Effective Practices in Educational Technology
(Sponsored by Committee on Educational Technologies)

As a result of being forced to learn effective modes of delivery for virtually engaging students, the physics teaching community has undoubtedly experienced some revelations regarding online learning. How much of this stuff is actually effective and should remain? What of this virtual approach is accursed and should never be considered again? This session looks to begin to address which virtual experiences should be become commonplace as we move back, or at least plan to move back, to being in the same room with our beloved students.

Virtual 2021 Summer Abstract

Video versus Interactive Video for Impact on Learning

With the rise of the flipped (active) classroom, in addition to more courses moving online, the use of video as a form of instruction has increased substantially. This raises the question about the impact of this method of delivery on student learning. Under NSF funding, we have developed and evaluated multiple interactive video-enhanced tutorials (IVETs). The IVETs involve web-based activities that lead students through a problem solution using expert-like problem-solving approaches. As part of the IVET evaluation, we assigned one group of students to complete the IVETs as homework, while another group watched a video summary of the problem solving process. Both groups later completed a follow-up problem as a means of measuring impact on learning. Significant learning gains were observed for students in the IVET group compared to the Video-only group. Results from multiple IVETs will be shared along with suggestions for making videos more mentally engaging for students.

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Video versus Interactive Video for Impact on Learning

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Interactive Video Vignettes (IVVs)

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

www.compadre.org/ivv or WebAssign

Interactive Video-Enhanced Tutorials (IVETs)

Torque and Rotation Tutorial 1 **Interactive Video-Enhanced Tutorials**

Q1: Which physics principle(s) should we use to solve this problem? Choose all that apply. If necessary, scroll down to see all four choices.

- A. Newton's 2nd Law for translations: $\sum \vec{F} = m\vec{a}$
- B. Conservation of Mechanical Energy
- C. Conservation of Linear Momentum
- D. Newton's 2nd Law for rotations: $\sum \tau = I\alpha$ where τ is the torque about a chosen point

Show comments by other students

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Designed to teach **problem solving strategies** for specific problem types, such as those involving conservation of energy or Newton's Laws.

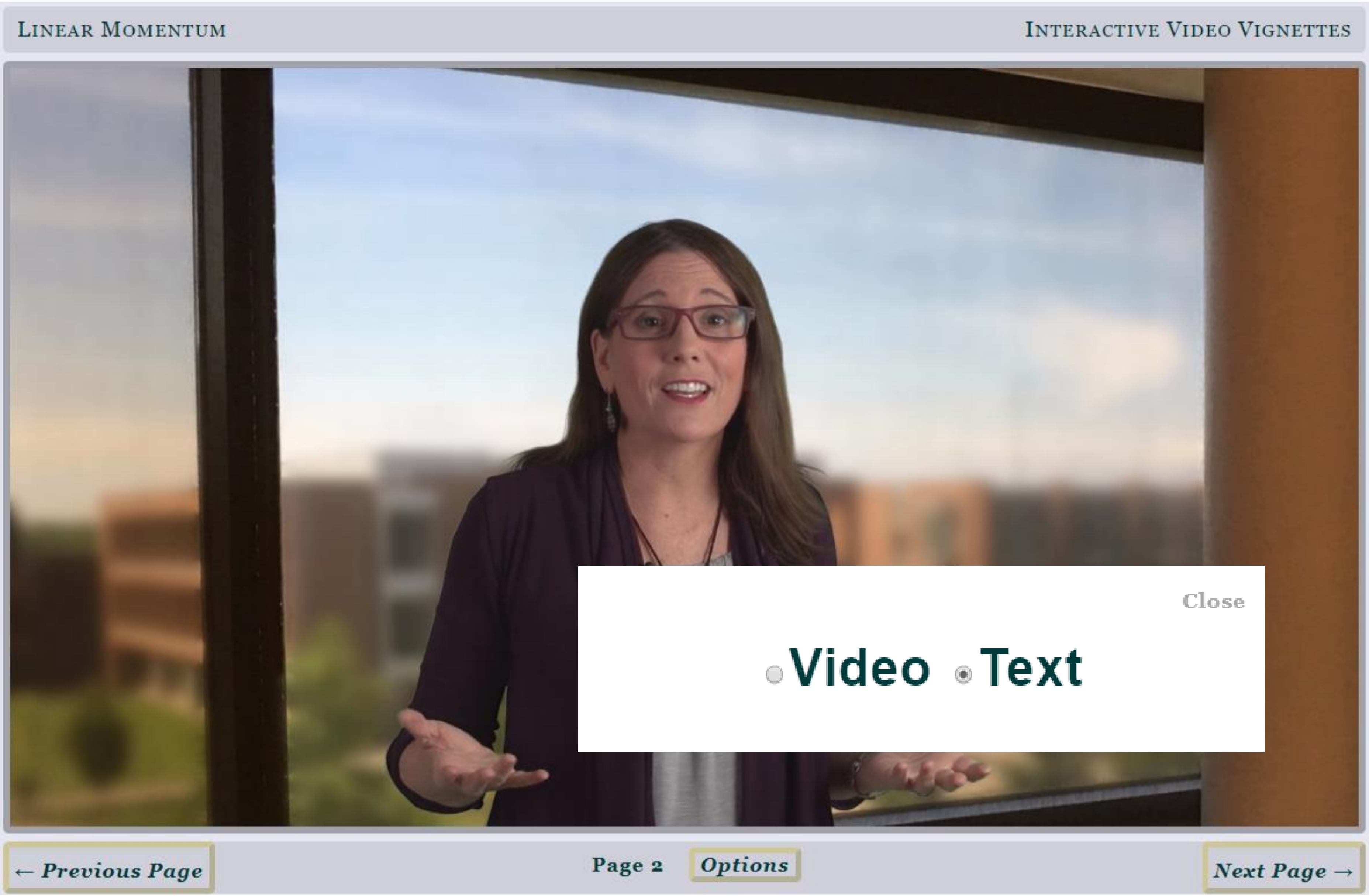
Under NSF funding, the goal is to create and evaluate 30 IVETs and make them available to instructors. https://ivet.rit.edu/IVET

