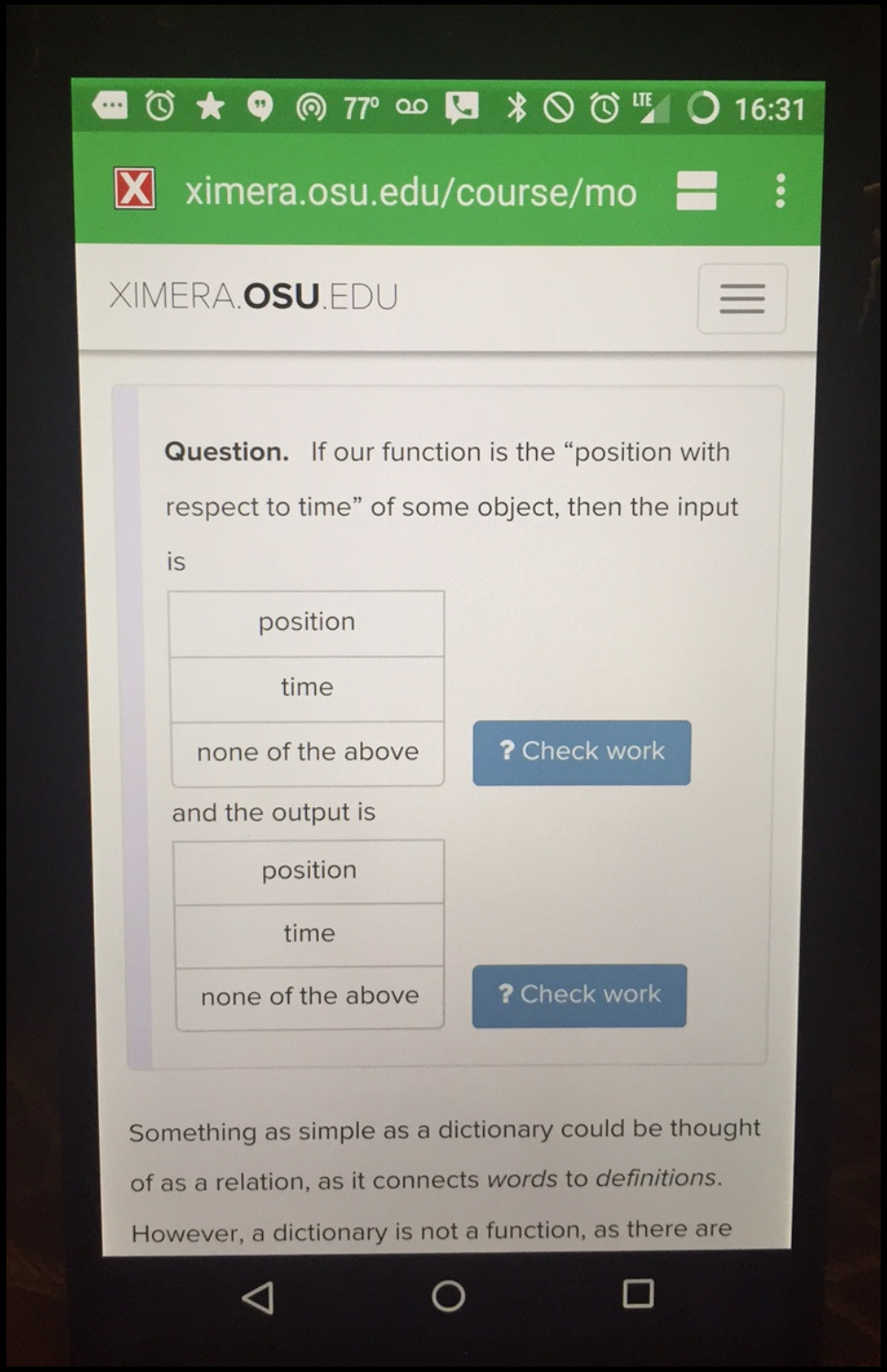
Explanation. Since f is a polynomial, we see that f is continuous for all real numbers. Since $f(0) =$ -2 ✓ and $f(1) =$?, and 0 is between -2 and 3, by the Intermediate Value Theorem, there is a $c \in [0, 1]$ such that $f(c) =$?.

This example also points the way to a simple method for approximating roots.

Example. Approximate a root of $f(x) = x^3 + 3x^2 + x - 2$ between 0 and 1 to within one decimal place.

Explanation. Again, since f is a polynomial, we see that f is continuous for all real numbers. Compute

x	$f(x)$
0.1	?
0.2	?
0.3	?

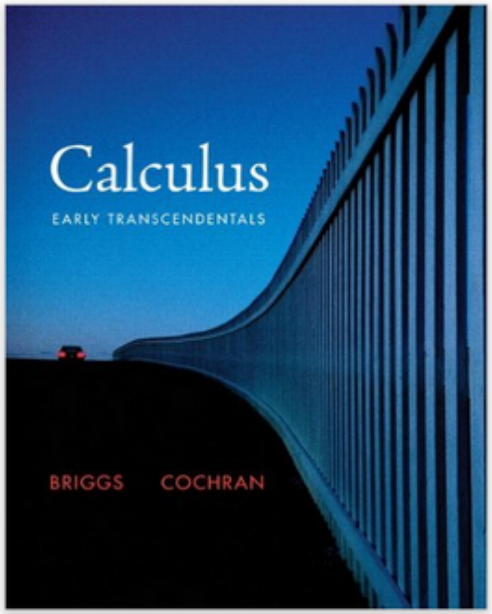

16:31
ximera.osu.edu/course/mo
XIMERA.OSU.EDU
Question. If our function is the "position with respect to time" of some object, then the input is
position
time
none of the above
? Check work
and the output is
position
time
none of the above
? Check work
Something as simple as a dictionary could be thought of as a relation, as it connects words to definitions. However, a dictionary is not a function, as there are

