Grand Rapids – abstract from Summer 2020

Interactive video-enhanced tutorials (IVETs) involve web-based activities which lead students through a solution using expert-like problem-solving approaches, such as those needed for solving problems involving conservation of energy or linear momentum. Under NSF funding we have been developing and evaluating multiple IVETs for use with college students in introductory physics. This presentation will showcase our research methods and the impact of various IVETs on student problem-solving abilities.

*Work supported by the NSF IUSE Program (DUE #1821396)

Special Request: Put this talk immediately after Alex Maries' contributed talk.

Interactive Video-Enhanced Tutorials: Impact on Student Problem-Solving Abilities

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NSF IUSE DUE 1821396 and 1821391

This presentation is the second part of what was to be two back-to-back talks.

Part I:

“Interactive Video-Enhanced Tutorials: Design to support effective problem-solving strategies” by Alexandru Maries showcases one of the IVETs and its **various design features**.

Where do your students go for help with homework?

When stuck on homework problems, which **ONE** did you use most?

	Spring 2019
Google (ex. Chegg.com)	47%
Other students	23%
Khan or other online videos	15%
Textbook	8%
Physics Learning Center	2%
Office hours	1%
Supplemental Instruction Sessions	1%
Didn't seek help or other	3%

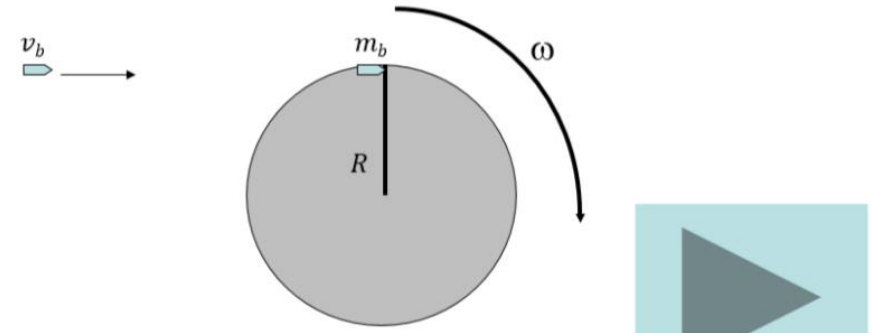
85% of students

See low correlation between student HW scores and exam scores.

Problem Solving Tutorials – Univ of Pittsburgh

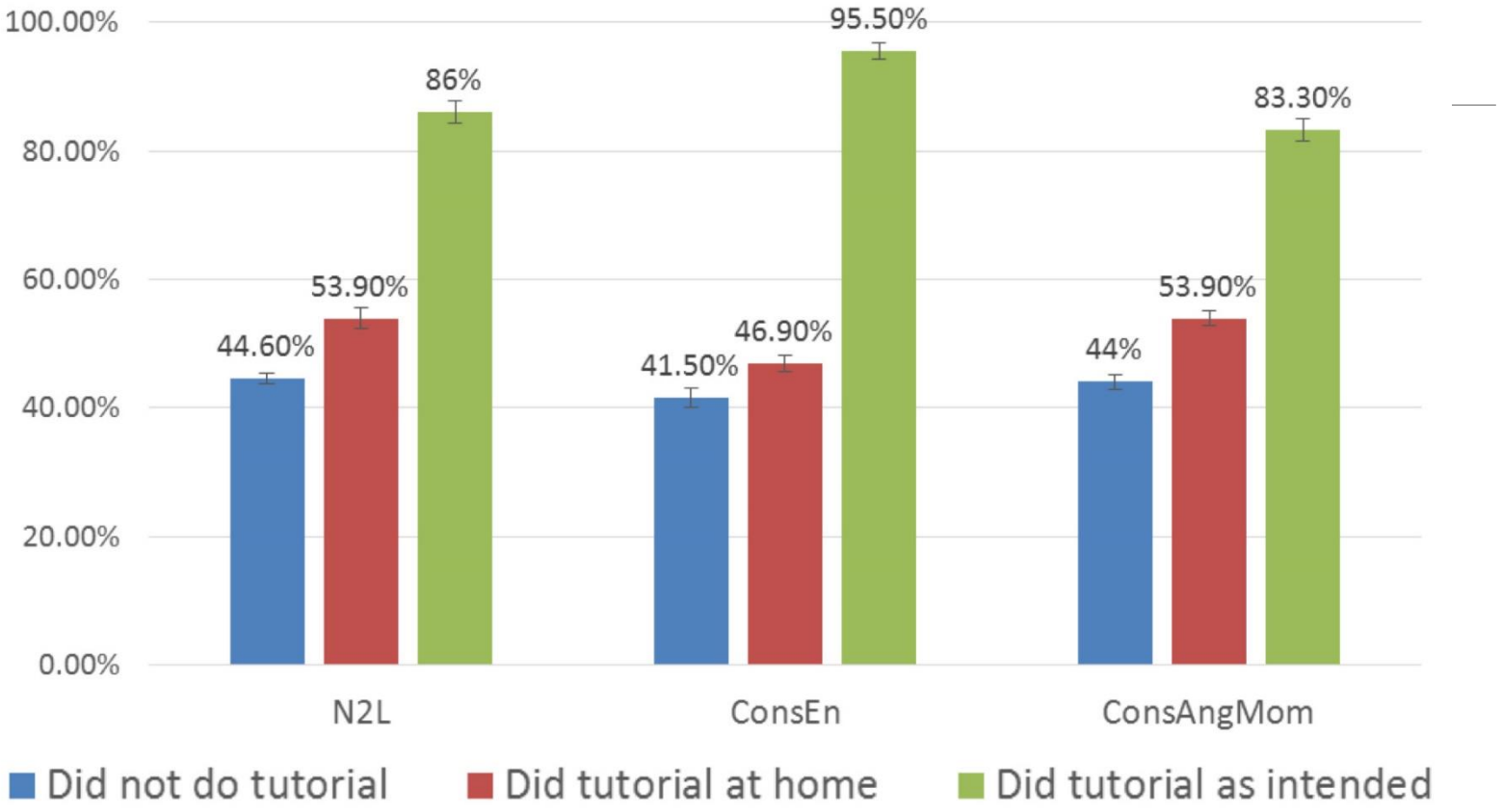
DeVore and Singh developed ~20 tutorials introductory physics.