IVETs are based on the work of Singh & DeVore (Univ of Pittsburgh).

Features of Design of IVETs

- Multiple-choice questions and video/text guide students through an ***effective* problem-solving approach** (e.g., define a coordinate system, draw a force diagram, identifying underlying physics principles, etc.)
- Questions branch based on student responses, providing relevant feedback for incorrect (and correct) answers
- Self-paced such that students who need less support can navigate through it quickly and vice versa
- 5-10 minutes to complete

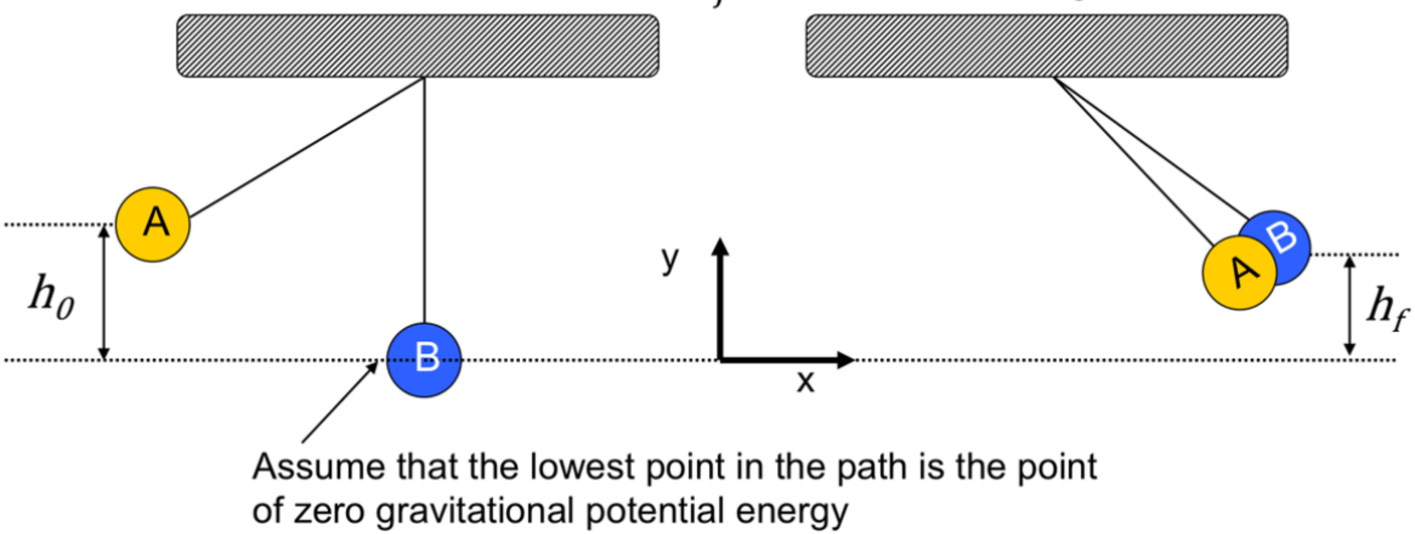
Example IVET – Linear Momentum and Energy



