

Teaching with Classroom Voting and Clickers

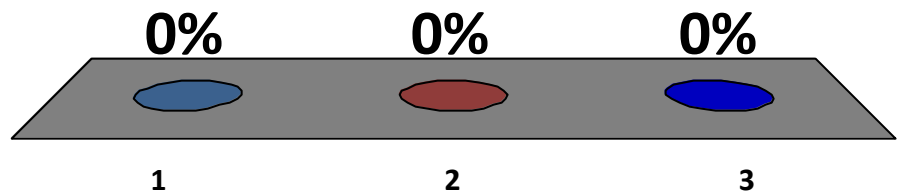
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I have previous experience with classroom voting.

1. Yes
2. No
3. What is classroom voting?



Project MathVote Team

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Outline

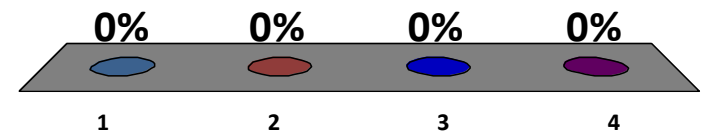
- Classroom voting demo
- Background on classroom voting pedagogy
- Sample lesson plans
- Results from research
- Question libraries
- Designing lesson plans
- Summary and Q&A

You are a passenger in a car and not wearing your seat belt. Without increasing or decreasing its speed, the car makes a sharp left turn, and you find yourself colliding with the right-hand door. Which is the correct analysis of the situation?

1. Before and after the collision, there is a rightward force pushing you into the door.
2. Starting at the time of collision, the door exerts a leftward force on you.
3. Both of the above
4. Neither of the above

10

Countdown
Timer
On Slide



What is Classroom Voting?

- Pose multiple choice or true/false question to class
- Students discuss with peers
- Each student or group votes on answer
- Instructor guides class-wide discussion
- Used to
 - Introduce new concepts
 - Practice material just learned
 - Deepen understanding
 - Review
- Integral to teaching – not just an add-on

Why Classroom Voting?

- Student engagement
 - Discuss mathematics with peers
 - Commit to an answer
 - Confront misconceptions in class
 - Get immediate feedback
 - Have fun!
- Instructor feedback
 - Instant snapshot of state of class
 - Hear from more than just the vocal students

Discussions are key!

- Pre-vote discussion with peers
- Post-vote discussion with class
 - Call on students by name
 - Let students volunteer
- No grade, so no pressure

Expectations for Classroom Voting

- Everyone must vote!
- Students are encouraged to discuss the question with at least one other person (Think-Talk-Vote!)
- Students may be called on to explain their votes.
- It doesn't matter whether you vote for the correct answer or not as long as you can explain your thinking.
- Ideally 100% of the votes come in before the results are shown but....

Presenting the Questions

- PowerPoint slides on screen
- Word document/PDF on screen
- Printed course packet
- PDF on Blackboard or Dropbox, etc. with access via mobile device

Collecting Votes

- Electronic
 - Clickers
 - TurningPoint
 - i>clicker
 - Mobile devices
 - Socrative, free (<50 students)
 - Poll Everywhere, free (<40 students), per month fee
 - TurningPoint and i>clicker, scaled access fee
- Other methods
 - Colored cards/white boards
 - Hands

Sample Lesson Plan

Linear Algebra

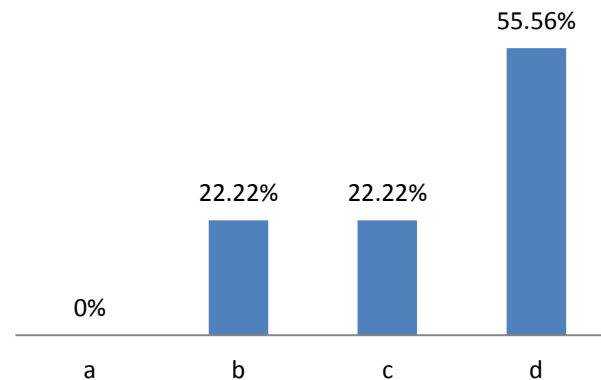
69. Let z be any vector from \mathfrak{R}^3 . If we have a set V of unknown vectors from \mathfrak{R}^3 , how many vectors must be in V to guarantee that z can be written as a linear combination of the vectors in V ?