A large wooden wheel of radius R and moment of inertia I_w about it's axis of symmetry is mounted on an axle so as to rotate freely. A bullet of mass m_b and speed v_b is shot and moves in a straight line (neglect gravity) tangential to the wheel and strikes its edge, lodging in it at the rim. If the wheel was originally at rest, what would its angular speed be after the collision between the bullet and the wheel?



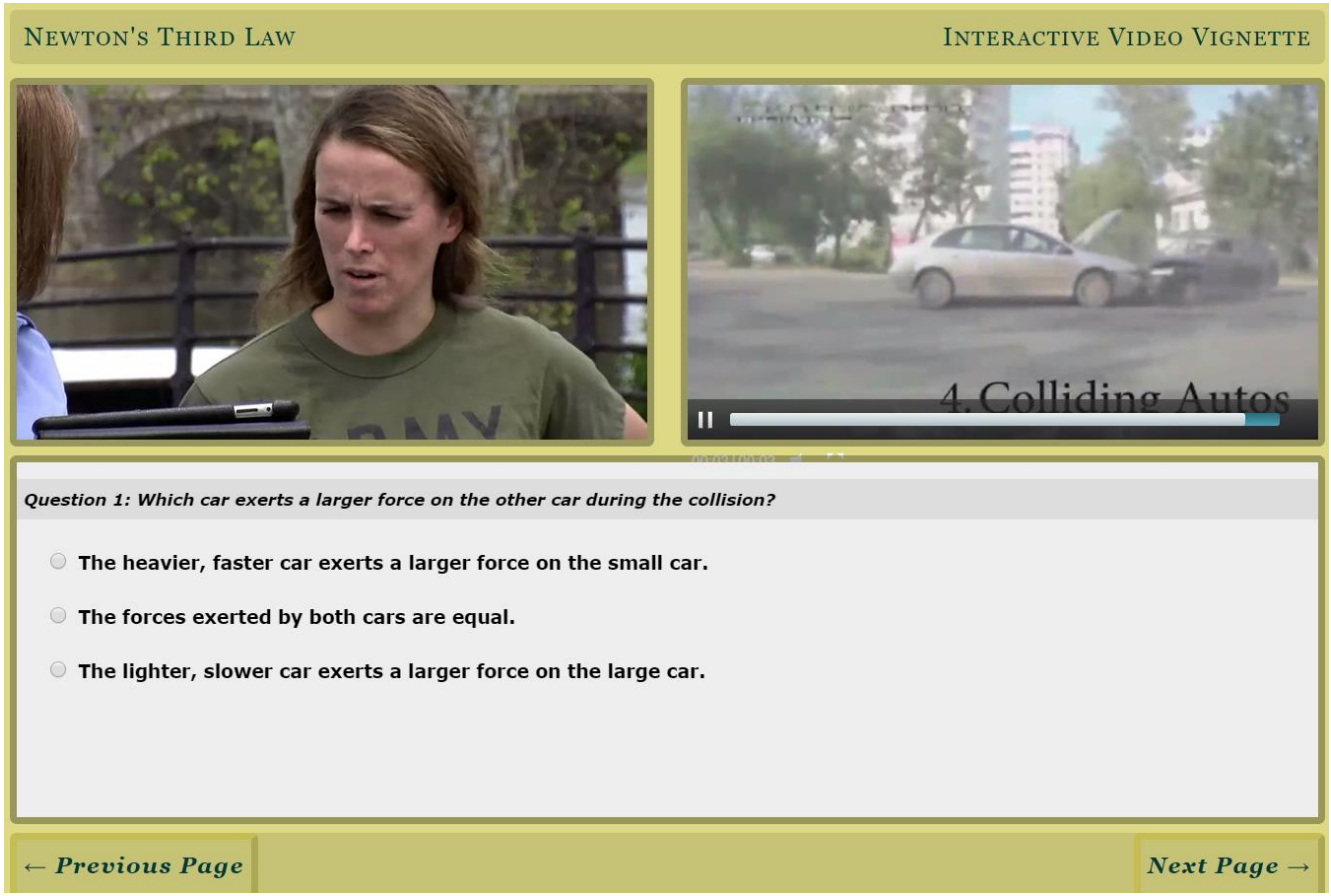
Implemented through Powerpoint and designed to carefully guide students to a solution through the use of branching questions.