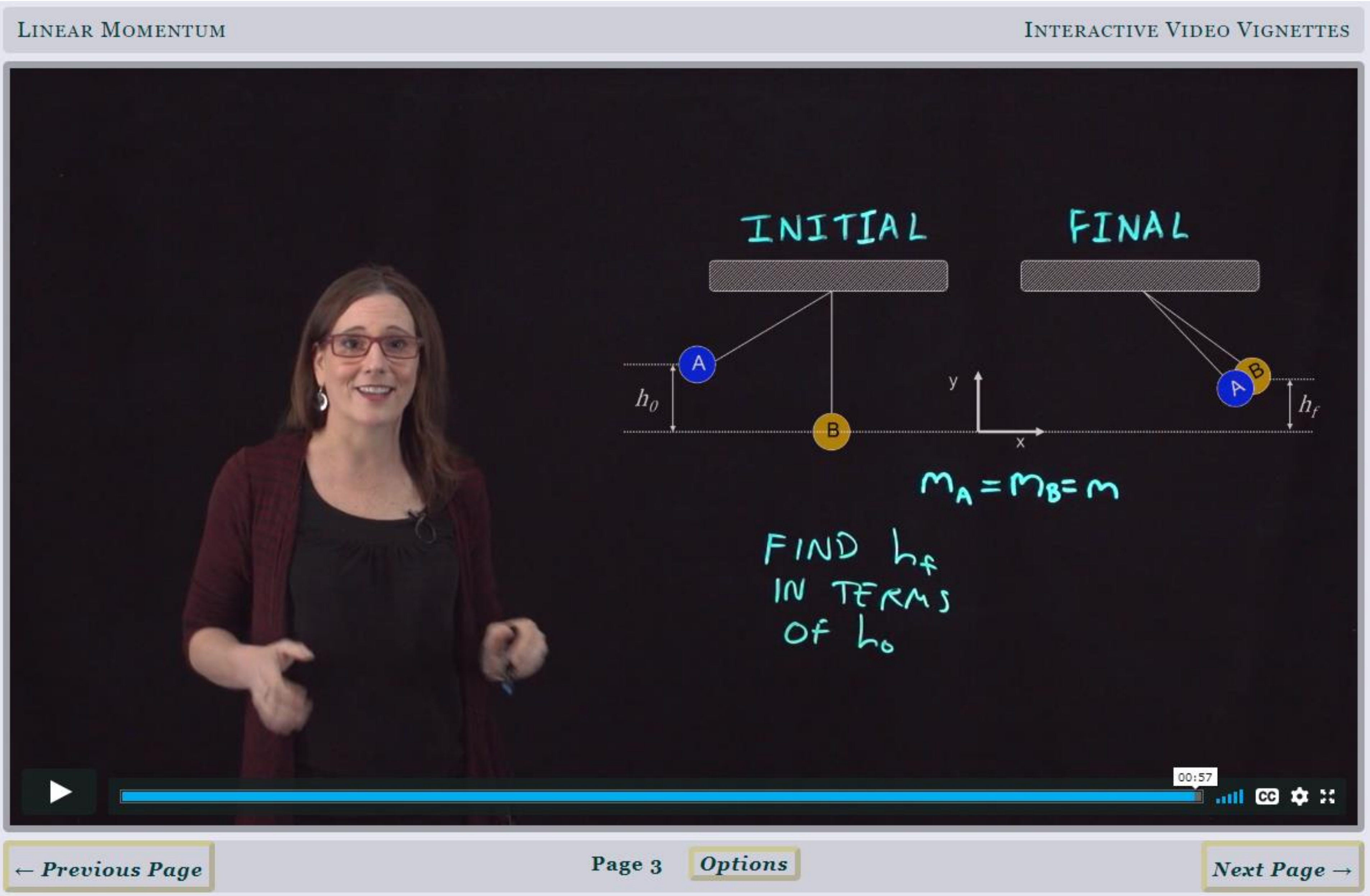
Text option: Page presents problem to be solved.

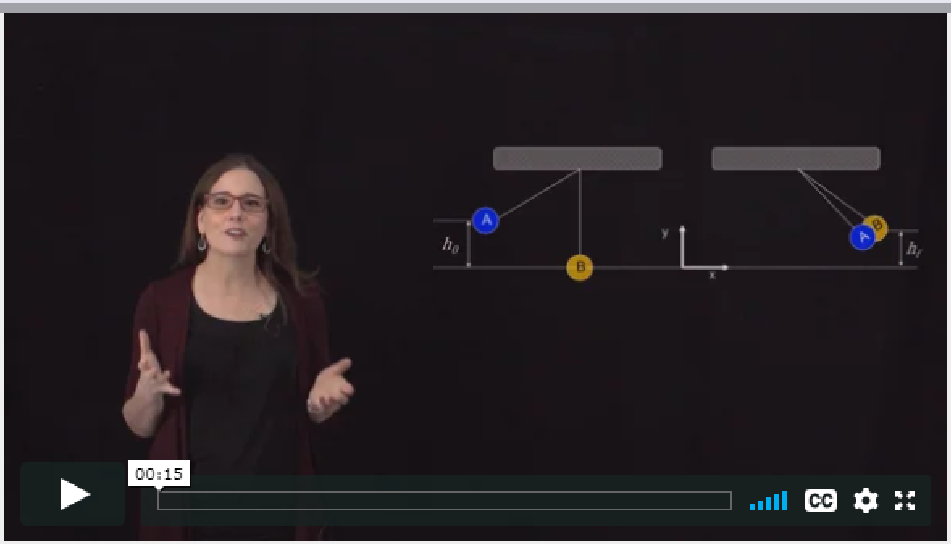
Two small spheres of putty, A and B, of equal mass m, hang from the ceiling on massless strings of equal length. Sphere A is raised to a height h_0 as shown below and released. It collides with sphere B (which is initially at rest). The two spheres stick and swing together to a maximum height h_f. (Assume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

Find the height h_f in terms of h_0.



Video option: Narrator presents problem to be solved.





Q1: Choose *all* of the following physics principles we should use to solve this problem:

- A. Conservation of Total Mechanical Energy
- B. Conservation of Momentum
- C. Newton's 2nd Law

Feedback is provided for all **incorrect** and **correct** responses.

Incorrect. Click the *Next Page* or *Previous Page* button to go back and try again.