(a) 2

(b) 3

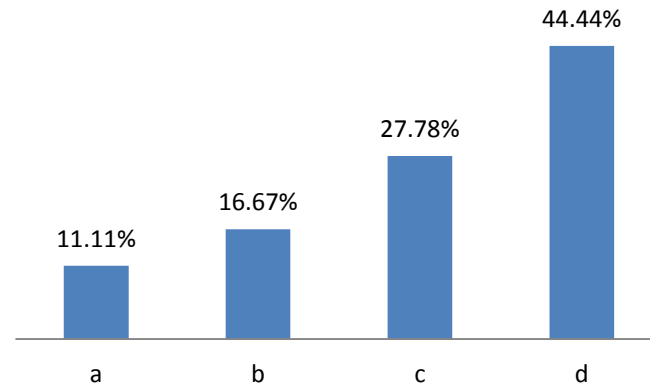
(c) 4

(d) It is not possible to make such a guarantee.



75. **True or False** The following vectors are linearly independent: $(1,0,0)$, $(0,0,2)$, $(3,0,4)$

- (a) True, and I am very confident
- (b) True, but I am not very confident
- (c) False, but I am not very confident
- (d) False, and I am very confident

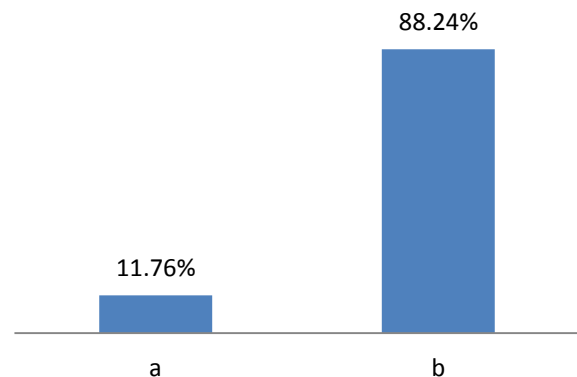


78. Suppose you wish to determine whether a set of vectors is linearly independent. You form a matrix with those vectors as the columns, and you calculate its

reduced row echelon form, $R = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 0 \end{bmatrix}$. What

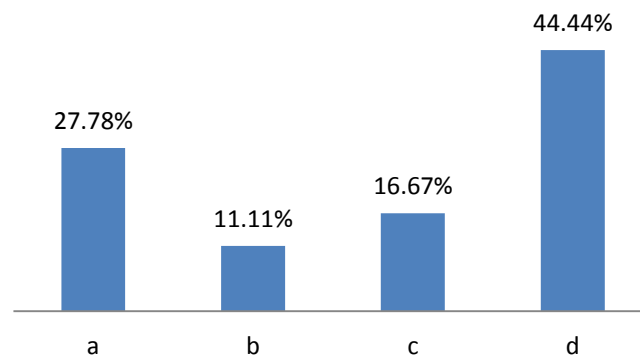
do you decide?

- (a) These vectors are linearly independent.
- (b) These vectors are not linearly independent.



83. To determine whether a set of n vectors from \mathfrak{R}^n is independent, we can form a matrix A whose columns are the vectors in the set and then put that matrix in reduced row echelon form. If the vectors are linearly independent, what will we see in the reduced row echelon form?

- (a) A row of all zeros.
- (b) A row that has all zeros except in the last position.
- (c) A column of all zeros.
- (d) An identity matrix.



Sample Lesson Plan

Math for Liberal Arts

Math for Liberal Arts: Voting Methods

- Consider the preference schedule below.
Which candidate has the best case for winning the election?

1. A
2. B
3. C
4. D
5. I don't know

9	8	7	1
A	C	D	B
B	B	B	C
C	D	C	D
D	A	A	A

Math for Liberal Arts: Voting Methods

- Who wins using Plurality?

1. A
2. B
3. C
4. D
5. I don't know

8	9	6	4
B	A	C	C
C	D	B	D
A	C	A	B
D	B	D	A

Math for Liberal Arts: Voting Methods

- Which candidate would have a legitimate complaint with Instant Runoff?

1. A
2. B
3. C
4. D
5. I don't know

100	98	97	2
A	B	C	D
C	C	A	C
D	D	D	A
B	A	B	B

Math for Liberal Arts: Voting Methods

- True or False: If A has a majority of the first-place votes, A will win using the Hare method.
 1. True, and I am very confident.
 2. True, but I am not very confident.
 3. False, but I am not very confident.
 4. False, and I am very confident.