Mobile

Calculus: Early Transcendentals (Briggs/Cochran Calculus) 1st Edition

by Bill Briggs (Author), Lyle Cochran (Author), Bernard Gillett (Author)

63 customer reviews



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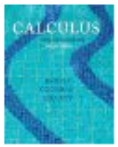

Calculus: Early Transcendentals Plus NEW MyMathLab with Pearson eText -- Access Card Package (2nd Edition) (Briggs/Cochran/Gillett Calculus 2e)

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Drawing on their decades of teaching experience, William Briggs and Lyle Cochran have created a calculus text that carries the teacher's voice beyond the classroom. That voice–evident in the narrative, the figures, and the questions interspersed in the narrative–is a master teacher leading readers to deeper levels of understanding. The authors appeal to readers' geometric intuition to introduce fundamental concepts and lay the foundation for

The choice is not

zero versus non-zero price.

The choice is between

open versus closed.

The choice is not

zero versus non-zero price.

The choice is between

open versus closed.

What does a closed textbook say about learning?

The choice is not

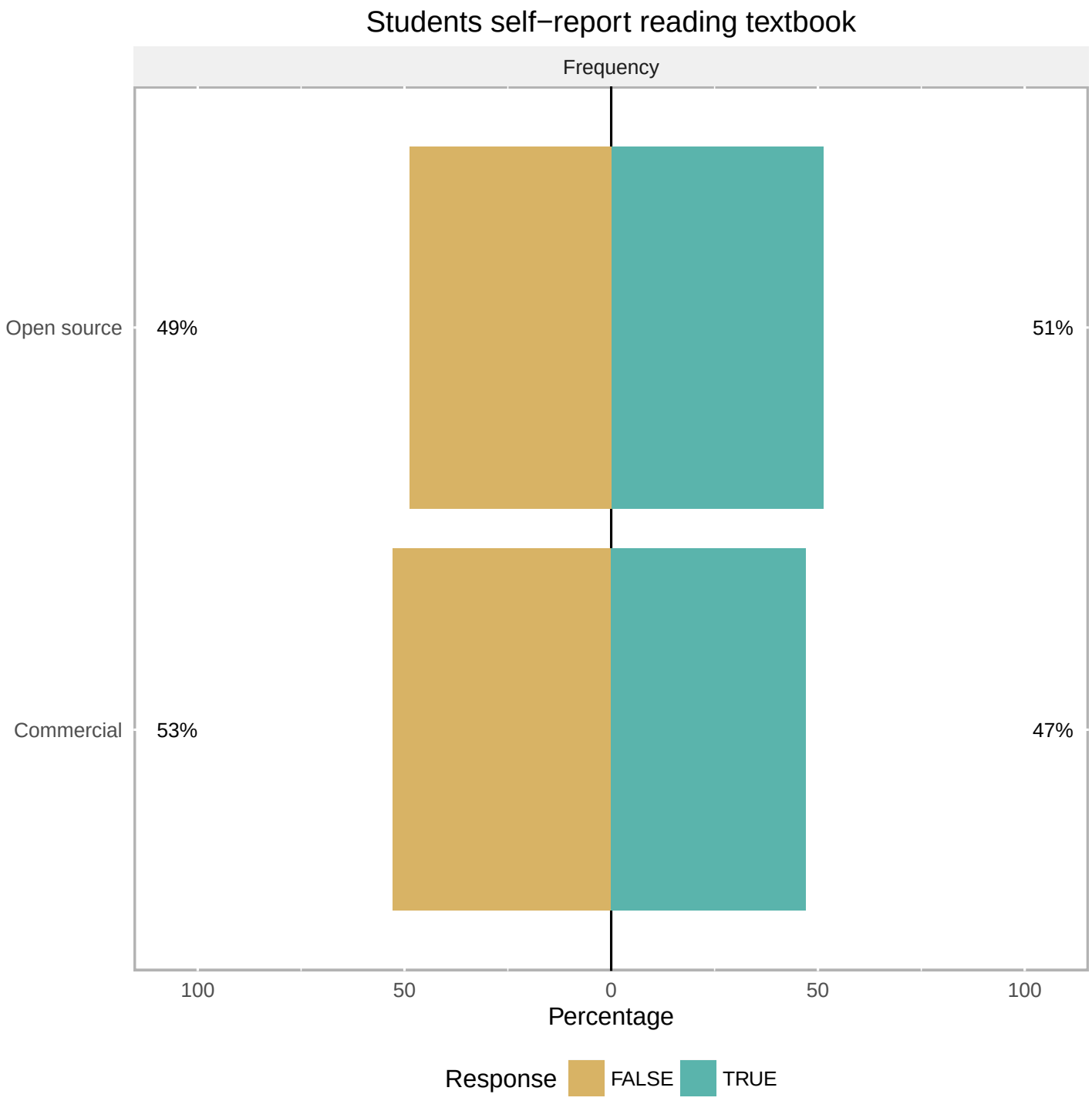
zero versus non-zero price.