Newton's 2

Rememb
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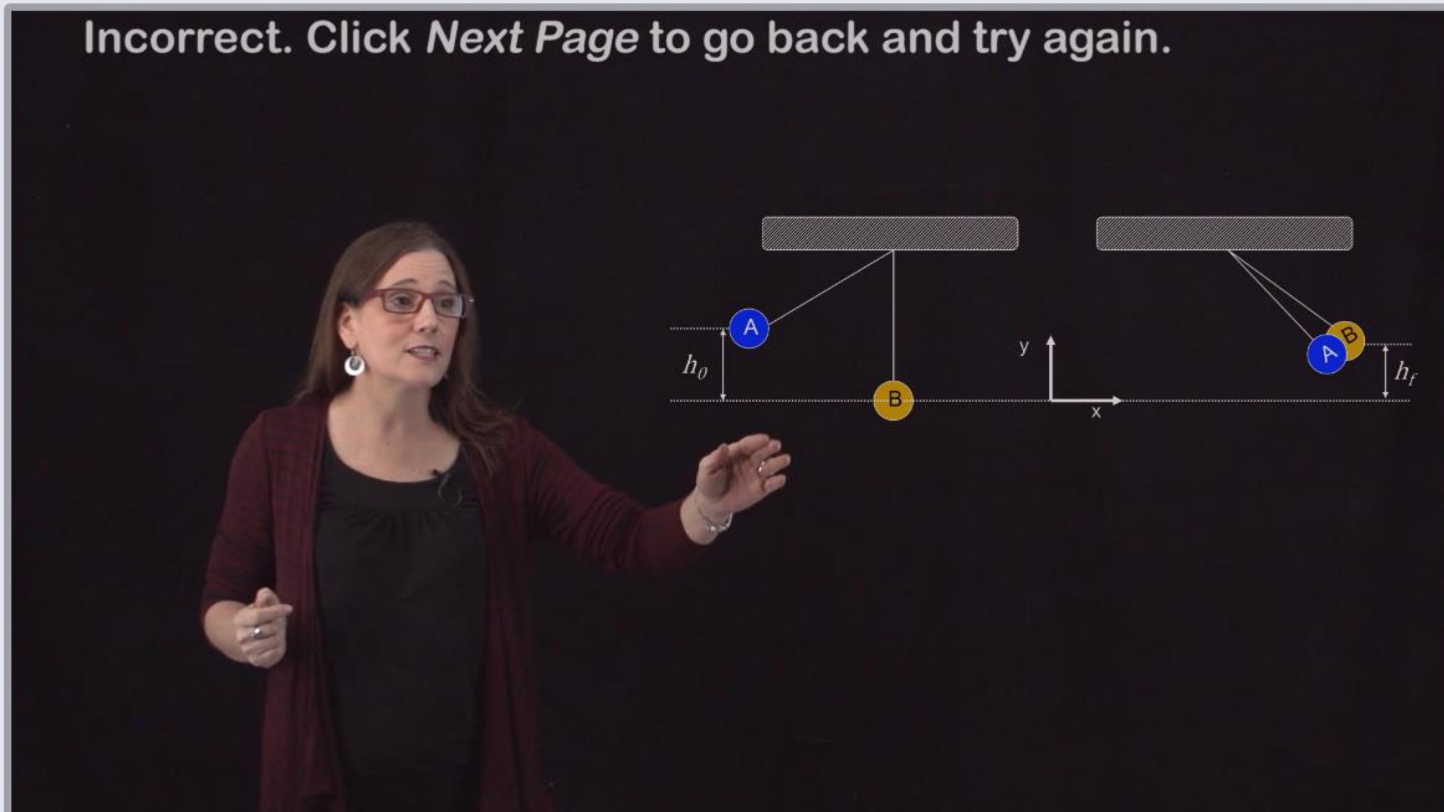
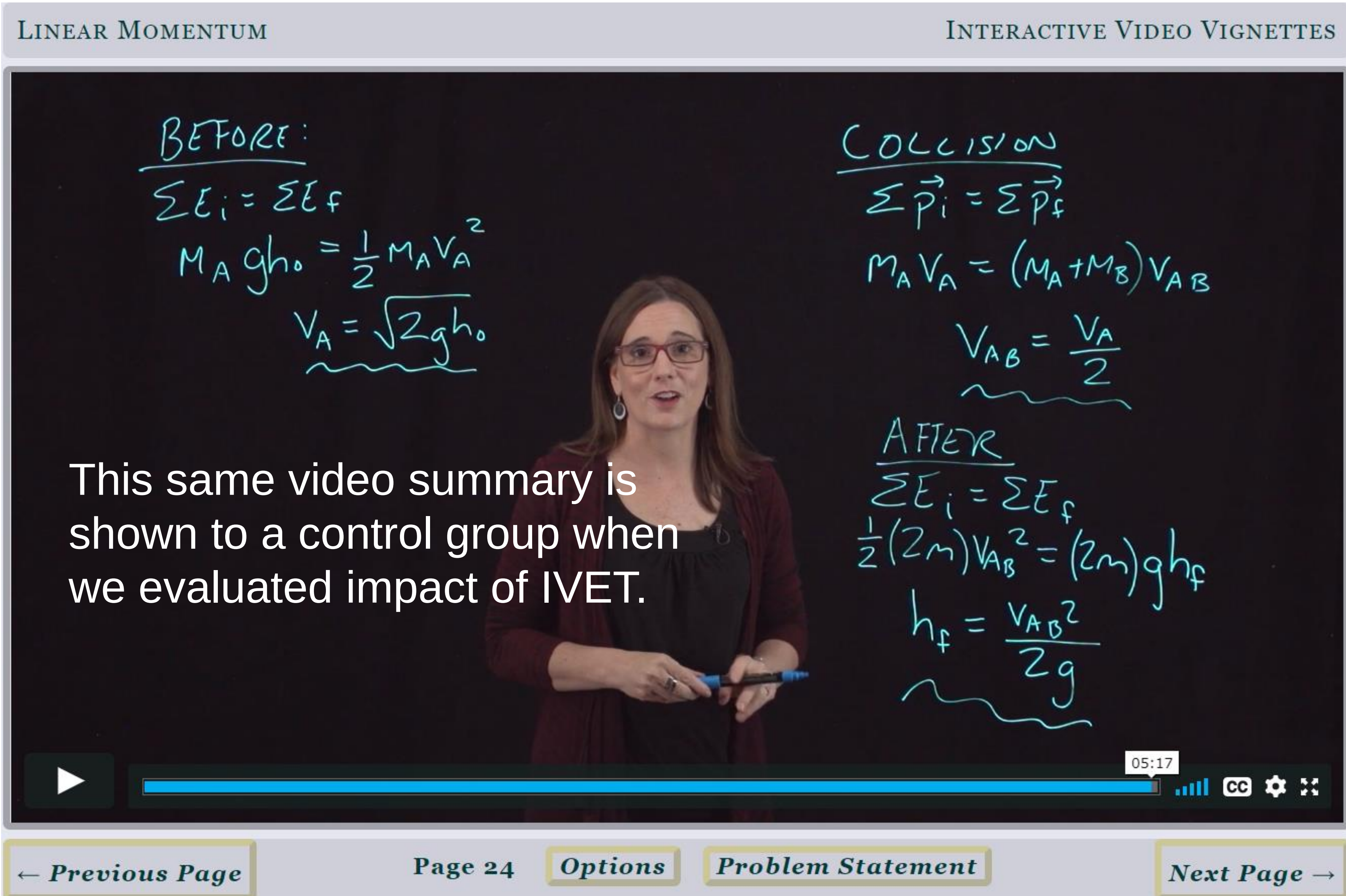
Linear Momentum Interactive Video Vignettes



