# Improving
# Science Education

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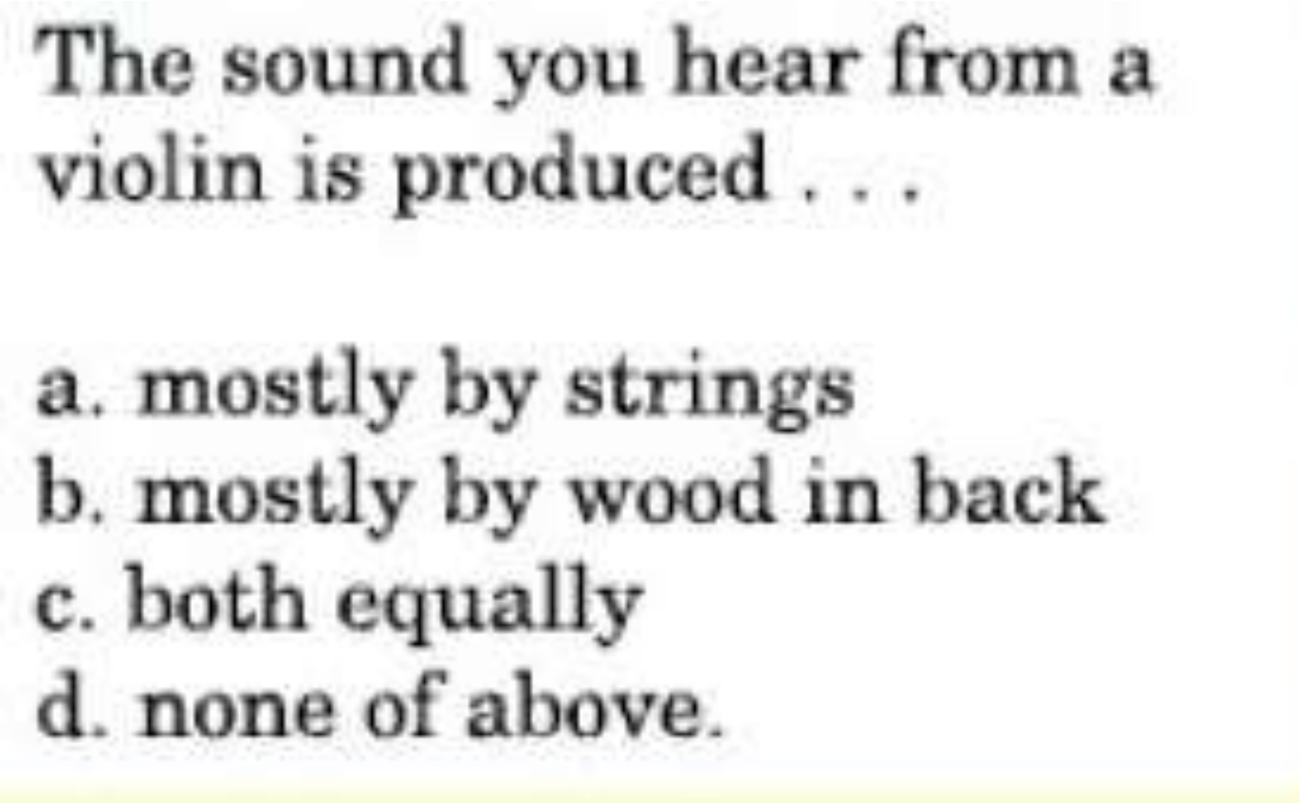
# Traditional Lecture

How effective is it?

A renown teacher (and Nobel-prize winner) explained in lecture that the sound from a violin is produced (mostly) by the wood in the back.

15 minutes later (same lecture period), he asked the following question:

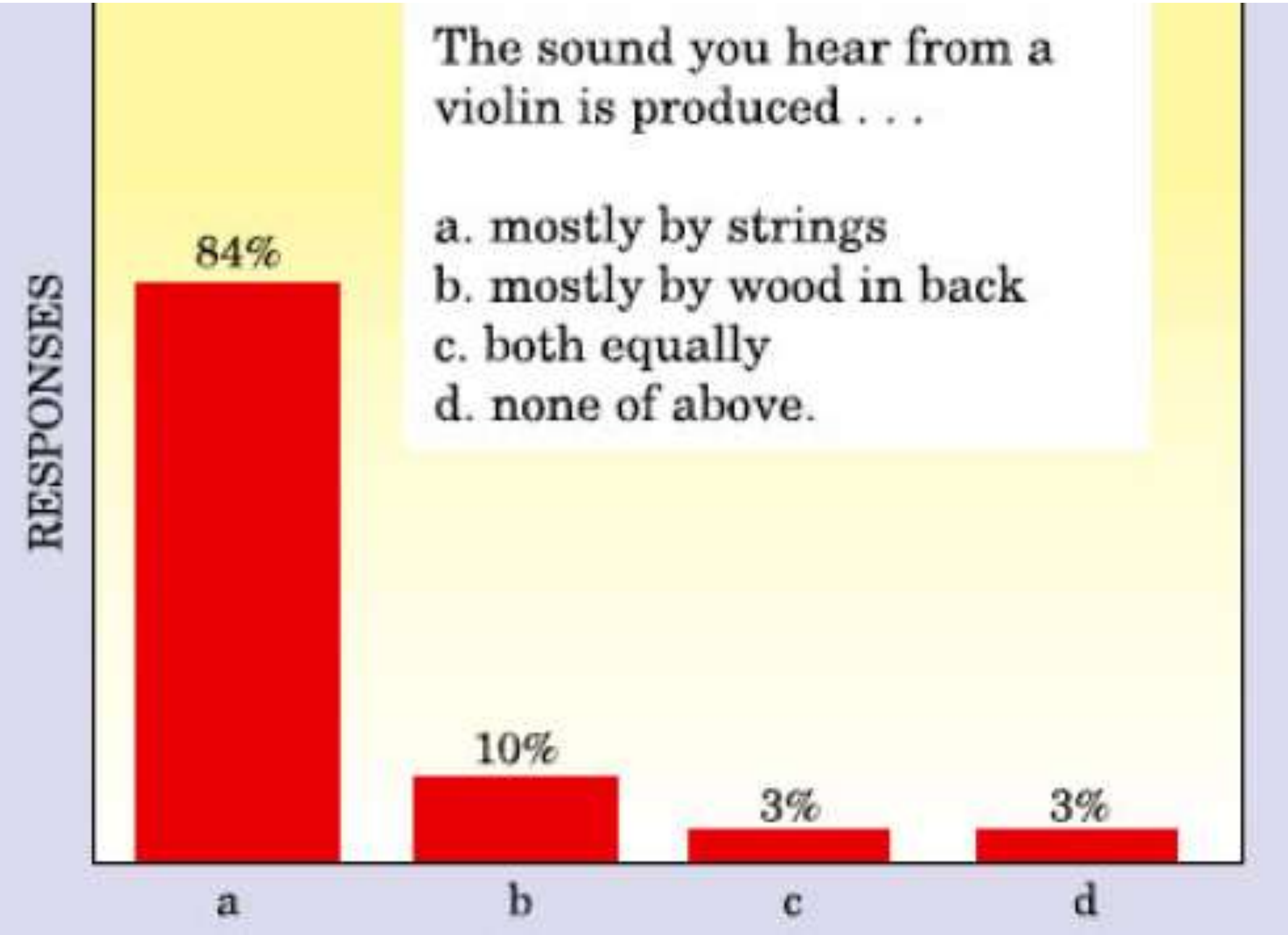


The sound you hear from a violin is produced . . .

a. mostly by strings
b. mostly by wood in back
c. both equally
d. none of above.

# Question: (for you)

What percentage of the class answered the question correctly?



The sound you hear from a violin is produced . . .

a. mostly by strings
b. mostly by wood in back
c. both equally
d. none of above.

Wieman & Perkins, *Phys. Today* (2005)

# MOOCs

# Eliminate traditional lectures/courses?

## MOOCs

(Massively Online Open Courses)

+ Online videos
+ Virtual discussion forums
+ Free
+ “Certificate” instead of credit