Effectiveness of Tutorials



S. DeVore, E. Marshman, and C. Singh, "Challenge of engaging all students via selfpaced interactive electronic learning tutorials for introductory physics," *Phys. Rev. ST Phys. Educ. Res.* **13** 010127, 1-18 (2017).

Interactive Video Vignettes (IVVs)



Designed to teach **concepts** for which students are known to struggle.

www.compadre.org/ivv
or WebAssign (Cengage)

Project Goals

- Create and evaluate a set of 30 IVETs
- Conduct research on
  - impact of IVETs on student problem solving abilities
  - techniques that motivate appropriate student behavior when using IVETs
- Disseminate through ComPADRE, publisher, etc.

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Features of Design of IVETs

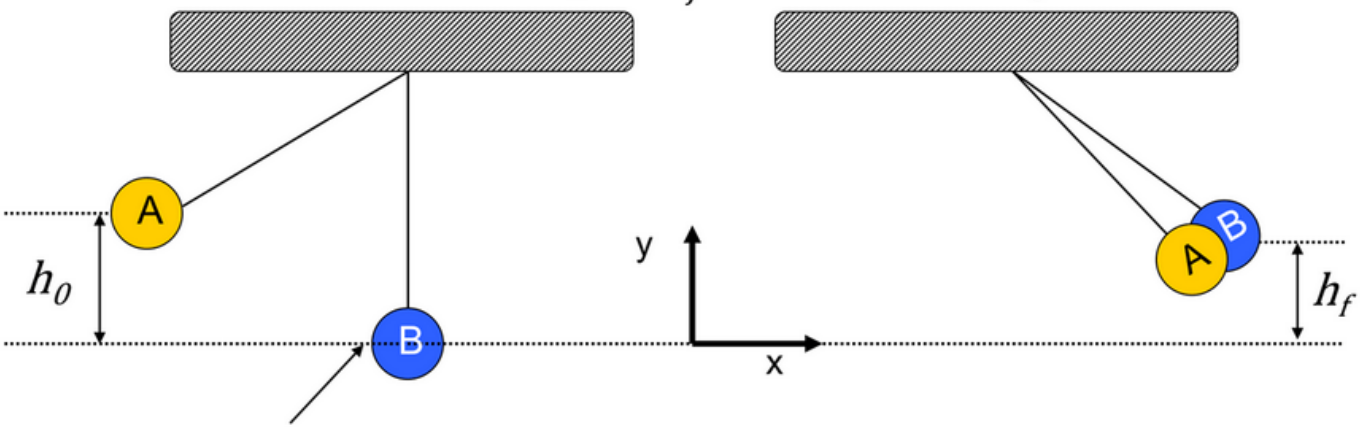
- Developed based on multimedia learning principles (Richard Mayer) and research on human learning and memory (Bransford)
- Mini-lectures, hints, or encouragement (affect) by a tutor (a real person in a video), and multiple-choice questions guide students through an ***effective*** **problem-solving approach** (e.g., define a coordinate system, draw a force diagram, etc.)