At end of IVET, students have option to watch a video summary of the solution they have just worked through. Videos are typically 5-8 minutes.



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

What impact does completing an IVET vs watching a video solution have on problem solving abilities?

Context: Large enrollment introductory physics courses

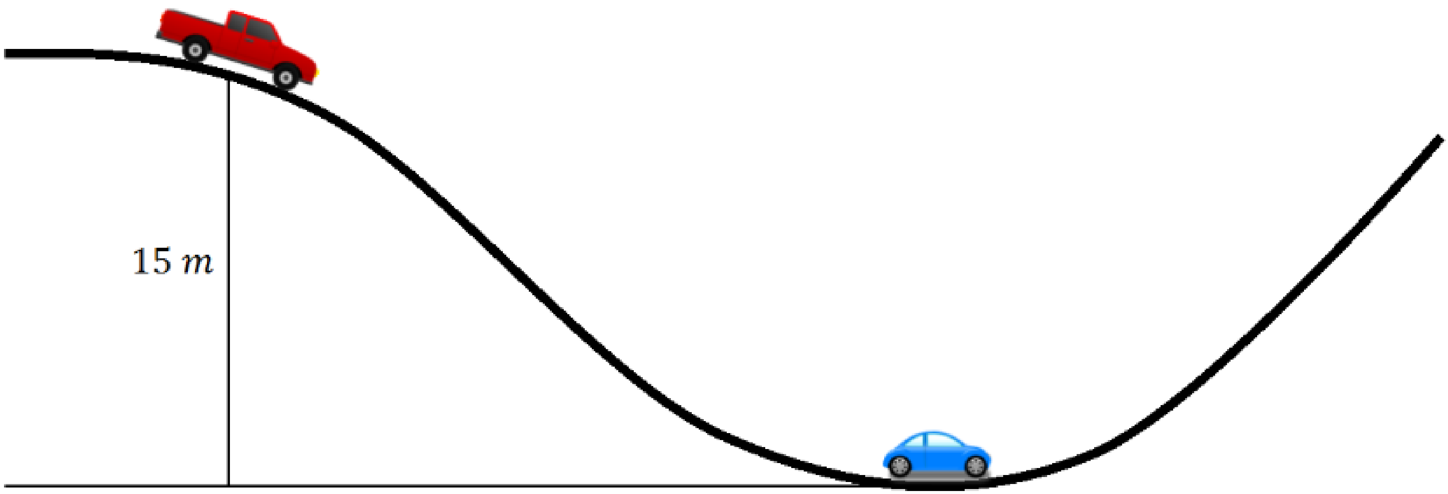
- One section assigned the IVET as homework
- One section assigned to watch the same video summary solution showcased in the IVET

Both groups are then given a follow up problem to complete in class the day the assignment was due.

