Facilitating Students' Transfer of Learning in Physics Problem Solving Using Computer-based Assessment

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Background

Student difficulties in applying their calculus to physics (e.g. Meredith & Marrongelle, 2008; Nguyen & Rebello, 2011)

- Differentiation in kinematics (e.g. Thompson, 1994; Beichner, 1994; Trowbridge & McDermott, 1980)
- Core Concept : Approximation

Average velocity $v_{avg} = \frac{\Delta x}{\Delta t}$ → Instantaneous velocity $v = \frac{dx}{dt}$

Approximation
(Δt is small)

Average acceleration $a_{avg} = \frac{\Delta v}{\Delta t}$ → Instantaneous acceleration $a = \frac{dv}{dt}$

Motivation

- Develop a tutorial to facilitate learning of approximation concept in a kinematics problem.
- Assess if tutorial facilitates transfer of approximation concept to new kinematics problem.

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Overarching Research Question

How does our tutorial compare with textbook problems in facilitating students' transfer of learning to a new problem?

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Theoretical Framework – Transfer

- **S**equestered **P**roblem **S**olving (**SPS**)
  - Assessment: Solve a new task
  - Evidence: Hard to observe
- **P**reparation for **F**uture **L**earning (**PFL**)
  - Assessment: Learning to solve new task
  - Evidence: More visible

Bransford & Schwartz (1999)

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Rephrased Research Questions

How does this tutorial compare with textbook problems in facilitating students to …

- solve transfer task without assistance? (SPS)
- *learn* to solve transfer task with online hints? (PFL)

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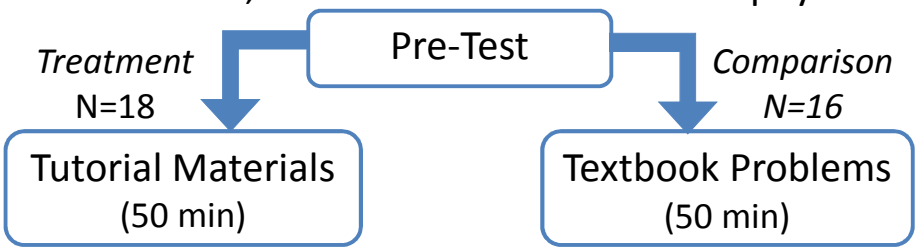
Experimental Design

34 students, 1st semester calculus-based physics



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Tutorial

- Two representations
  - algebraic
  - graphical
- Scaffolding connection of different concepts
  - Slope
  - Rate of change
- Reflection questions

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Example Tutorial Problem

A car is traveling along a straight line, and the position of the car is described in the graph.

a. Draw a straight line which passes through the two points (t=1s and t=2s) on the curve and calculate the slope of this line. Explain what the slope of this straight line means.

b. Now draw a tangent line of the curve at t=1s and calculate the slope of this tangent line. Explain what this slope "means."

c. Now, compare the slopes of the four straight lines. Which two of the slopes are closest to each other? How are the two slopes related to each other?

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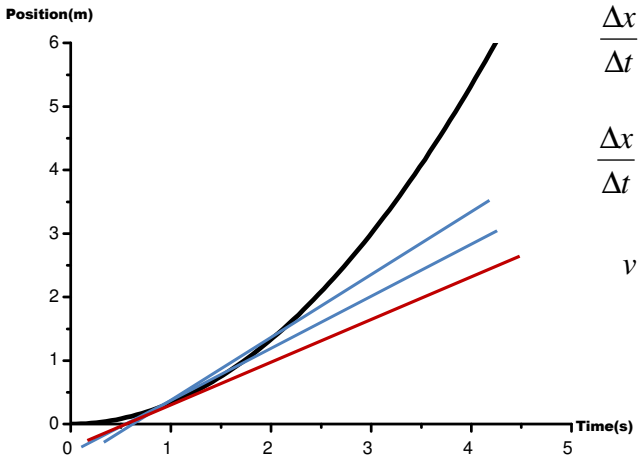
Example Tutorial Problem