The choice is between

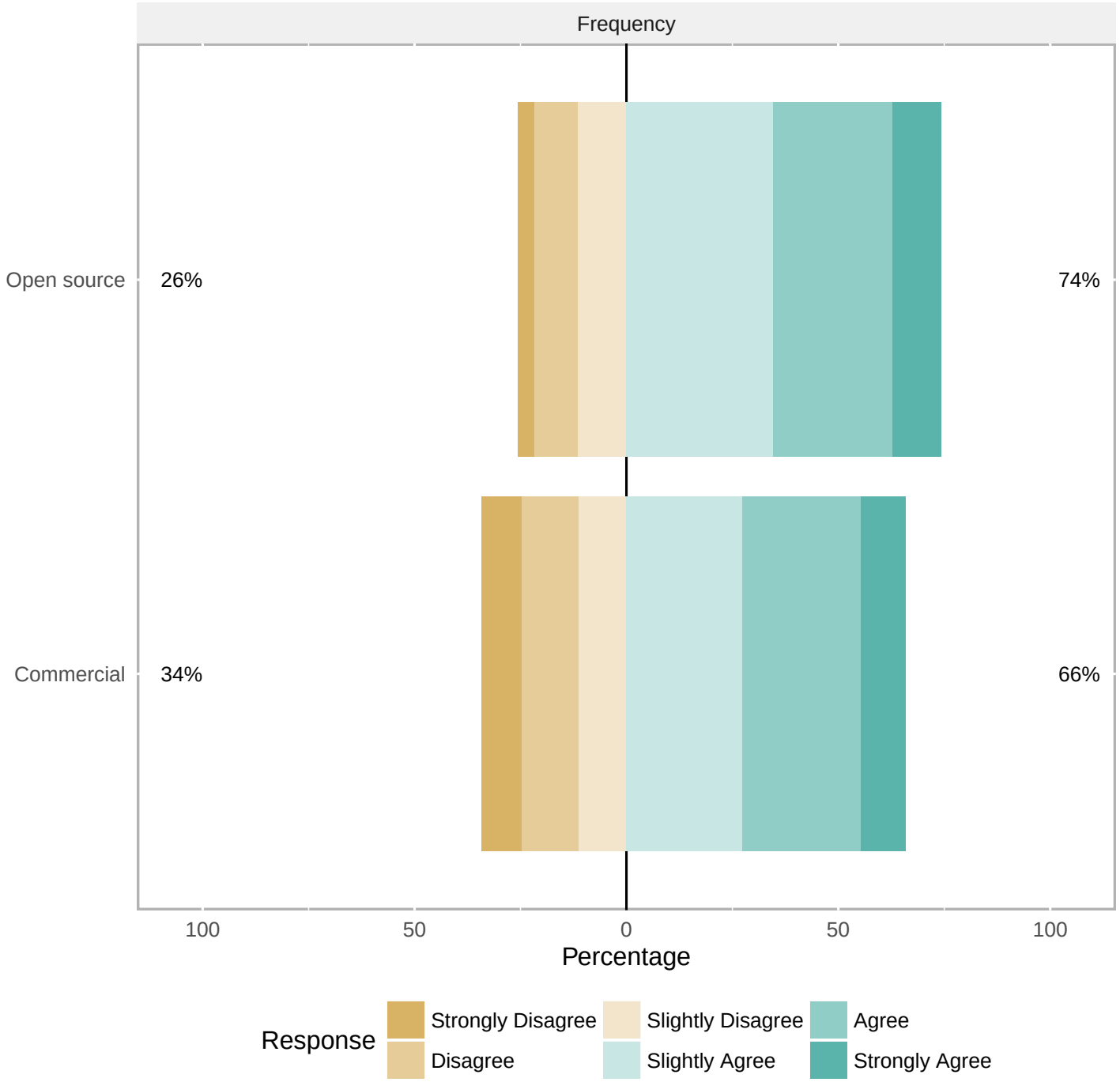
open versus closed.

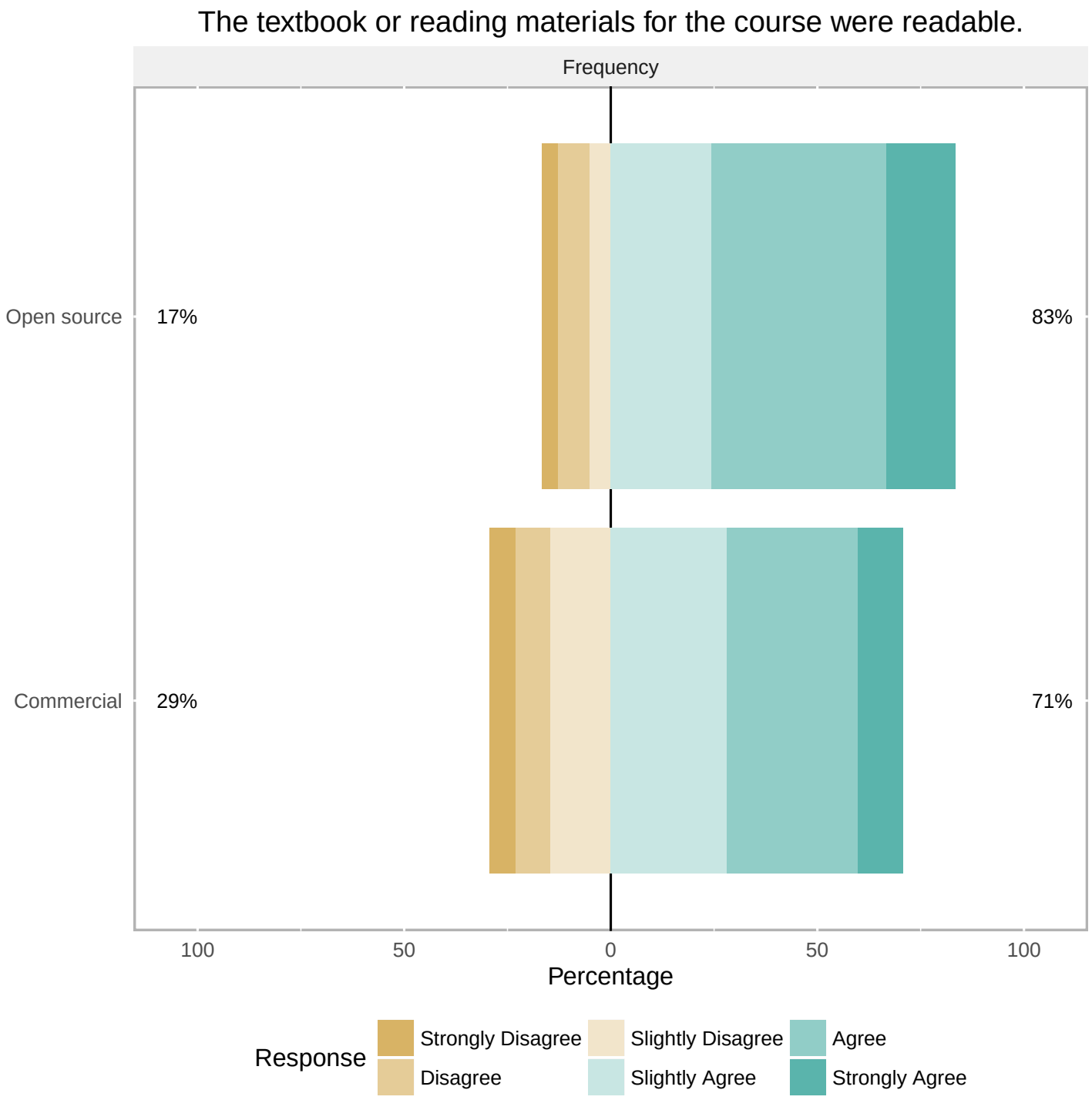
What does a closed textbook say about learning?