# MOOC Example

CS221:  Intro. to Artificial Intelligence
Sebastian Thrun:  Stanford/Google

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\+ Enrollment: 160,000 students
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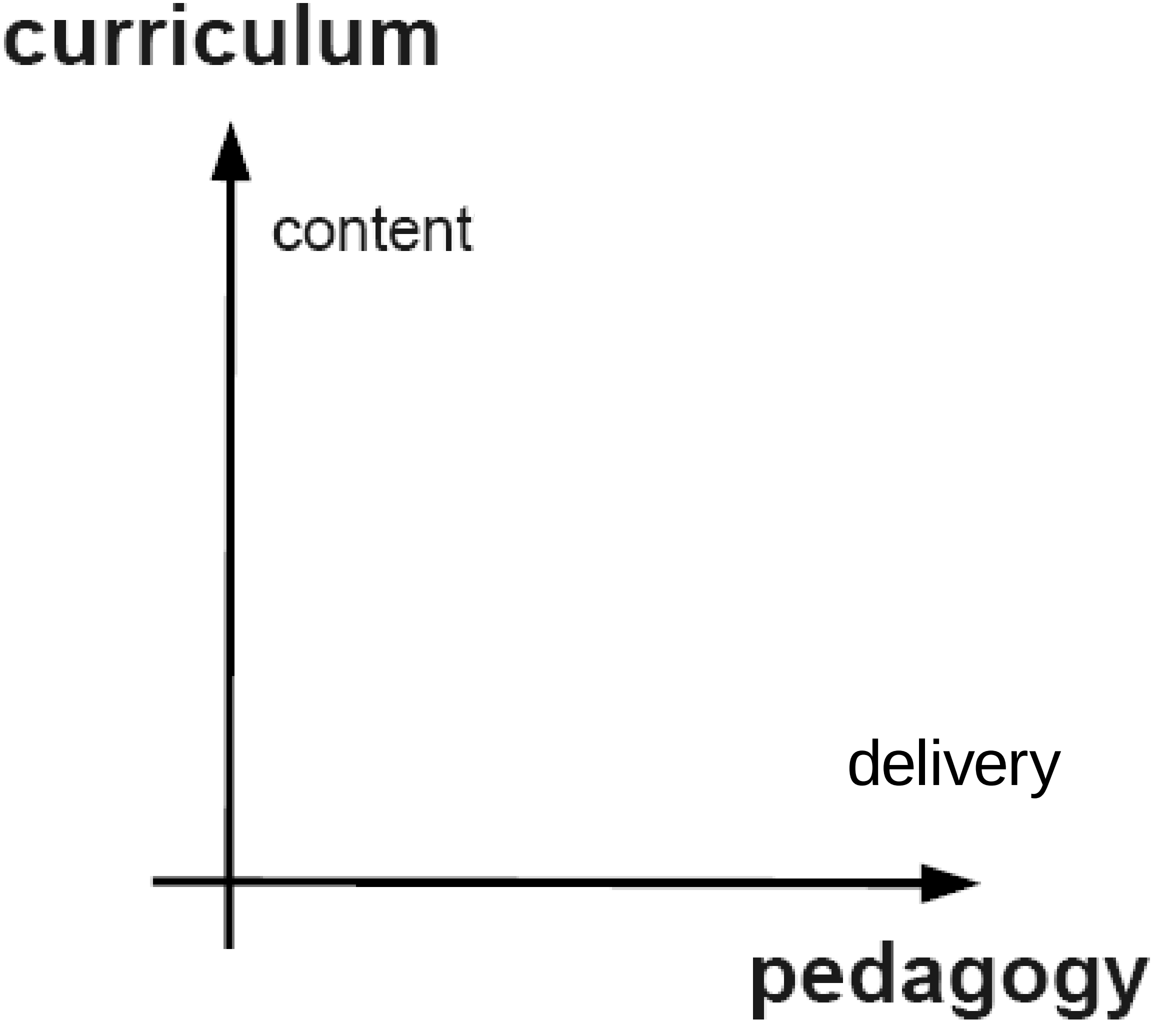
(None from Stanford)

# Eliminate Traditional Universities?

## MOOC Providers

- Udacity
- Coursera
- edX

# Improving
# Science Education



curriculum

content

delivery

pedagogy

# Challenges
# of Traditional Lectures

- Limited Short-term Working Memory
- Passive Learning

# Interactive Engagement Techniques

Peer Instruction (Eric Mazur, Harvard)

+ Reduce cognitive load

+ Stimulate student thinking

# Peer Instruction Example

## Step 1: Mini-Lecture (~10 minutes)

Buoyancy: Archimedes' Principle

The buoyancy force is equal to the weight of the displaced fluid.

# Peer Instruction Example

## Step 2: Pose Concept Question

**Boulder in a Boat**: A boat with a big rock floats on a lake. The rock is dropped into the lake and the water level in the lake:

1. Rises.
2. Falls.
3. Remains the same.

# Peer Instruction Example

Step 3: Each student selects, writes down answer (~1 minute)

No talking

# Peer Instruction Example

## Step 4: Peer Instruction (~2 minutes)

Turn to a neighbor and compare answers; if you differ, convince your neighbor that you are correct.