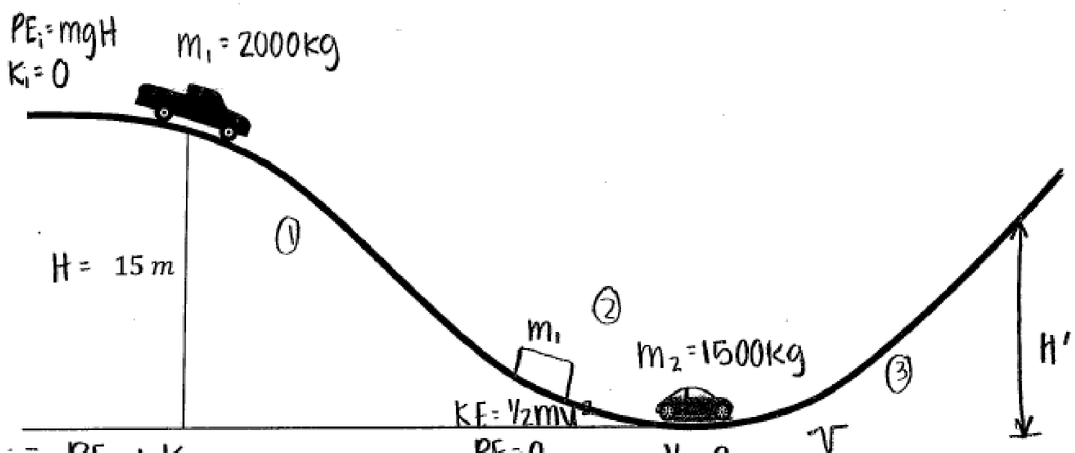
The assignments were flipped between sections during terms when multiple IVETs were evaluated.

Assessing Impact: Follow Up 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

$$PE_i + K_i = PE_f + K_f$$
$$mgH + 0 = 0 + \frac{1}{2}mu_1^2$$
$$\cancel{m}gH = \frac{1}{2}\cancel{m_1}u_1^2$$
$$u_1 = (2gH)^{1/2}$$

+3 ②

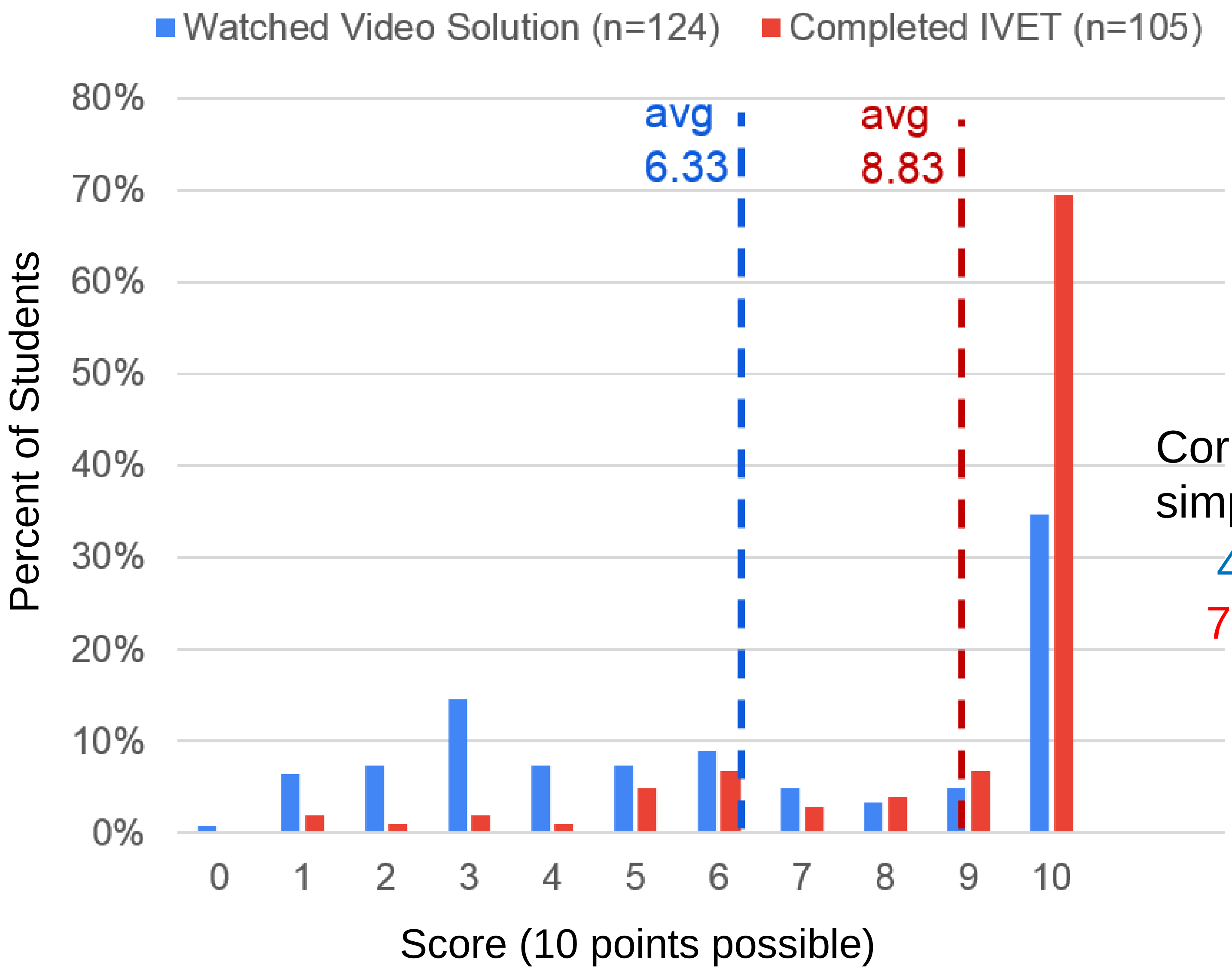
$$m_1u_1 + m_2\cancel{u_2}^{0} = V(m_1 + m_2)$$
$$2000kg(2gH)^{1/2} = V(2000kg + 1500kg)$$
$$2000(2 \cdot 9.8 \cdot 15)^{1/2} = 3500V$$
$$34292.856399 = 3500V$$
$$V = 9.79796\ m/s$$