an open textbook


Students self−report reading textbook
Frequency
Open source
49%
51%
Commercial
53%
47%
100
50
0
50
100
Percentage
Response
FALSE
TRUE

The textbook and/or class materials helped me learn the material.



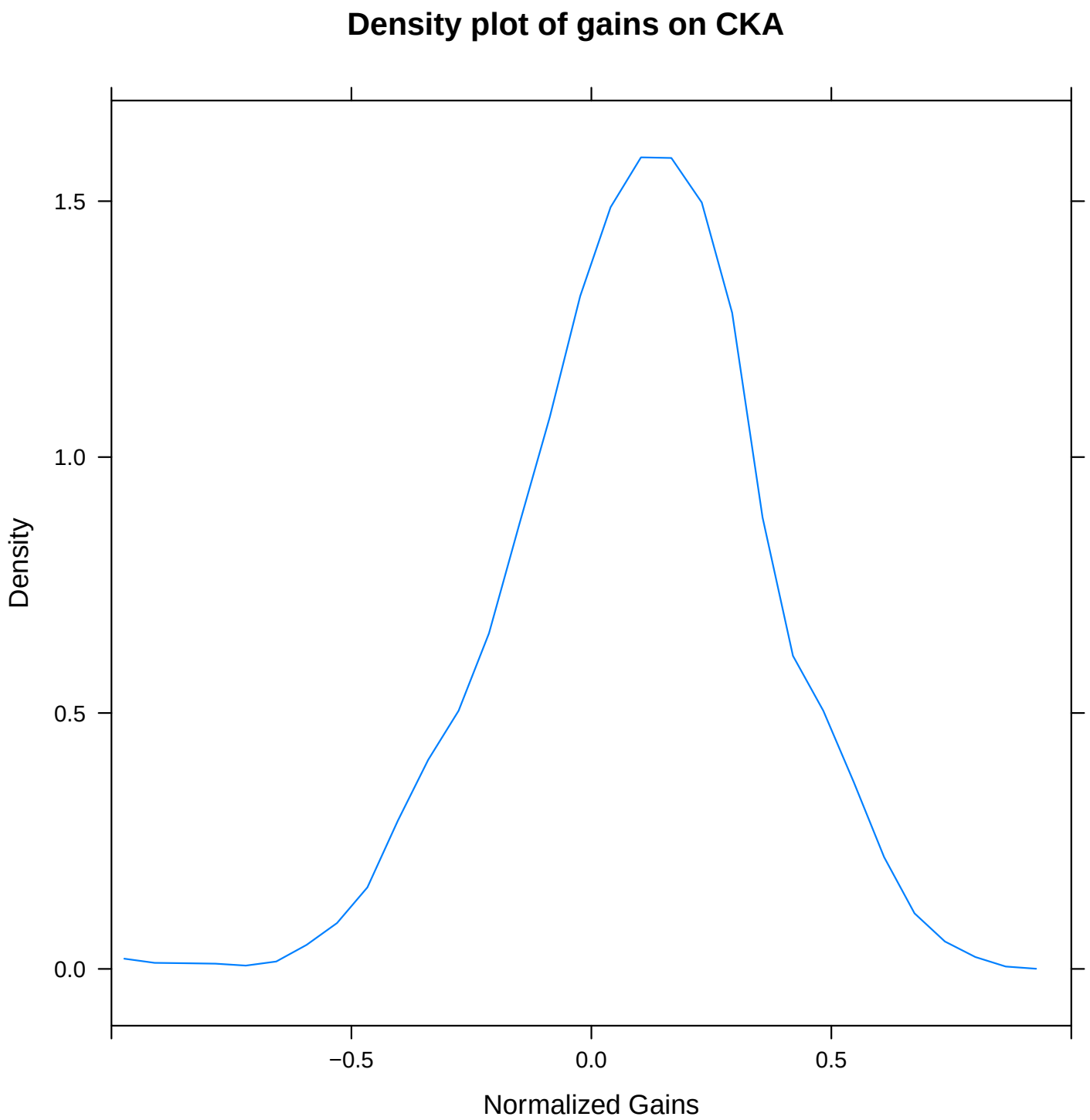

The textbook or reading materials for the course were readable.
Frequency
Open source
17%
83%
Commercial
29%
71%
100
50
0
50
100
Percentage
Response
Strongly Disagree
Disagree
Slightly Disagree
Slightly Agree
Agree
Strongly Agree