# Peer Instruction Example

## Step 5:  Vote

Initial Response

Final Response

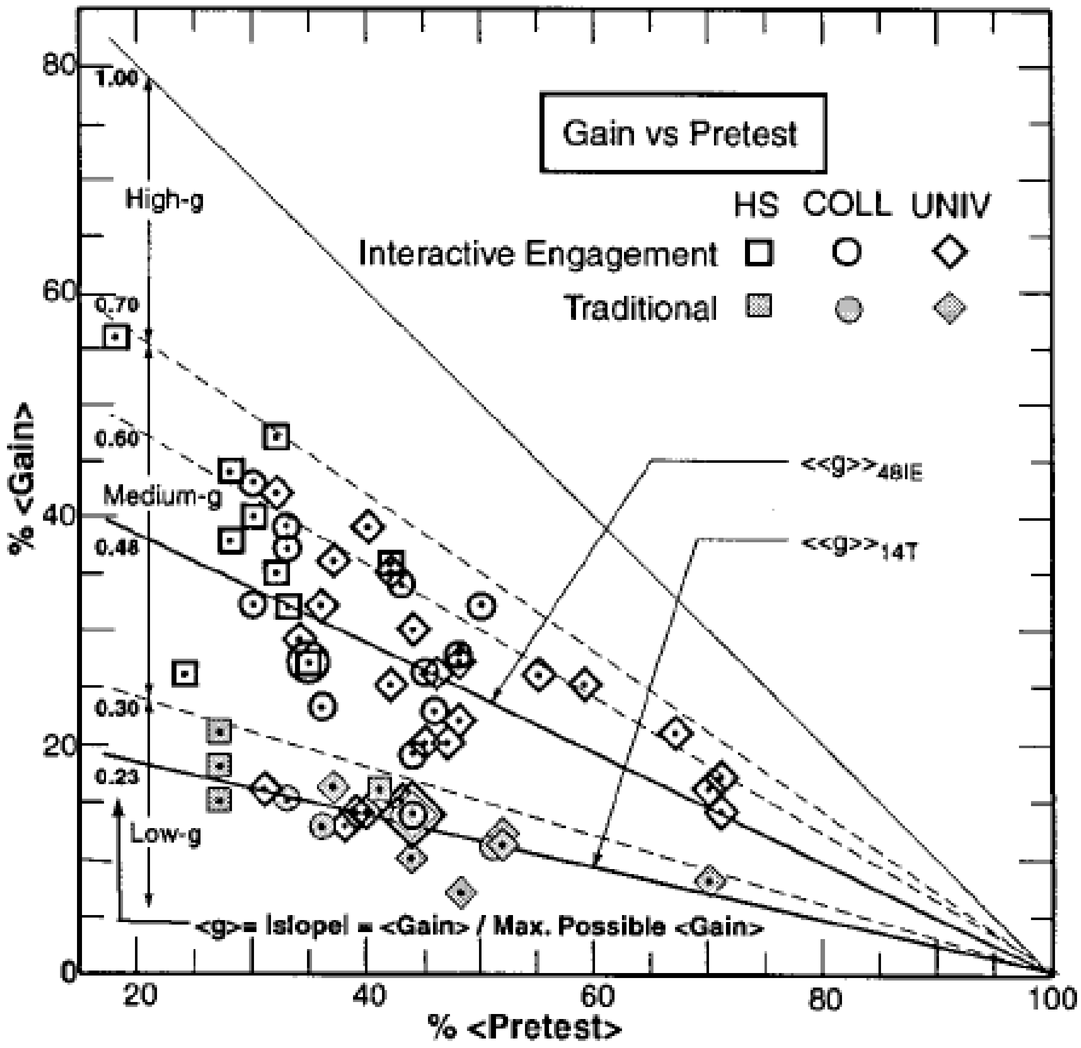
# Peer Instruction Example

## Step 5: Recap

Student difficulties? Revisit topic.