+4 ③

$$\frac{1}{2}(m_1 + m_2)V^2 = (m_1 + m_2)gH'$$
$$\frac{1}{2}(2000kg + 1500kg)(9.798)^2 = (3500kg)(9.8m/s^2)H'$$
$$1750\ (96.0003) = 34300H'$$
$$168\,000.58397 = 34300H'$$
$$H' = 4.897976\ m$$

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

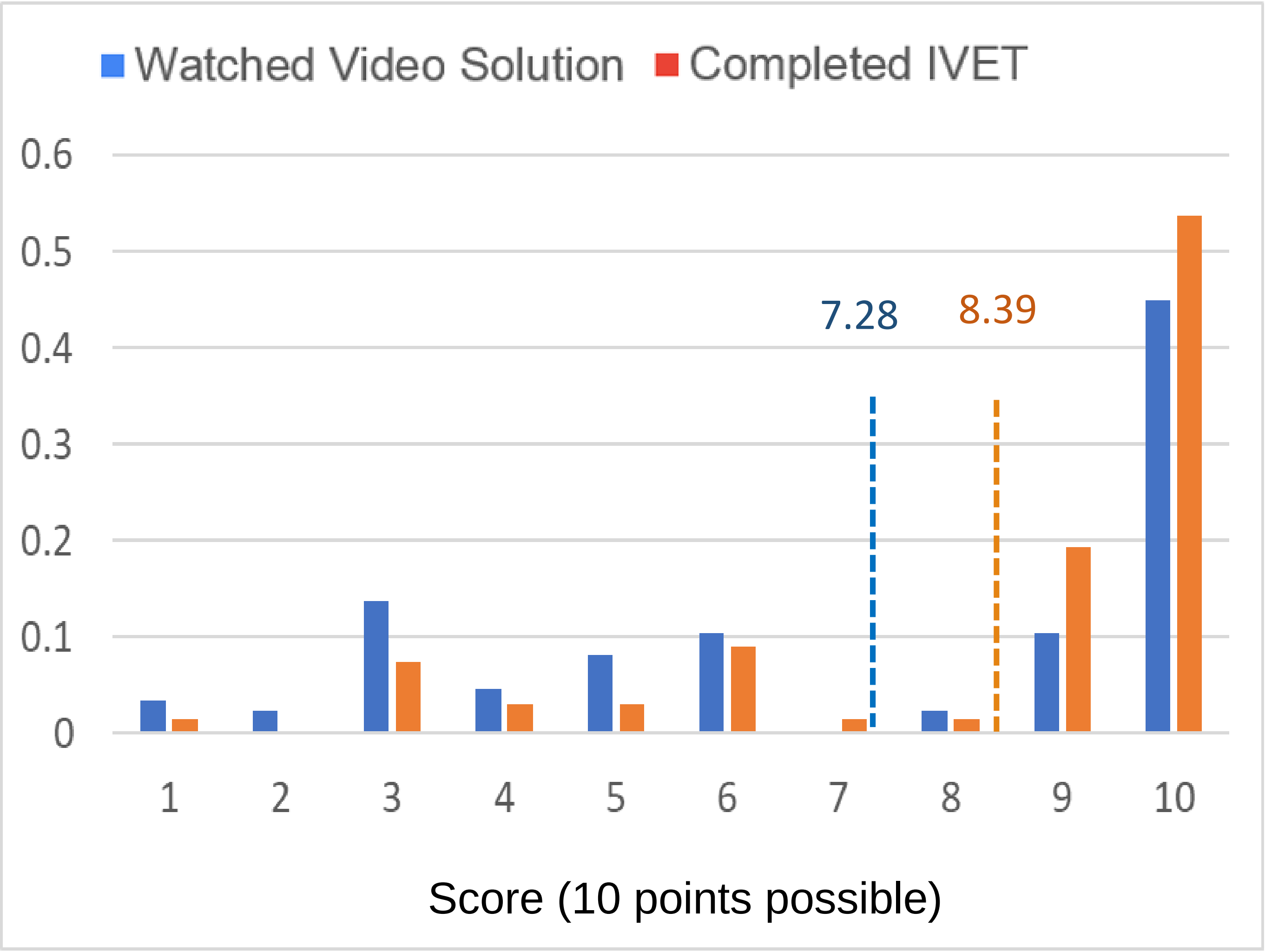
Linear Momentum:
Results of Scoring Follow Up Problem (alg-based)



$p < 0.001$
Eff Size = 0.91

Correct (or with simple math error):
43% (video)
77% (IVET)

Linear Momentum:
Results of Scoring Follow Up Problem (calc-based)