“Active” shifts focus

Calculus Knowledge Assessment

Goals:

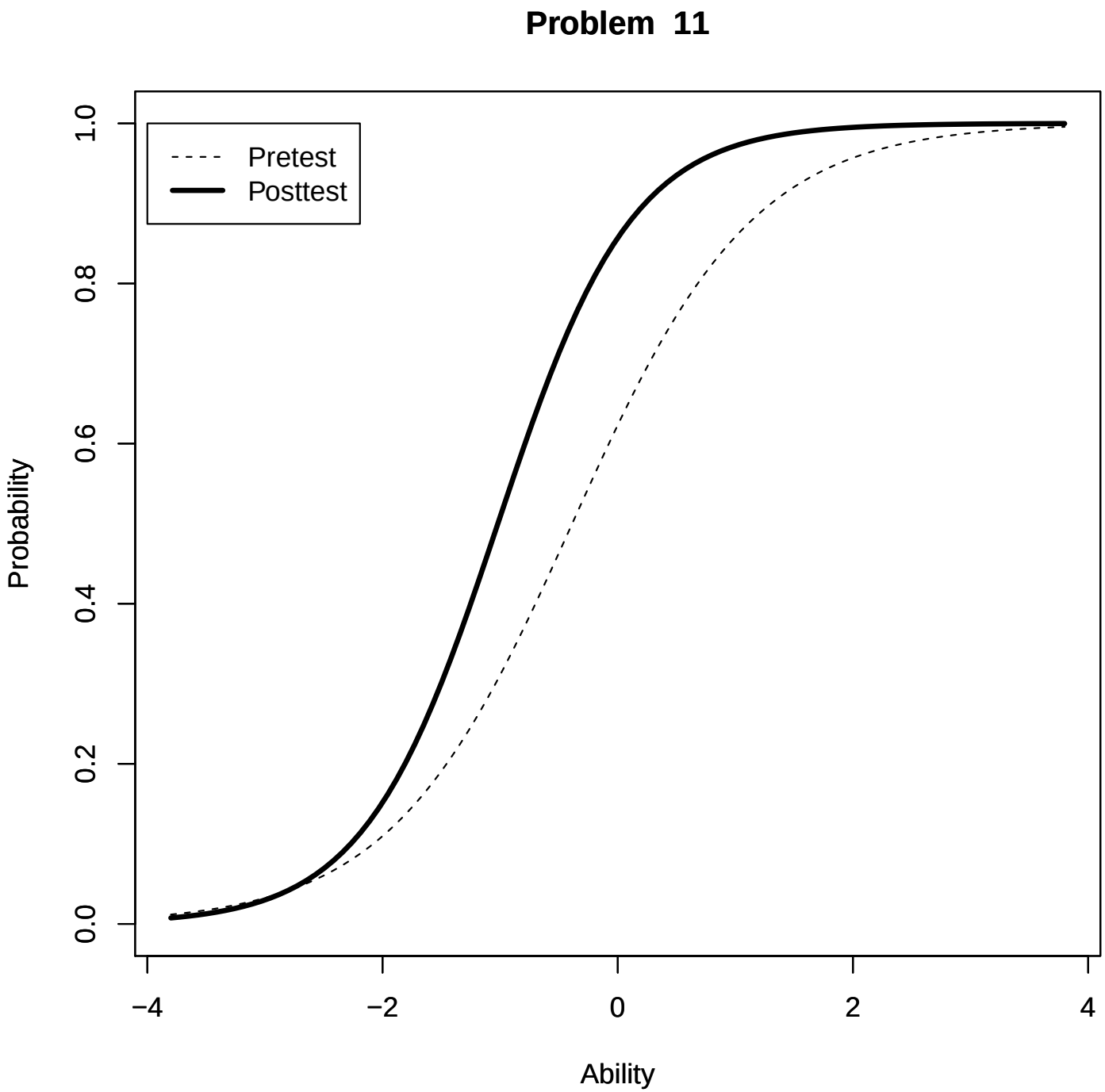
- Open
- A "concept inventory"
- Large bank of aligned items
- Easy to administer
- Quick for students


Density plot of gains on CKA
Density
1.5
1.0
0.5
0.0
−0.5
0.0
0.5
Normalized Gains

P11

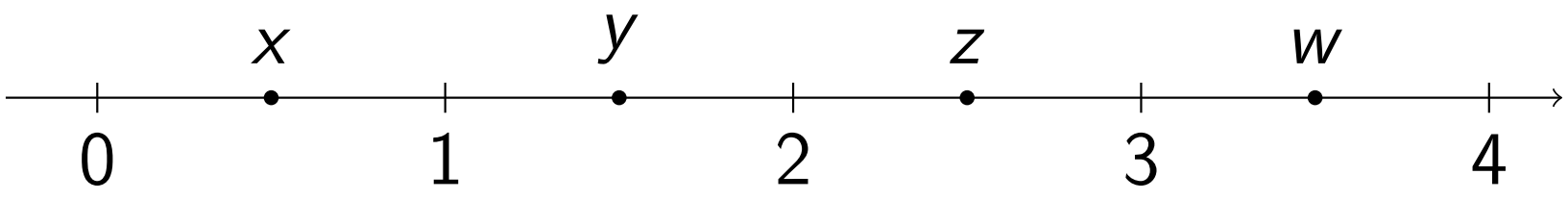
The graph of the position of an object with respect to time is given by a straight line with a positive slope.
What can we say about the acceleration of the object?

- It is positive.
- It is negative.
- It is zero.
- The acceleration changes from negative to positive.
- We cannot say anything about the sign of the acceleration.