Results from Research

Overview

- Research on classroom voting pedagogy across the disciplines indicate:
 - When used to create small group discussions, classroom voting improve students' test scores and conceptual understanding.
 - Students report having more fun learning mathematics and being more engaged in the material.
 - It can increase attendance and improve retention.

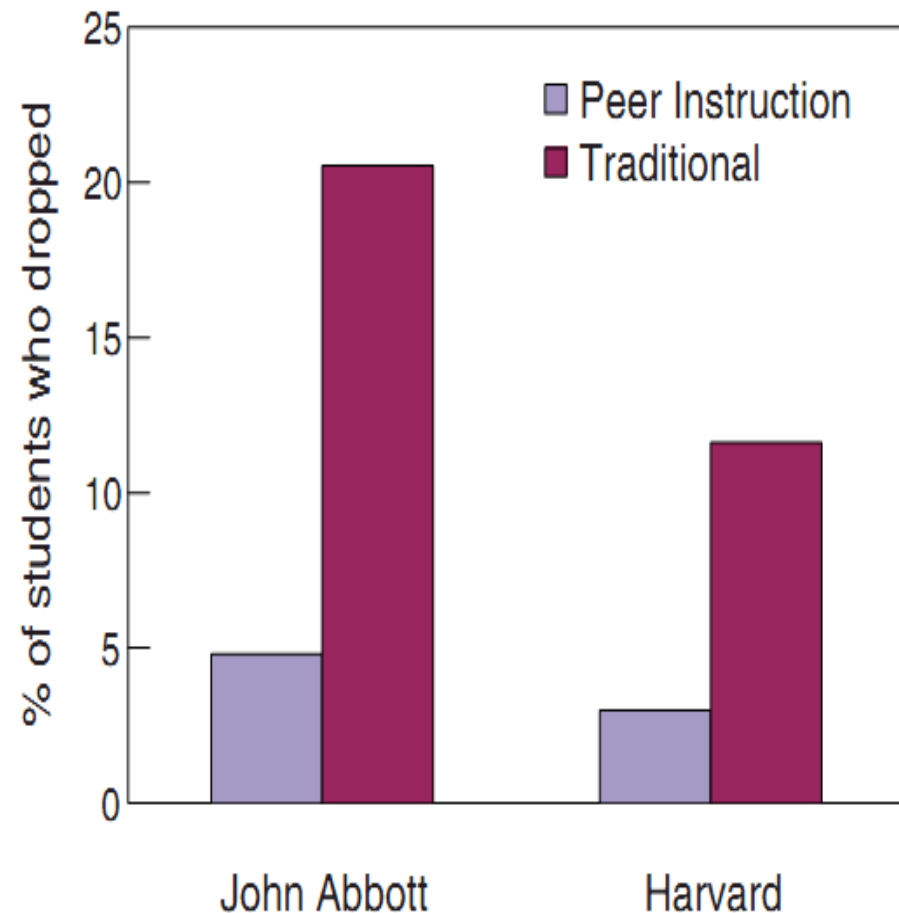
Physics: University of BC

- Two sections of introductory physics ($n_A=267$, $n_B=271$)
- In the twelfth week of the course
 - One taught via a traditional lecture by instructor A
 - One taught by inexperienced instructor using classroom voting and discussion (B)
- Experimental group (B) had a mean score 2.5 standard deviations above the control group (A) on common exam
- Results also showed increased attendance and higher engagement in the experimental group.

From Deslauriers *et al.* *Science* **332**, 862-864 (2011).

Physics: John Abbott and Harvard

- Introductory physics courses
- Compared performance and attrition rates in traditional vs. peer instruction (PI) sections of physics
- PI-taught students demonstrated better conceptual learning and similar problem-solving abilities than traditionally taught students.
- PI students with less background knowledge gained as much as students with more background knowledge in traditional instruction
- PI section had substantially fewer students drop the class.