For specific details, please see presentation "Interactive Video-Enhanced Tutorials: Design to support effective problem-solving strategies" by Alex Maries

Text option: Page presents problem to be solved.

Two small spheres of putty, A and B, of equal mass m, hang from the ceiling on massless strings of equal length. Sphere A is raised to a height h_0 as shown below and released. It collides with sphere B (which is initially at rest). The two spheres stick and swing together to a maximum height h_f. (Assume a completely inelastic collision with the two spheres sticking together after the collision.)

Find the height h_f in terms of h_0.



Assume that the lowest point in the path is the point of zero gravitational potential energy

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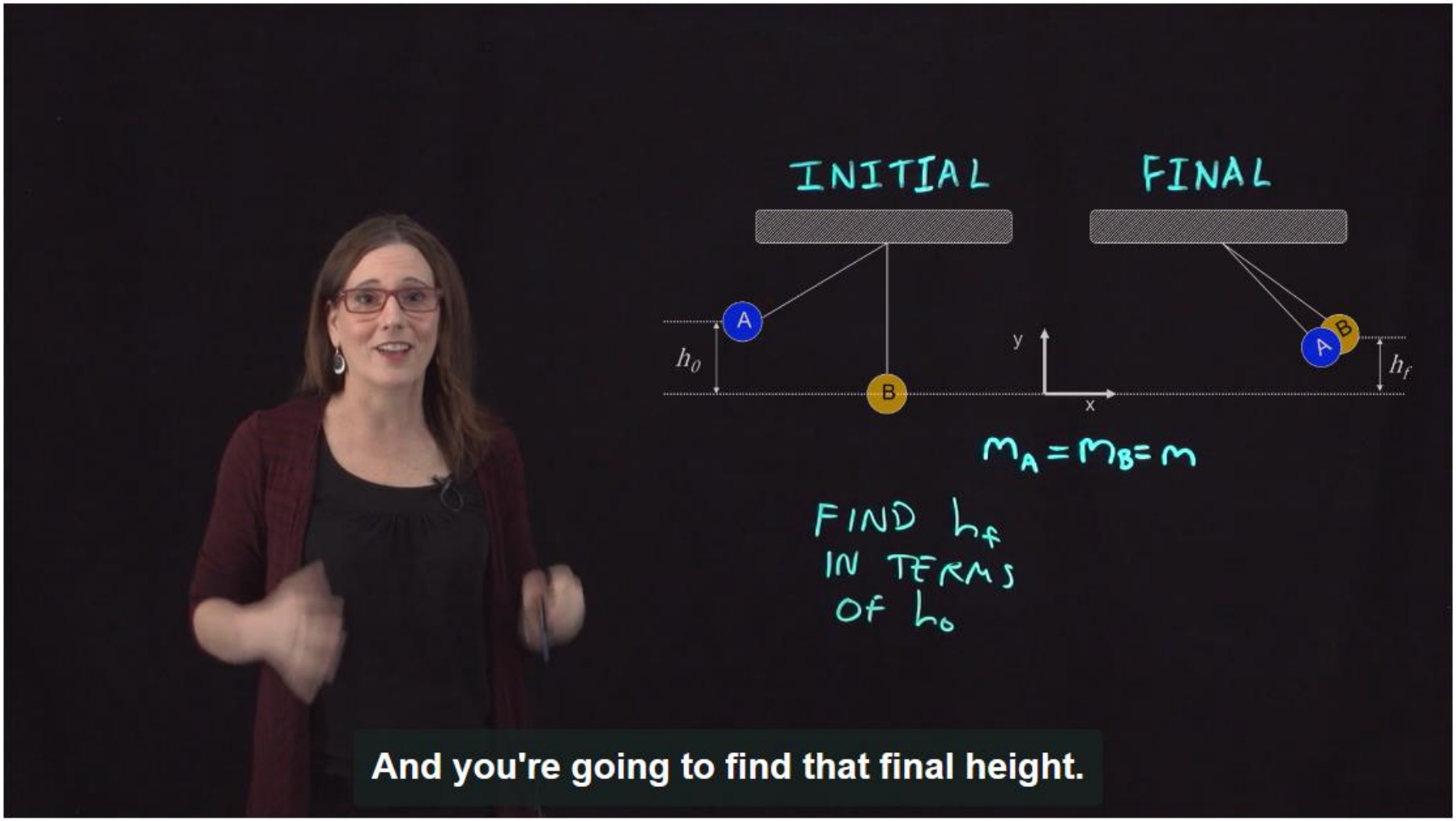
Options
Show Problem Statement
Continue to Next Page →

Video option: Narrator presents problem to be solved.