$$\frac{\Delta x}{\Delta t} = \frac{x(2) - x(1)}{2s - 1s}$$

$$\frac{\Delta x}{\Delta t} = \frac{x(1.5) - x(1)}{1.5s - 1s}$$

$$v \approx v_{avg} = \frac{\Delta x}{\Delta t}$$

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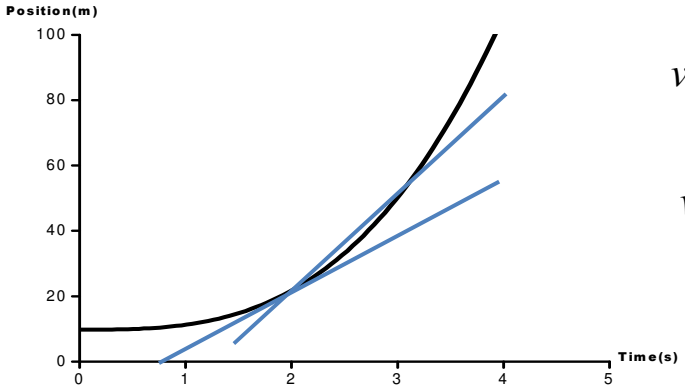
Example Textbook Problem

The position of a particle moving along the x axis is given in meters by $x = 9.75 + 1.50\,t^3$, where t is in seconds. Calculate:

a. The average velocity during the time interval t = 2.00 s to t = 3.00 s.

b. The instantaneous velocity at t = 2.00 s.

c. Graph x versus t and indicate your answers graphically.



$$v_{avg} = \frac{\Delta x}{\Delta t}$$

$$v = \frac{dx}{dt}$$

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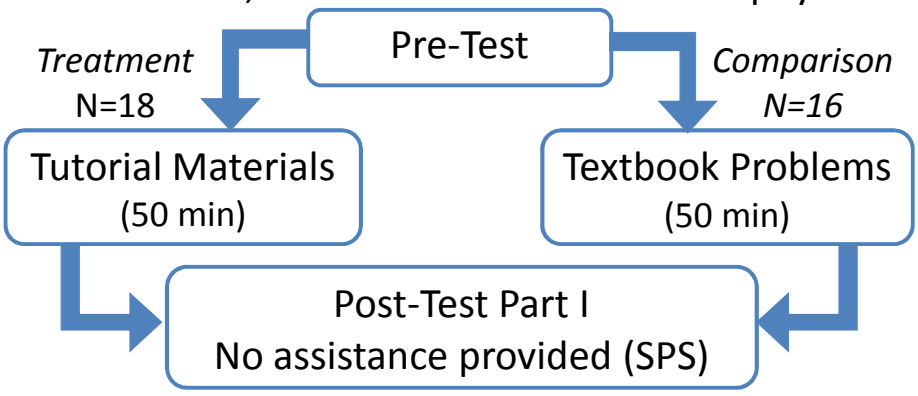

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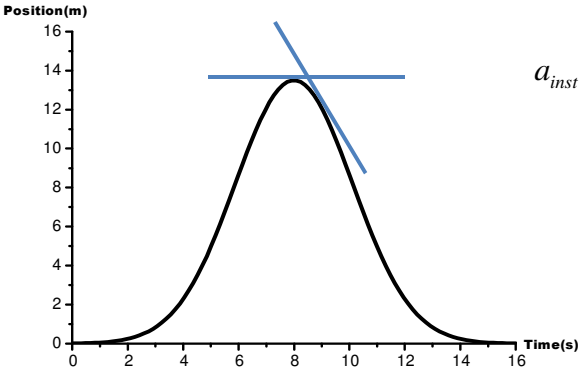
Post-Test Problem

A fish swims back and forth in a straight line. The position of the fish, x(t), in meters, is plotted on the graph. Estimate the acceleration of the fish, in m / s^2, at time t = 8 s.