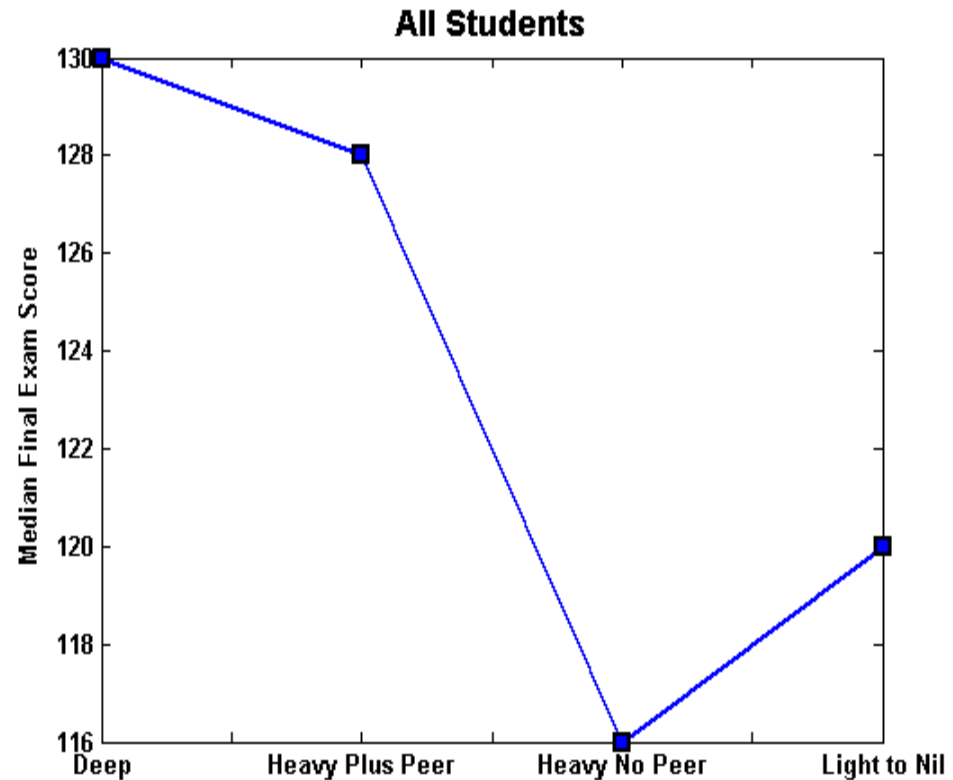
From Lasry *et al. Am. J. Phys.* **76** 1066-1069 (2008).

Mathematics: Cornell University

- 330 students, in 17 sections of Calculus I, taught by 14 different instructors
- Classes fell into one of four categories
 - **Deep:** Classes asked lots of deep and probing conceptual questions (1-4 times per week) with 2-cycle voting, including regular pre-vote peer discussions.
 - **Heavy Plus Peer:** (Voting used 3-4 times per week with 2-cycle voting and regular pre-vote peer discussions.)
 - **Heavy Low Peer:** (Voting used 3-4 times per week but usually one vote/question with no pre-vote peer discussions.)
 - **Light to Nil:** (Voting used 1-2 times per week or not at all)

Mathematics: Cornell University

- Classes which asked lots of deep and probing conceptual questions to stimulate peer discussions saw the best results, with statistically significant differences. Voting without discussion had no significant effect.
- Sections using little to no peer discussion were statistically no different from sections using only lecture.



Note: The final exam was out of 150 points, with 130 being an A, and 116 being a B-.

Mathematics: 10 Institutions

- Post-course surveys were given to 513 students in 26 courses, taught by 14 instructors at 10 different institutions all of which used voting and discussion as a primary teaching method (avg. class size=20)
 - 93% of students say voting makes class more fun
 - 90% say voting helps them engage in the material
 - 84% say voting helps them learn

From “Student Surveys: What Do They Think?” in *Teaching with Classroom Voting: with and without clickers* (MAA Notes Vol. 79, 2011)

Other Studies

- When students perceive voting as being used primarily for the teacher's benefit (for attendance, to quickly grade quizzes), then they are more likely to resent clickers. When students perceive voting as being used primarily for their own benefit, they enjoy and appreciate clickers (Trees & Jackson, 2009).

Trees, A. R., & Jackson, M. H. (2007). The learning environment in clicker classrooms: Student processes of learning and involvement in large university-level courses using student response systems. *Learning, Media, and Technology*, 32(1).

- Students stay more alert and attentive to the lesson when clickers are used, especially when clicker questions are scattered throughout the period. They pay more attention because they never know when a question may come up (Hoekstra, 2008).