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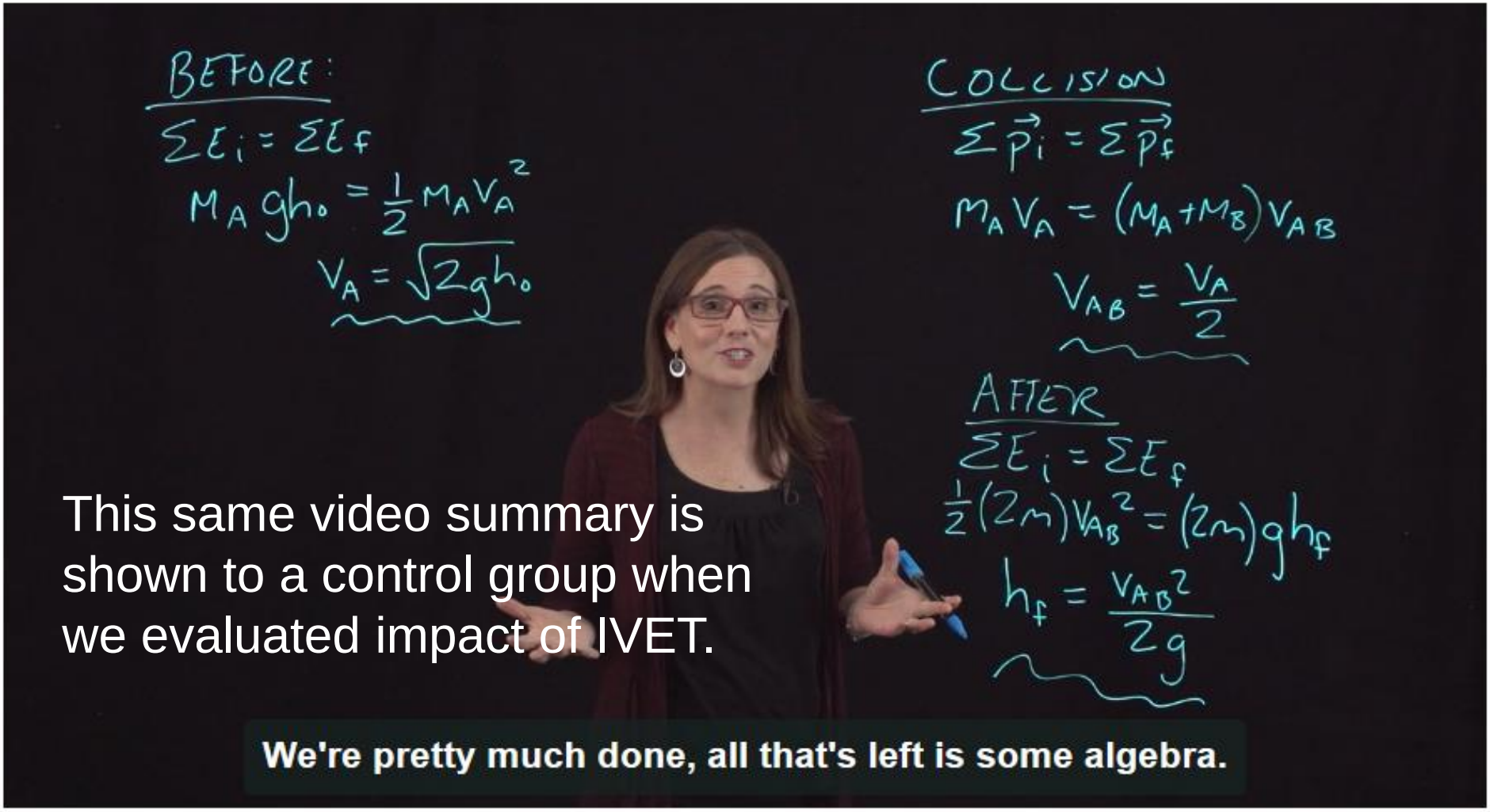
Do you want to see a video summary of what we have done, or would you rather continue with the tutorial?

○Watch a video summary.

○Continue with the tutorial.

Video summary is ~5 minutes long.



This same video summary is shown to a control group when we evaluated impact of IVET.