$$a_{inst} \approx a_{avg} = \frac{\Delta v}{\Delta t}$$

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Data Analysis

Code for whether approximation strategy is

- used
  - Evidence of knowledge of procedure of approximation
- used correctly
  - Evidence of executing procedure correctly

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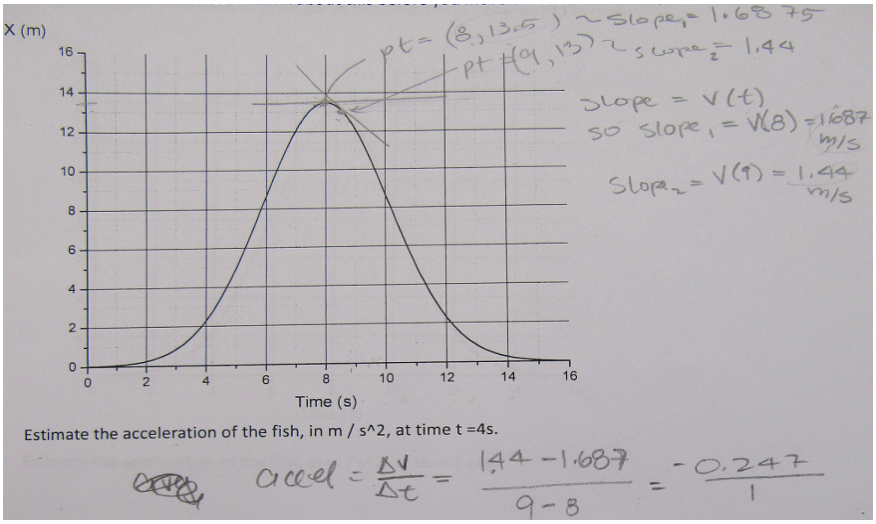
Example Solution
Approximation Used Incorrectly



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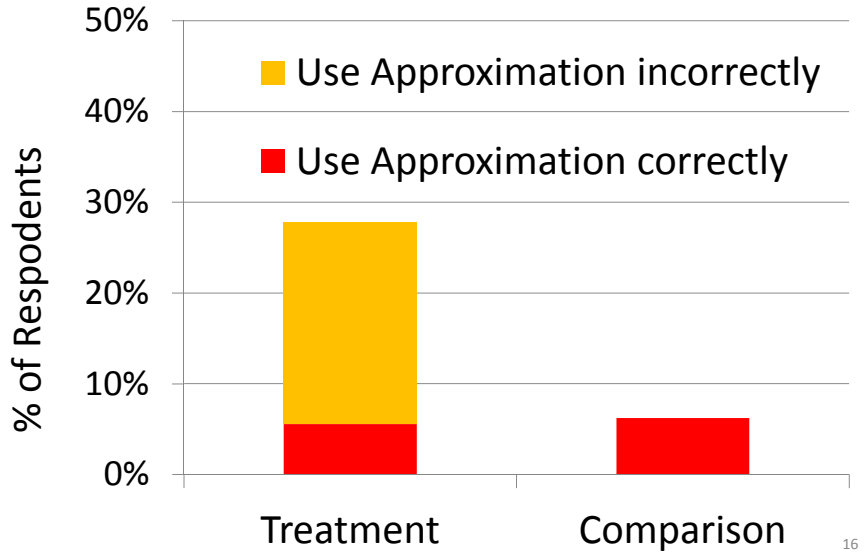
Use Approximation Strategy
Post-Test – Part I (No Hints)