Hoekstra, A. (2008). Vibrant student voices: Exploring effects of the use of clickers in large college courses. *Learning, Media, & Technology*, 33(4), 329-341.

Project MathQuest and MathVote: Voting Results

- Beginning in 2004, results from classroom votes were recorded
- Today there are many questions for which we have records of 5, 10 or more votes
- These results
 - Allow instructors to identify which questions are more likely to challenge students and therefore provoke prolonged discussions.
 - Provide insights to student thinking and identify common misconceptions

Project MathVote: Characteristics of Good Questions

- Between 2010 and 2012, 1345 voting events with post-vote discussions, at five different institutions and involving 6 different instructors, were rated and recorded.
- Post-vote discussions were rated as High, Medium and Low level.
- Highly rated discussions were characterized by
 - A high-level of student engagement
 - A large number of students participating
 - Students articulating mathematical concepts clearly
 - Students responding to peers' comments
- Characteristics of questions that yielded the best discussion
 - Informal language and personal experience
 - Applications
 - Visual
 - No numbers and general cases
 - Difficult concepts and multi-step problems

Question Libraries

<http://mathquest.carroll.edu>

Topics Covered

- Algebra
- Liberal Arts Math
- Statistics
- Precalculus
- Calculus
 - Differential
 - Integral
- Multivariable Calculus
- Linear Algebra
- Differential Equations

Instructor's Guide

- Question
- Answer/solution
- Results
 - Vote distribution
 - Time to vote

Your Turn!

- Pick course
- Pick lesson topic
- Find classroom voting questions (maybe 3-5)
- Sketch an outline of a lesson using voting questions

There is a document here with helpful links (question libraries, clicker information, additional sample lesson plans):

<http://db.tt/8jpwuxhq>

Wrap-Up

- Main goal: Promote discussion
- Worth the time – yours and students'
- Lots of resources available
- Technology not necessary
- Teach same material in a different way

Keep in touch!

- Please let us know what you are doing with classroom voting.
- If you have any difficulties, we're here to help.
- If you write any questions you're willing to share, let us know and we will add them to our website.

Project MathVote

Project website:

<http://mathquest.carroll.edu/>

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A Cornucopia of Questions

Multivariable Calculus

Which of the following is an equation of a line in three dimensions?

(a) $x = 4$

(b) $y = 2x + 3$

(c) $z = 3x + 2y + 7$

(d) All of the above

(e) None of the above

- CC KC MA233 F09: 0/14/36/29/**21** time 2:30
- CC HZ MA233 F10: 5/5/45/23/**23** time 2:00
- CC MP MA233 F10: 0/0/23/31/**46** time 3:00
- CC HZ MA233 F11: 0/0/41/14/**46** time 2:45
- CC TM MA233 F11: 0/0/62/24/**15** time 3:00

Calculus I Question

- Class period on second derivatives
- Have already discussed questions relating 2nd derivative to concavity
- Have related position, velocity, and acceleration

In *Star Trek: First Contact*, Worf almost gets knocked into space by the Borg. Assume he was knocked into space and his space suit was equipped with thrusters. Worf fires his thrusters for 1 second, which produces a constant acceleration in the positive direction. In the next second he turns off his thrusters. In the third second he fires his thruster producing a constant negative acceleration. The acceleration as a function of time is given in Figure 2.31. Which of the following graphs represent his position as a function of time?