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Does IVET impact student problem solving ability?

Two sections of algebra-based physics included in study

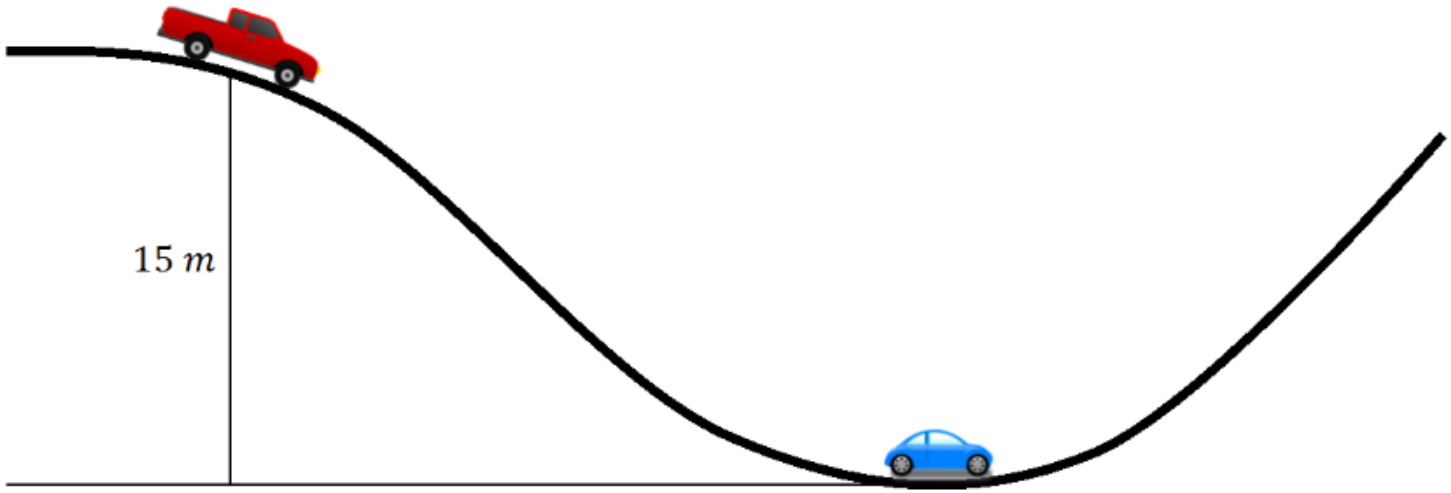
- One section given the Linear Momentum IVET to complete at home
- One section asked to watch the same ~5 minute solution showcased in the IVET

Both groups given a paired problem to complete in class on the day the assignment was due.

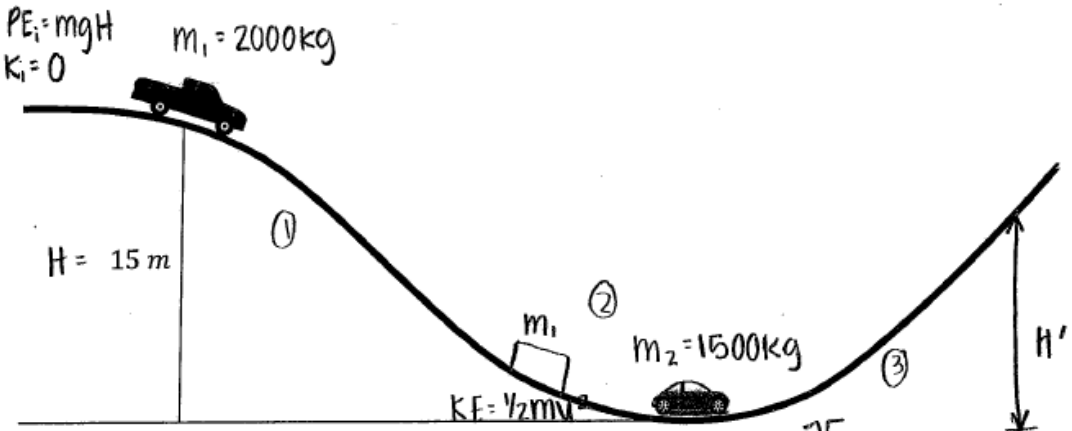
The assignments were flipped between sections when subsequent IVETs were tested.

Assessing Impact: Paired Problem

A 2000 kg truck starts at rest 15 m above the bottom of a hill. It rolls down the hill and at the bottom the truck collides and locks bumpers with (sticks to) a 1500 kg car which is at rest at the bottom of the hill in a completely inelastic collision. The two vehicles then roll together up a second hill. Assuming that both vehicles are in neutral and roll without energy loss due to friction or air resistance, how high up the second hill will the two vehicles travel before stopping?