Problem 11
Pretest
Posttest
Probability
0.0
0.2
0.4
0.6
0.8
1.0
−4
−2
0
2
4
Ability

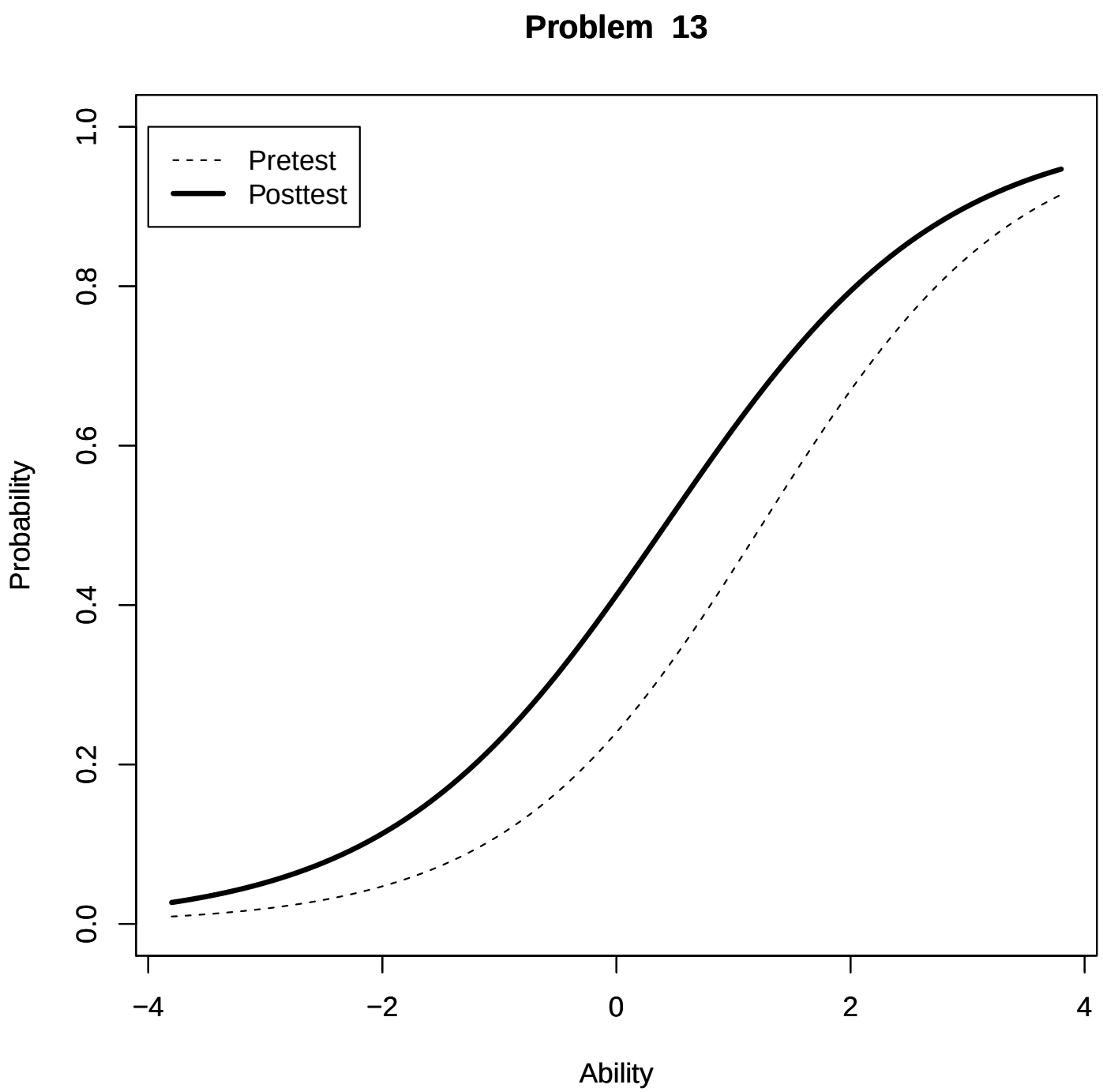
P13

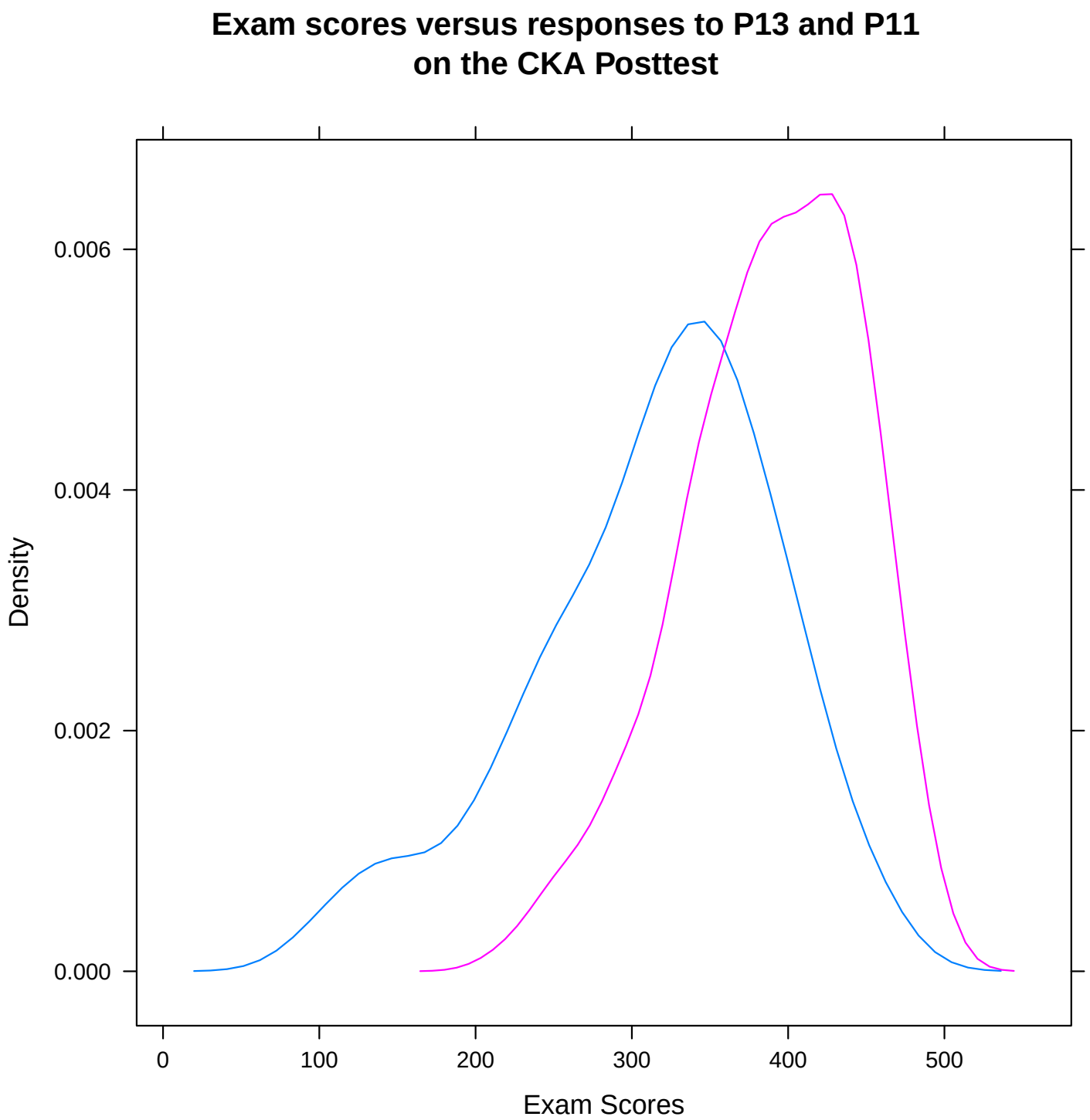
Four equally spaced numbers are shown below on a number line.



Let $f(t) = \ln t$ and consider $f(x)$ and $f(y)$ and $f(z)$ and $f(w)$. Among the