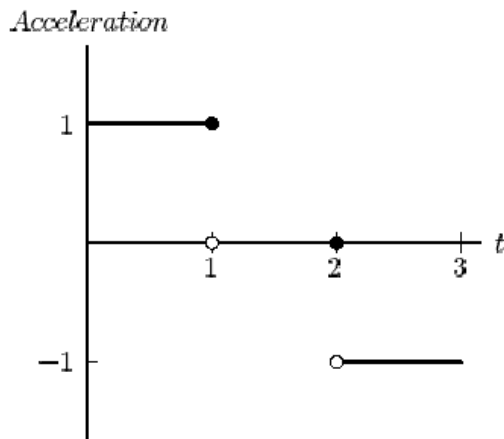
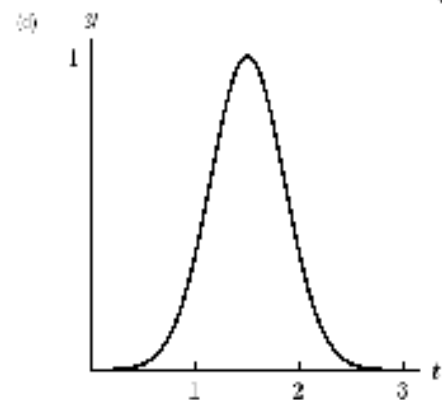
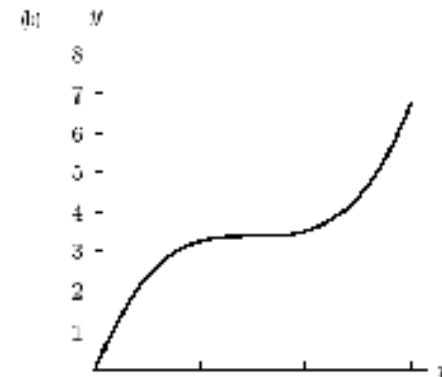
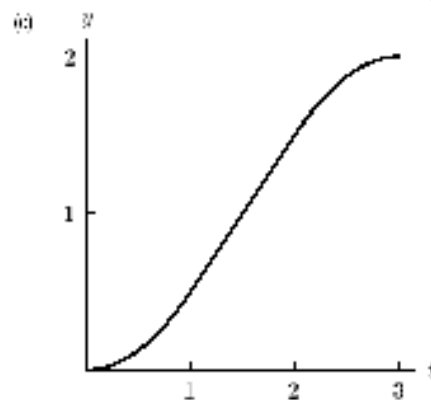
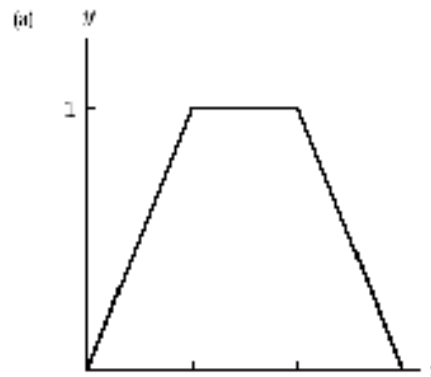


Figure 2.31



Results

- Correct answer: c
- 45/0/**35**/20, 13/0/**48**/39, 48/7/**7**/37
- Graphs a, c, and d regularly get substantial numbers of votes, producing great discussions.
- Key misconception: can have a negative 2nd derivative with a positive 1st derivative, particularly in context of motion
- (*ConceptTests to accompany Calculus by Hughes-Hallett et al.*)

Calculus

(Language, Personal Experience)

Your mother says, “If you eat your dinner, you can have dessert.” You know this means, “If you don’t eat your dinner, you cannot have dessert.” Your calculus teacher says, “If f is differentiable at x , f is continuous at x .” You know this means

- (a) If f is not continuous at x , f is not differentiable at x .
- (b) If f is not differentiable at x , f is not continuous at x .
- (c) Knowing f is not continuous at x , does not give us enough information to deduce anything about whether the derivative of f exists at x .

Differential Equations

(Application)

For which of the following predator-prey population models is the predator most successful at catching prey?