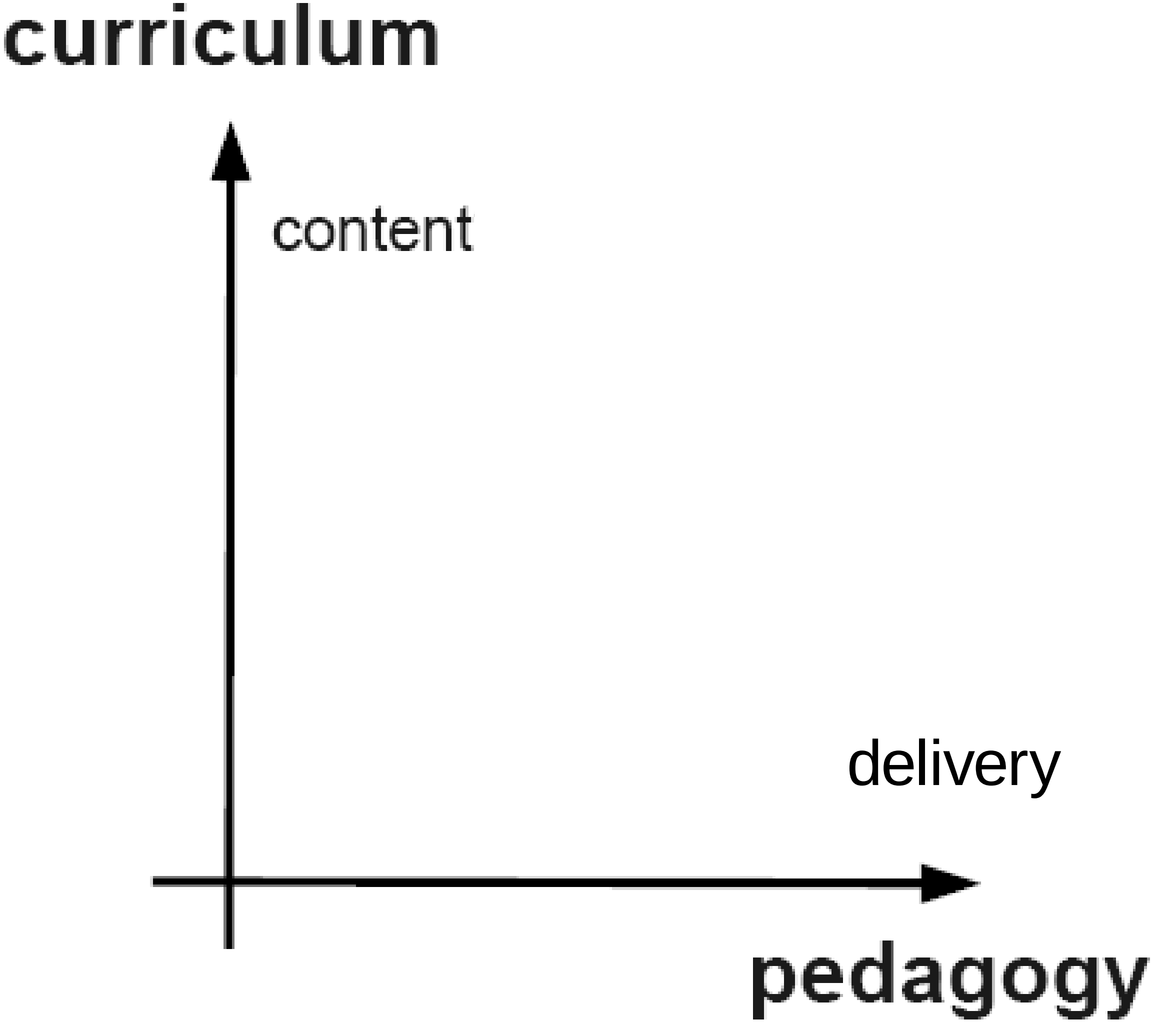
Mostly correct? Go to next topic

# Measurement

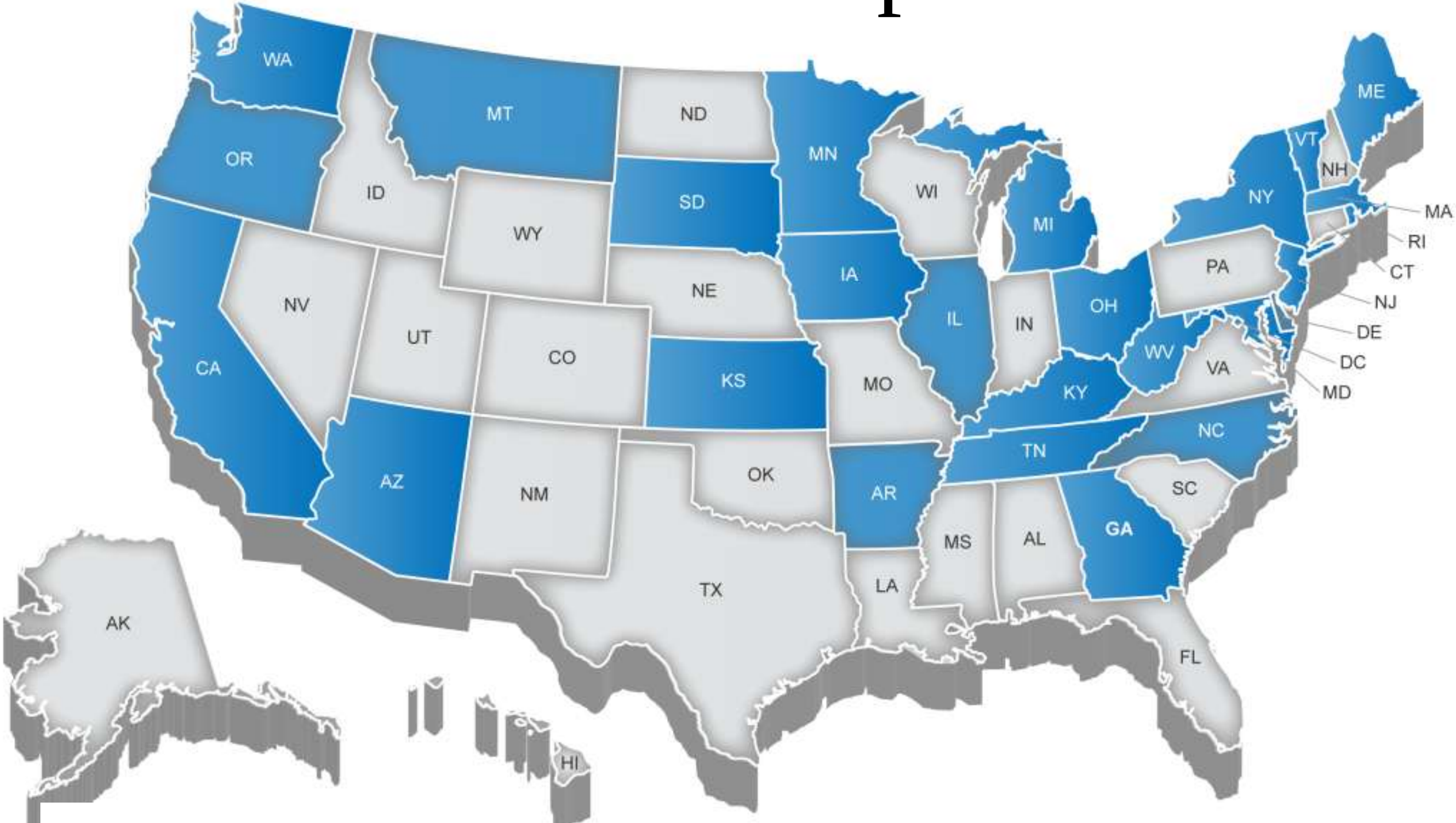


- R. Hake, *Am. J. Phys.* (1998)

# Improving Science Education

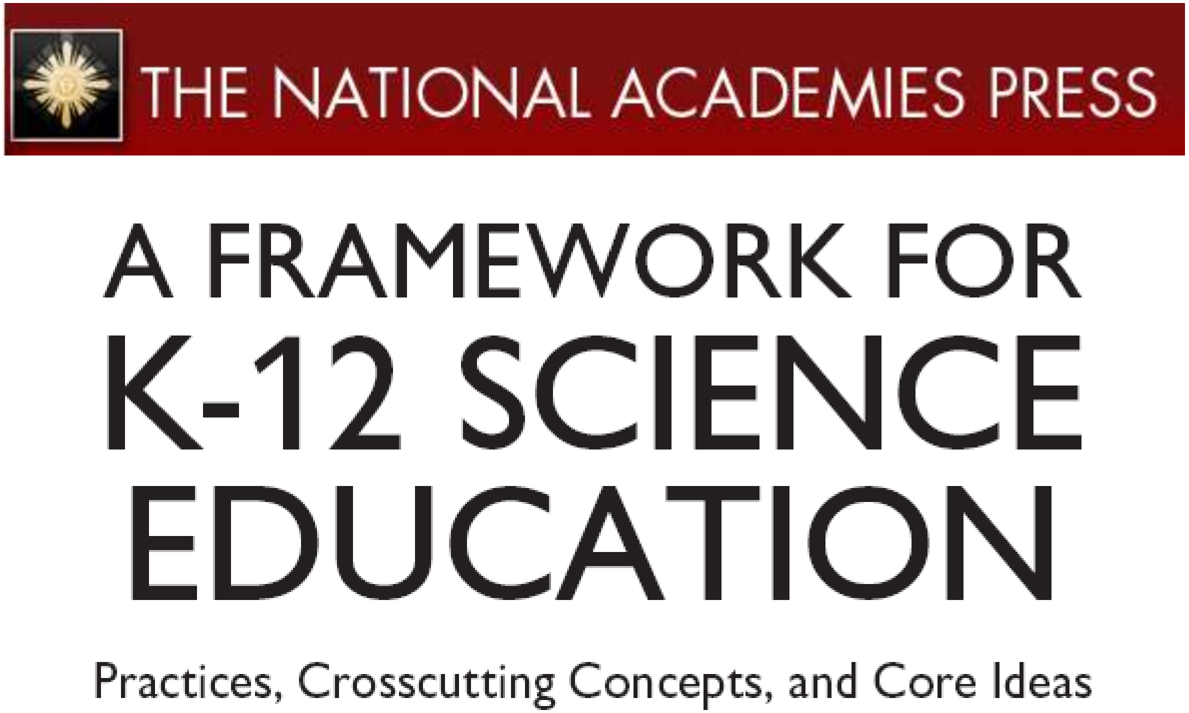


# U.S National Science Standards (Pre-college) Under Development



H. Quinn, Stanford

# Foundation for Standards
# (from US National Academy of Sciences)



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A FRAMEWORK FOR
K-12 SCIENCE
EDUCATION

Practices, Crosscutting Concepts, and Core Ideas

2012

# Three Dimensions of Modern Science Education

+ Disciplinary core ideas

+ Crosscutting concepts

+ Scientific and engineering practices

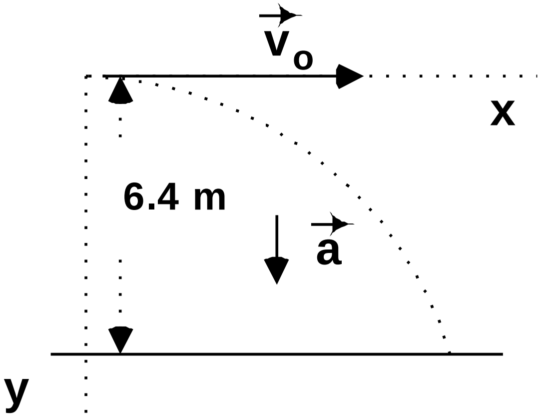
# Scientific and Engineering Practices

1. Asking questions and ***defining problems***
2. ***Developing and using models***
3. Planning and carrying out investigations
4. ***Analyzing and interpreting data***
5. Using mathematics and ***computational thinking***
6. Developing explanations and ***designing solutions***
7. ***Engaging in argument from evidence***
8. Obtaining, ***evaluating***, and communicating information