pairs listed below, which pair of numbers is farthest apart?

- The pair $f(x)$ and $f(y)$.
- The pair $f(y)$ and $f(z)$.
- The pair $f(z)$ and $f(w)$.
- These pairs are all equally far apart.

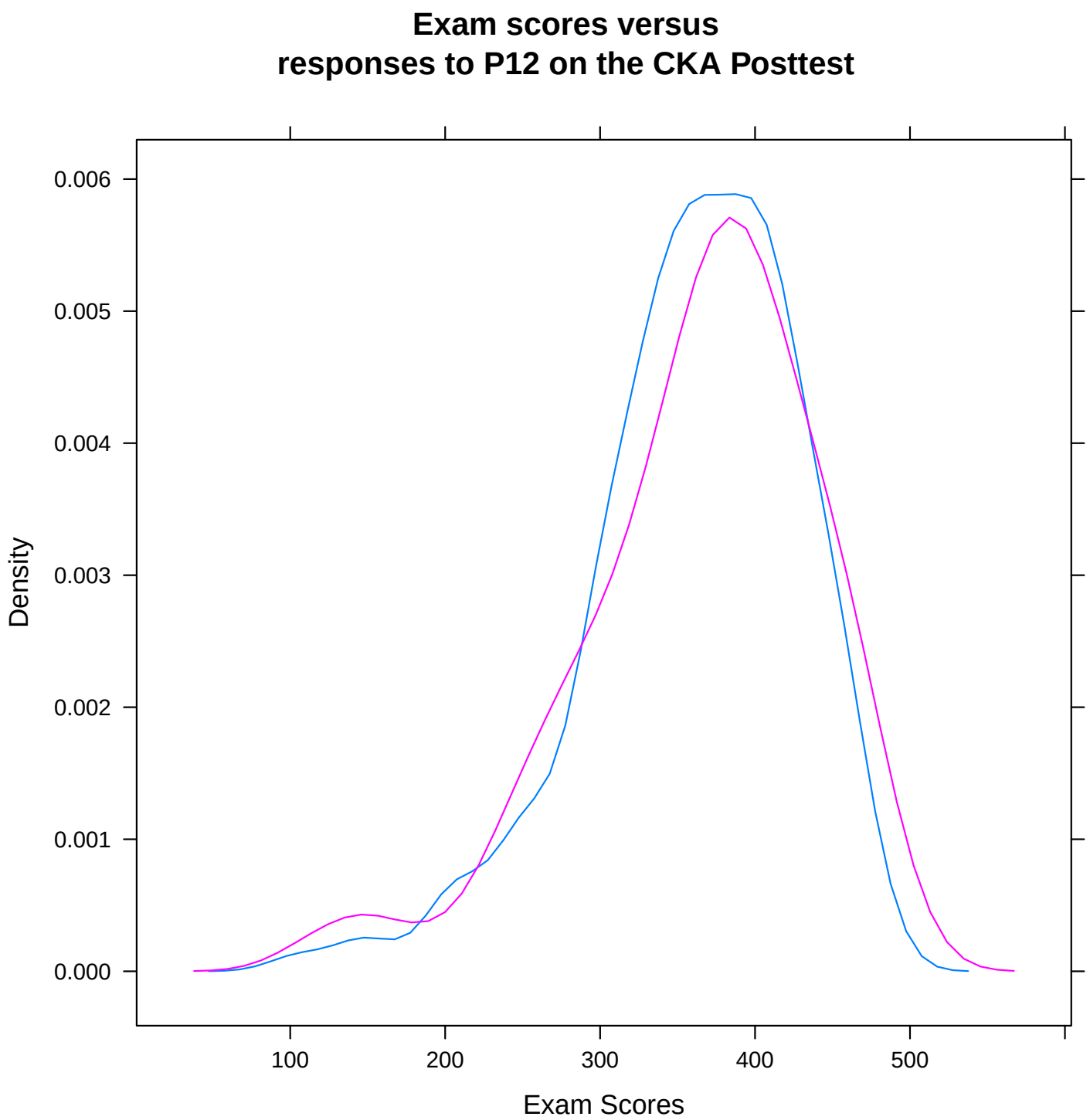

Problem 13
Pretest
Posttest
Probability
0.0
0.2
0.4
0.6
0.8
1.0
−4
−2
0
2
4
Ability