(a)
$$\frac{dx}{dt} = 2x - 3xy$$
$$\frac{dy}{dt} = -y + \frac{1}{2}xy$$

(c)
$$\frac{dx}{dt} = x(3 - 2y)$$
$$\frac{dy}{dt} = y(-1 + x)$$

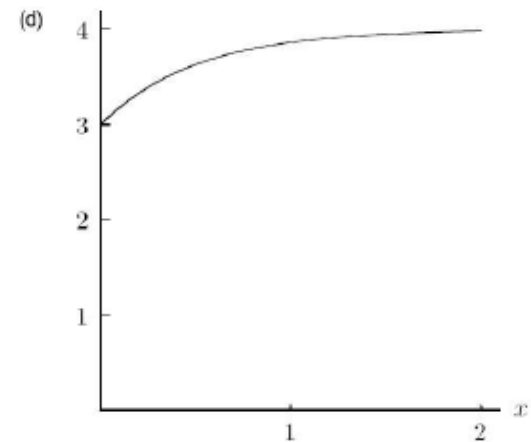
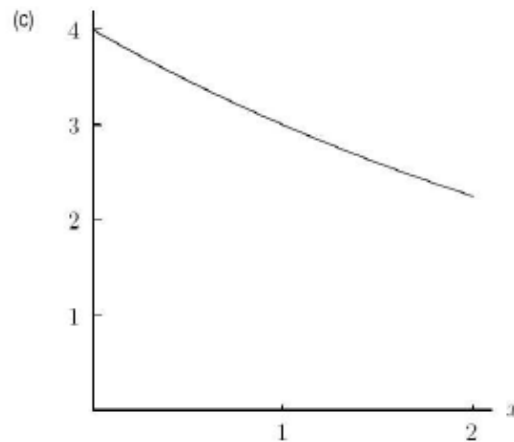
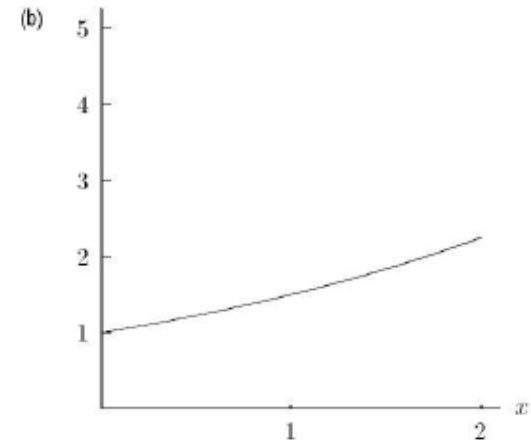
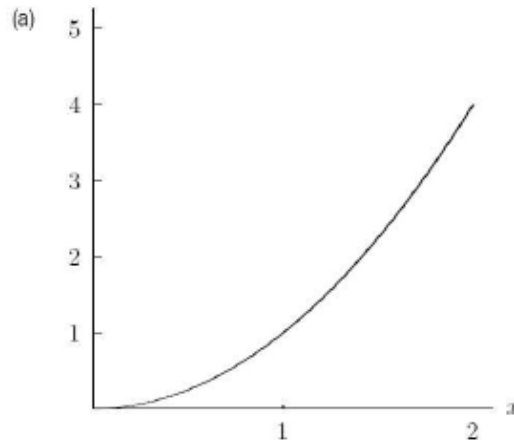
(b)
$$\frac{dx}{dt} = x(1 - 4y)$$
$$\frac{dy}{dt} = y(-2 + 3x)$$

(d)
$$\frac{dx}{dt} = 4x\left(\frac{1}{2} - y\right)$$
$$\frac{dy}{dt} = 2y\left(-\frac{1}{2} + x\right)$$

Precalculus

(Graphical)

Which of the following graphics could be that of $y = ab^x$ if $b > 1$?



Results

- Answer: (b).
- 4 – 48% get correct answer; most vote for (a)
- Key Misconception: exponential functions do not go through the origin
- ConcepTests - to accompany Calculus 4th Edition, Hughes-Hallet et al. John Wiley & Sons.

Linear Algebra

General Case

Suppose a 4×4 matrix A has rank 4. How many solutions does the system $Ax=b$ have?

(a) 0

(b) 1

(c) Infinite

(d) Not enough information is given.

Liberal Arts Math

No numbers / general case

Which is correct?

- (a) If you have a majority of the votes then you have a plurality.
- (b) If you have a plurality then you have a majority of the votes.
- (c) Both statements are false.

Algebra

Computational, Multi-Step

Given $f(x)=x+1$ and $g(x)=3x^2-2x$, what is the composition $g(f(x))$?

(a) $3x^2-2x+1$

(b) $(3x^2-2x)(x+1)$

(c) $3x^2+4x+1$

(d) $3(x+1)^2-2x$

Linear Algebra

True/False with confidence

Let matrix R be the reduced row echelon form of matrix A . **True or False:** The solutions to $Rx=b$ are the same as the solutions to $Ax=b$?

- (a) True, and I am very confident.
- (b) True, but I am not very confident.
- (c) False, but I am not very confident.
- (d) False, and I am very confident.

Average Rate of Change Lesson Plan (Precalculus)

- Define average rate of change, and present a simple example
- A series of three questions based on real data
 - Questions 91, 92, 93
- Could given data be linear?
 - Questions 78 and 79
- Quadratic example, build on question by asking about different intervals
 - Question 90