H. Quinn, Stanford

# Predicting Motion: Traditional Approach

A bullet has a speed of 350 m/sec as it leaves a rifle.
If it is fired horizontally from a cliff 6.4 m above a lake,
how far does the bullet travel before striking the water?



Solution: A 2-dimensional problem with constant acceleration due to gravity (Projectile motion). The origin is placed at the bullet's location at time t=0. Hence the initial conditions for the problem are:

$x(t=0) = x_o = 0$ ; $y(t=0) = y_o = 0$

$v_x(t=0) = v_{ox} = 350$ m/s; $v_y(t=0) = v_{oy} = 0$

For constant gravitational acceleration (downward = + y direction), we have: $a_x = 0$; $a_y = + g = + 9.8$ m/sec$^2$.

The general solutions for the constant acceleration problem in two dimensions are:

$x(t) = (1/2)\, a_x\, t^2 + v_{ox}\, t + x_o$ $\qquad$ $y(t) = (1/2)\, a_y\, t^2 + v_{oy}\, t + y_o$

$v_x(t) = a_x\, t + v_{ox}$ $\qquad$ $v_y(t) = a_y\, t + v_{oy}$

Inserting the values of acceleration and the initial conditions gives us the specific equations.

$x(t) = (350)\, t$ $\qquad$ $y(t) = (1/2)(9.8)\, t^2$

$v_x = 350$ m/s $\qquad$ $v_y(t) = 9.8\, t$

Let t' be the time when the bullet hits the lake. We then know that: $y(t') = + 6.4$ m. Thus:

$y(t') = + 6.4 = + 4.9\, t'^2 \rightarrow t' = 1.143$ sec.

The horizontal (x) position of the bullet at this time is then: $x(t') = (350)(1.143) = 400$ m.

# Predicting Motion: Alternative Approach

Model: Newton's Laws of Motion

Initial Conditions: $\mathbf{t_o}$ , $\mathbf{x_o}$ , $\mathbf{v_o}$
Physical Properties: mass, M
Total Interactions: $\mathbf{F_{net}}$

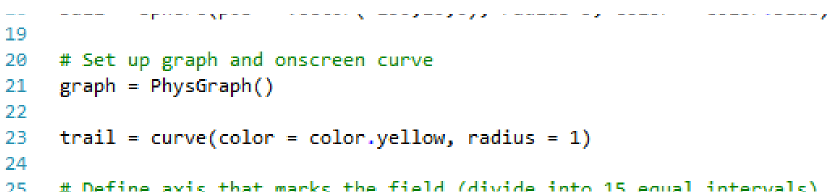
Predict motion
a short time later ($\Delta$t)

$$\mathbf{v_f} = \mathbf{v_0} + (\mathbf{F_{net}}/M)\,\Delta t$$

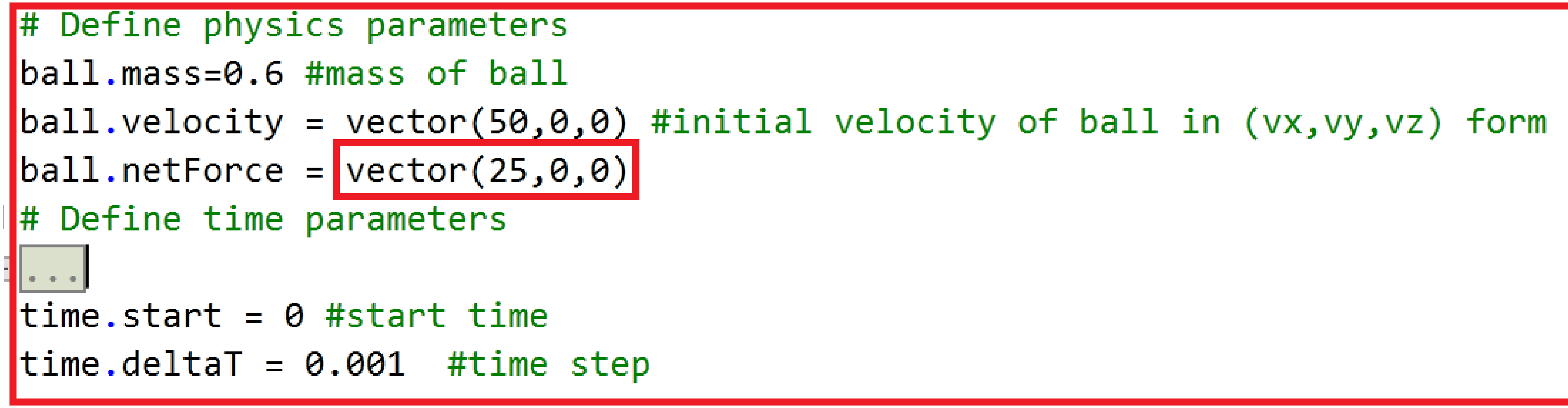
$$\mathbf{x_f} = \mathbf{x_0} + (\mathbf{F_{net}}/M)\,\Delta t$$