Correct Solution



+3 ① $PE_i + K_i = PE_f + K_f$

$mgH + 0 = 0 + \frac{1}{2}mv_1^2$

$mgH = \frac{1}{2}mv_1^2$

$v_1 = (2gH)^{1/2}$

+3 ② $m_1v_1 + m_2v_2 = V(m_1+m_2)$

$2000kg(2gH)^{1/2} = V(2000kg + 1500kg)$

$2000(2 \cdot 9.8 \cdot 15)^{1/2} = 3500V$

$34292.856399 = 3500V$

$V = 9.79796\ m/s$

+3 ③ $\frac{1}{2}(m_1+m_2)V^2 = (m_1+m_2)gH'$

$\frac{1}{2}(2000kg+1500kg)(9.798)^2 = (3500kg)(9.8m/s^2)H'$

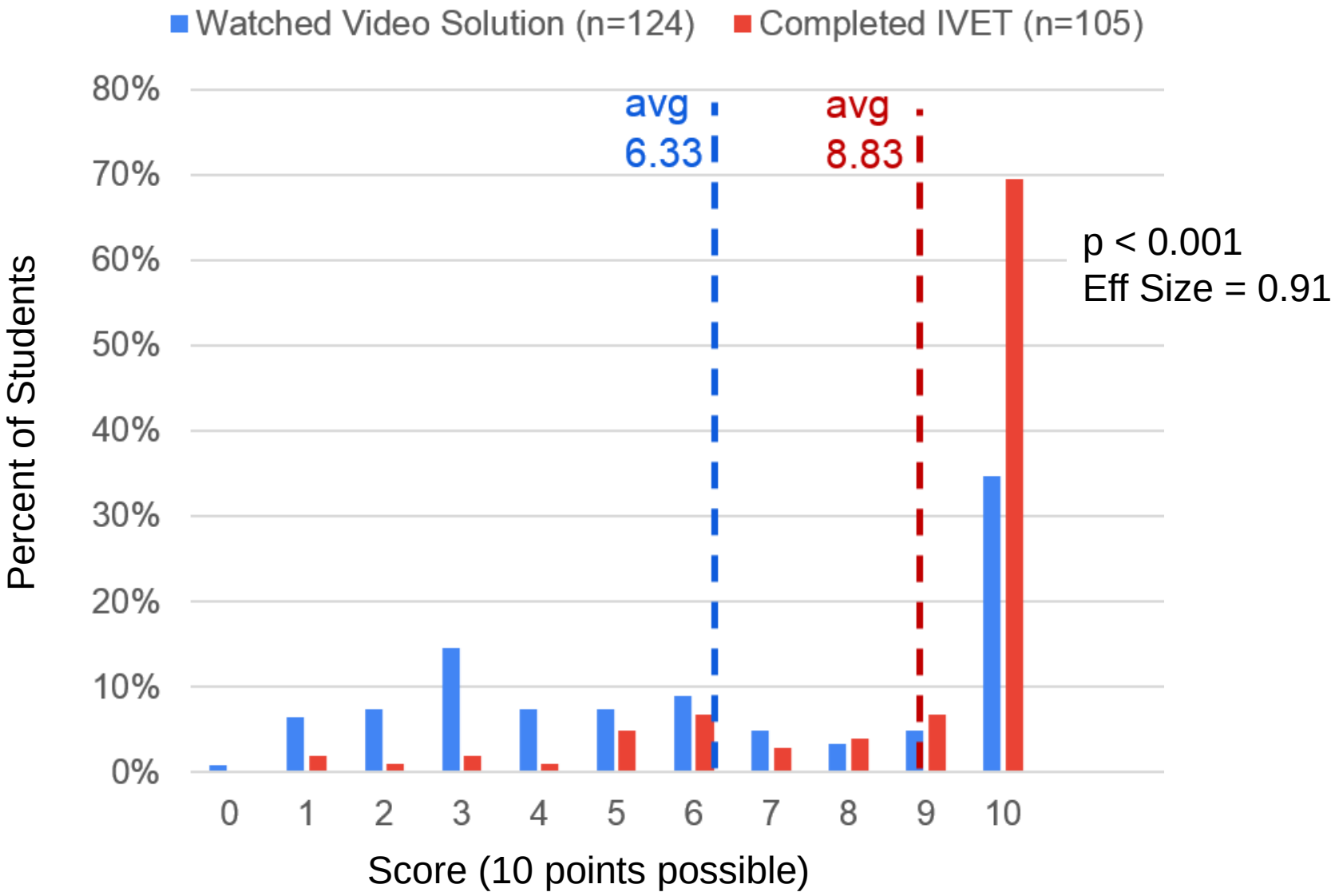
$1750(96.0003) = 34300H'$

$168000.50397 = 34300H'$

$H' = 4.897976\ m$

+1 The 2 vehicles will travel **4.90 m** up the hill before coming to a stop.