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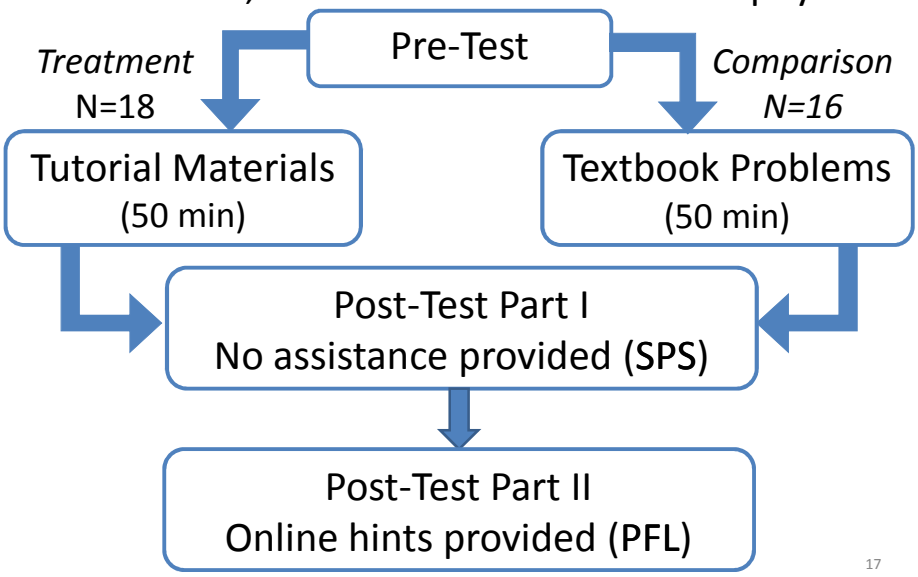

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Online Hints

- Guide students to use approximation
- Recall major concepts associated with approximation introduced in tutorial
- Ordered from
  - General (e.g. use idea of approximation)

    To
  - Specific (e.g. approximate instantaneous acceleration from average acceleration)

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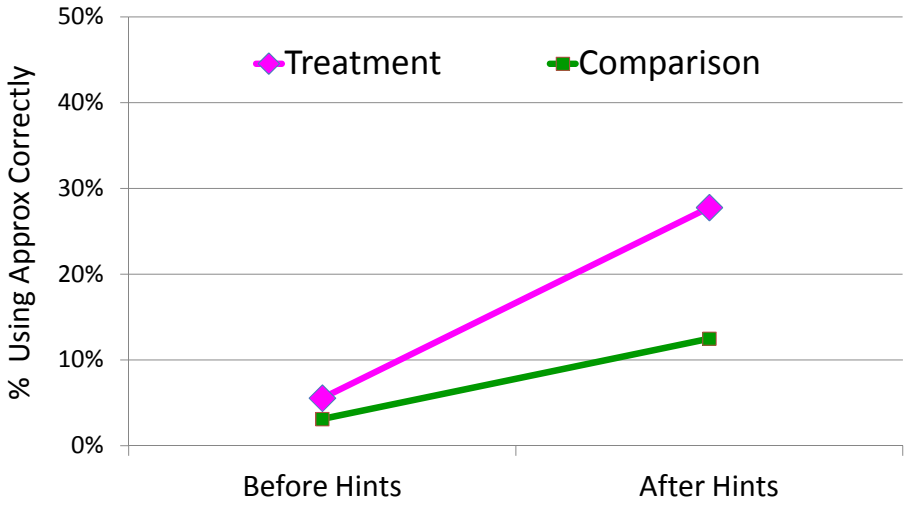
Correct Use of Approximation Strategy

Post-Test I (No Hints) → Post-Test II (With Hints)



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Conclusions

How does our tutorial compare with textbook problems in facilitating students to …

- solve transfer task without assistance? (SPS)
  - Higher proportion of tutorial group than textbook group used approximation strategy on transfer task without hints.
- *learn* to solve transfer task with online hints?(PFL)
  - Higher increase in proportion of treatment group than textbook group using approx strategy correctly with hints.

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Implications

- Using SPS tests to assess impact of classroom interventions may overlook their effectiveness in facilitating future learning.
- PFL perspective may offer a useful paradigm to assess classroom instruction in conjunction with online learning.

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Future Work

- Experiments needed with
  - More physics topics
  - Larger student population
- Generation of online hints
  - Student-controlled adaptive hints

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Thank you !

For further information

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