Long time motion prediction: Iterate

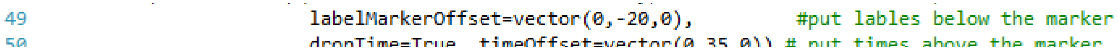
# Motion Prediction with a Computer



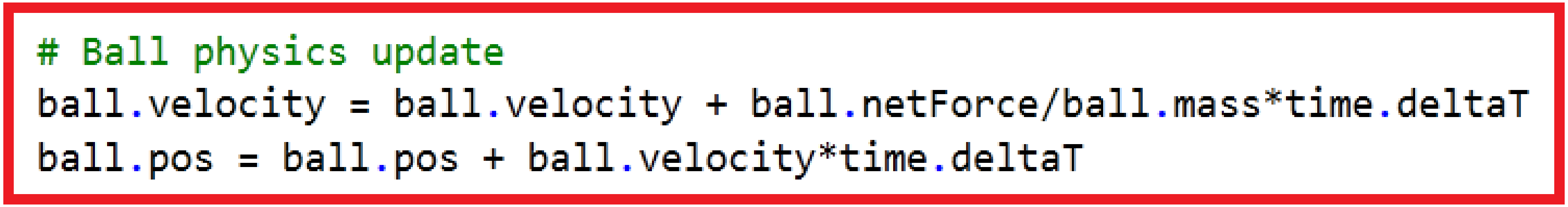
```

# Set up graph and onscreen curve
graph = PhysGraph()

trail = curve(color = color.yellow, radius = 1)

# Define axis that marks the field (divide into 15 equal intervals)
```



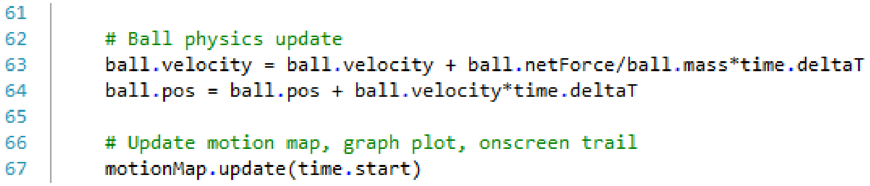
```
# Define physics parameters
ball.mass=0.6 #mass of ball
ball.velocity = vector(50,0,0) #initial velocity of ball in (vx,vy,vz) form
ball.netForce = vector(25,0,0)
# Define time parameters
...
time.start = 0 #start time
time.deltaT = 0.001  #time step
```



```
                labelMarkerOffset=vector(0,-20,0),        #put lables below the marker
                dropTime=True, timeOffset=vector(0,35,0)) # put times above the marker
```



```
# Ball physics update
ball.velocity = ball.velocity + ball.netForce/ball.mass*time.deltaT
ball.pos = ball.pos + ball.velocity*time.deltaT
```



```

    # Ball physics update
    ball.velocity = ball.velocity + ball.netForce/ball.mass*time.deltaT
    ball.pos = ball.pos + ball.velocity*time.deltaT

    # Update motion map, graph plot, onscreen trail
    motionMap.update(time.start)
```

# Integrating Computational Thinking

+ Model-building skills

+ Accessibility

  * Pre-college and introductory students

  * More problems (Angry Birds → Piglantis)

+ Provides new representations, visualizations

# Summary

## Try a Hands-on Approach to Teaching, too!

* Project-Based Learning (Murphy, Goldman)

* Integrated Science (Schoetz)

* Afternoon Sessions: Peer Instruction (Session JJ), Lecture Demonstrations (Session HH), Computational Thinking (Session GG)

…..

# References

* MOOCs:
http://www.nytimes.com/2012/03/05/education/moocs-large-courses-open-to-all-topple-campus-walls.html?pagewanted=all

* Peer Instruction:
http://mazur.harvard.edu/research/detailspage.php?rowid=8

* New Science Standards
http://www.nap.edu/catalog.php?record_id=13165

* Computational Thinking:
http://www.physics.gatech.edu/content/physics-education,
http://vpython.org/

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