Results of Scoring Paired Problem



Range of solutions presented

Video	IVET	Code Description
43%	77%	Correct (includes minor math errors or unit omission)
5%	0%	Correct but conserved KE for collision instead of momentum
8%	11%	"*Correct*" idea, incorrectly transferred from Video/IVET
30%	12%	Used conservation of energy only; one or two steps
4%	0%	Used conservation of momentum only (collision)
5%	0%	Applied incorrect concepts in solution (Work-KE Thm, etc)
6%	1%	Appeared to have no idea

Big take-away from IVET is how to break problem into sub-parts to solve.

Applied Conservation of Energy Only
(one step solution)

$\sum E_i = \sum E_f$ $KE_i, U_{gi}, U_{gf}, W_{ext} =$

$M_c g h_0 + M_t g h_0 = (M_t + M_c) \cdot g h_f$

$(1500)(9.8)(0) + (2000)(9.8)(15) = (2000 + 1500) \cdot (9.8) \cdot h_f$

$294000 = 34300 h_f$

$\boxed{h_f = 8.57\ m}$

18% Video
4% IVET

A few students indicated momentum was conserved but didn't include idea in solution

Applied Conservation of Energy Only (two step solution)

① $U_g = KE_f$

$m_1 g h_1 = \frac{1}{2}(m_1 + m_2)v^2$

$(2000)(9.8)(15) = \frac{1}{2}(2000 + 1500)v^2$

$v = 12.96 \text{ m/s}$

② $KE_i = U_g$

$\frac{1}{2}(m_1 + m_2)v^2 = (m_1 + m_2)g h_2$

$\frac{1}{2}(2000 + 1500)(12.96)^2 = (2000 + 1500)(9.8)h_2$

$294000 = 34300 h_2$

$h_2 = 8.57 \text{ m}$

12% Video Only

8% IVET

A few of these indicated momentum was conserved but didn't include idea in solution.

Incorrectly transferred ideas from Video/IVET

1 $V_a = \sqrt{2gh_b}$

$V_a = \sqrt{2(9.8)(15)}$

$V_a = 17.15$ m/s

2 $V_{AB} = V_A / 2 = 8.58$ m/s

3 $h_f = \frac{(V_{AB})^2}{2g}$

$h_f = \frac{(8.58)^2}{2(9.8)}$

$h_f = 3.76$ m

Memorized eqns used in video/IVET:

5% Video

6% IVET

Student comments about learning from IVETs

I learned to separate into sections and work on each one, one by one. This allows for a more clear way to set up problems.

I learned how to integrate different formulas together to solve 1 problem.

This activity was extremely easy to follow and I finally followed a physics problem all the way through.

Very good at explaining how to obtain equations. Related concepts to solving the problem.

I really enjoyed the tutorial. Very well made and easy to follow.

Future Work

Characterize how students are navigating the IVETs and how this behavior may influence learning

- Using video vs. text as feedback within IVET
- Time spent completing tutorial; are certain parts skipped?

Identify techniques that motivate appropriate student behavior when using IVETs

- How should they be assigned?
- Should notes taken during tutorial be submitted for a grade?
- What can instructor discuss in class relative to the IVETs to improve learning?

We have developed and evaluated IVETs involving:

- Newton's 2nd Law (force on two blocks)
- Static Equilibrium (person on ladder leaning against wall)
- Conservation of Energy (will string break on tire swing?)
- Linear Momentum and Energy (pendulum balls collide)
- Angular Momentum (bullet shot into wheel)
- Torque and Rotation

Under development:

- Projectile Motion ("monkey gun" demonstration)
- Conservation of Energy (use of energy bar charts)
- Adding vectors
- Circular motion
- Fluid mechanics
- Thermal energy transfer
- Thermal processes and laws of thermodynamics

Goal is to have at least one IVET for each chapter in both semesters of introductory physics.

Thank you!

If you are interested in seeing or using the tutorials we have, please email me!

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