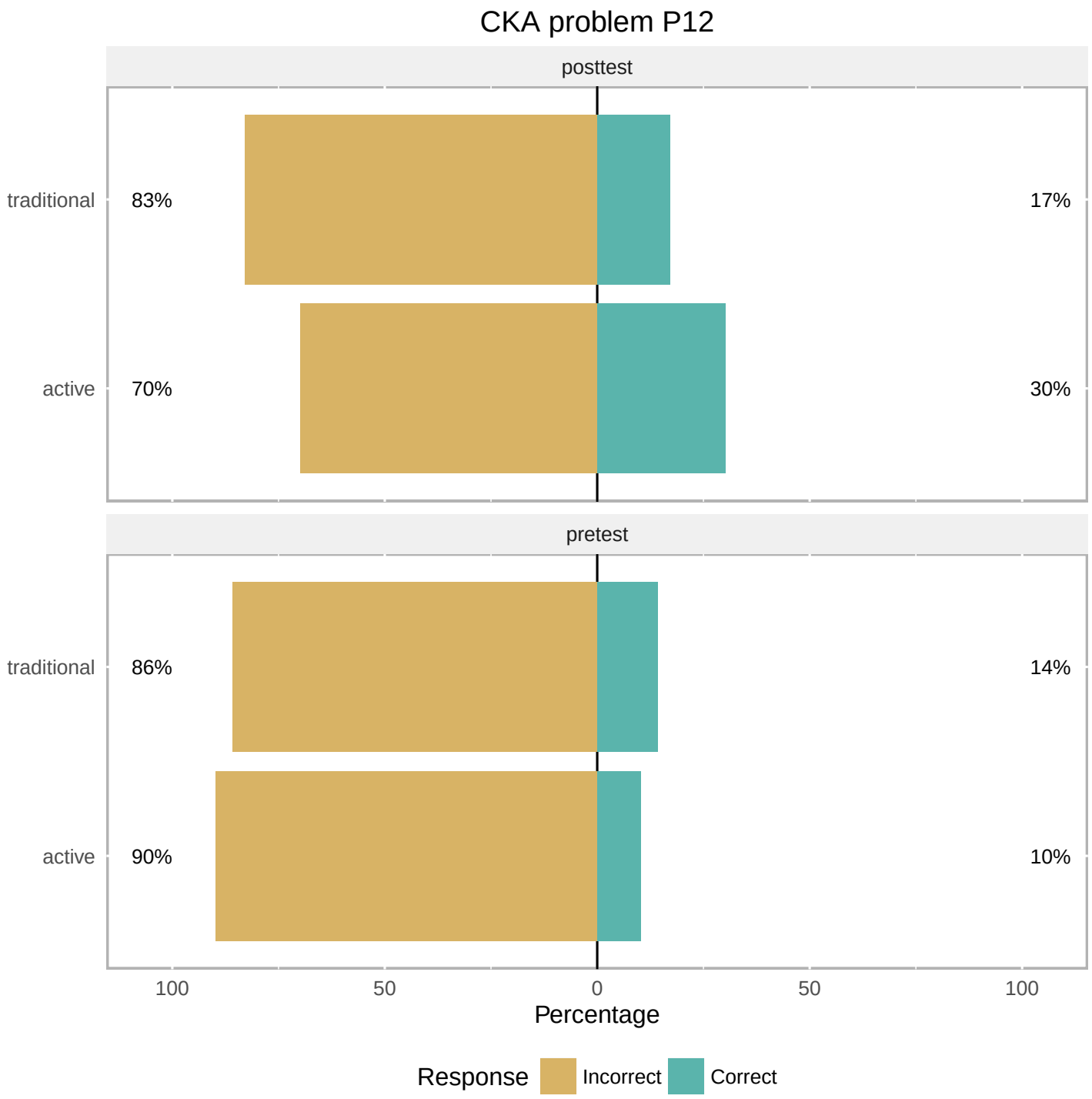

Exam scores versus responses to P13 and P11
on the CKA Posttest
Density
0.000
0.002
0.004
0.006
0
100
200
300
400
500
Exam Scores

P12

Two racers start a race at the same moment and finish in a tie. Which of the following must be true?

- At some point during the race the two racers were not tied.
- The racers' speeds at the end of the race must have been exactly the same.
- The racers must have had the same speed at exactly the same time at some point in the race.
- The racers had to have the same speed at some moment, but not necessarily at exactly the same time.


Exam scores versus
responses to P12 on the CKA Posttest
Density
0.000
0.001
0.002
0.003
0.004
0.005
0.006
100
200
300
400
500
Exam Scores


CKA problem P12
posttest
traditional
83%
17%
active
70%
30%
pretest
traditional
86%
14%
active
90%
10%
100
50
0
50
100
Percentage
Response
Incorrect
Correct

Community

Math Education Forum

The theory of change depends on creating a community of change.

The Ohio Math Initiative is a model of such a community.

Thank You

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