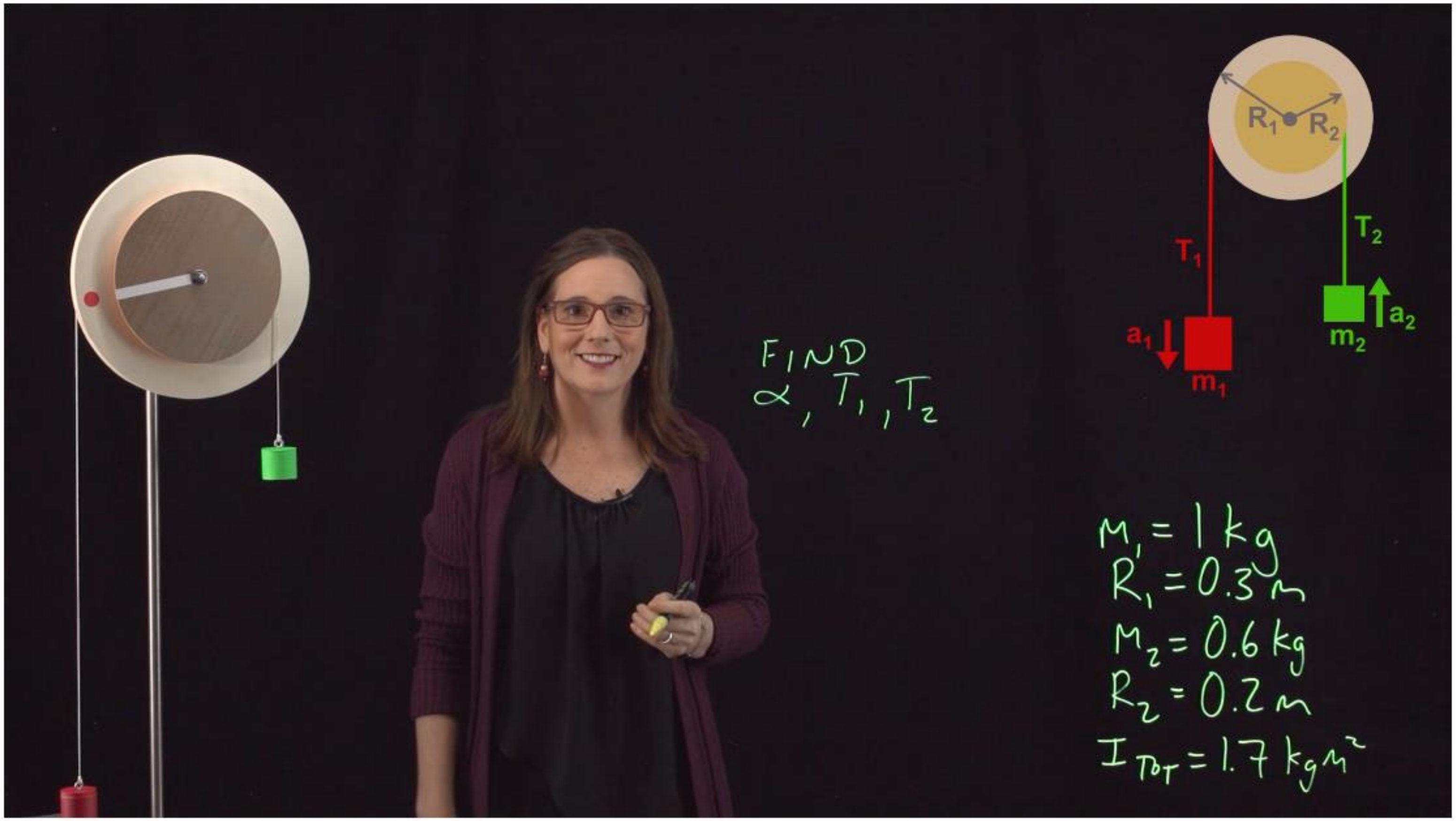
$p = 0.015$
Eff Size = 0.40

Linear Momentum IVET:
Range of solutions presented by students

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
30%	12%	Used conservation of energy only (ignored collision)
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 plan for solving

Torque and Rotation IVET

Torque and Rotation Tutorial 1 | Interactive Video–Enhanced Tutorials



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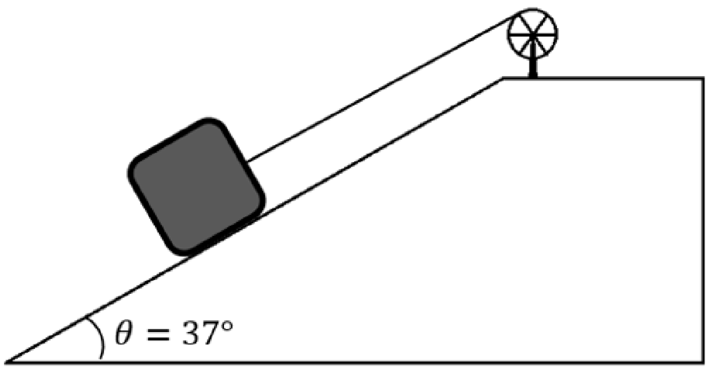
Torque and Rotation Follow Up Problem

A block is connected to a wheel as shown below. The moment of inertia of the wheel is 8.0 kgm^2, and its radius is 40 cm. Find the angular acceleration of the wheel caused by the downward motion of the 10 kg mass. Assume that the incline is frictionless. Also assume that the string wound around the wheel is massless, the wheel turns without friction, and the string unwinds without slipping.



Expectations for Students' Solutions

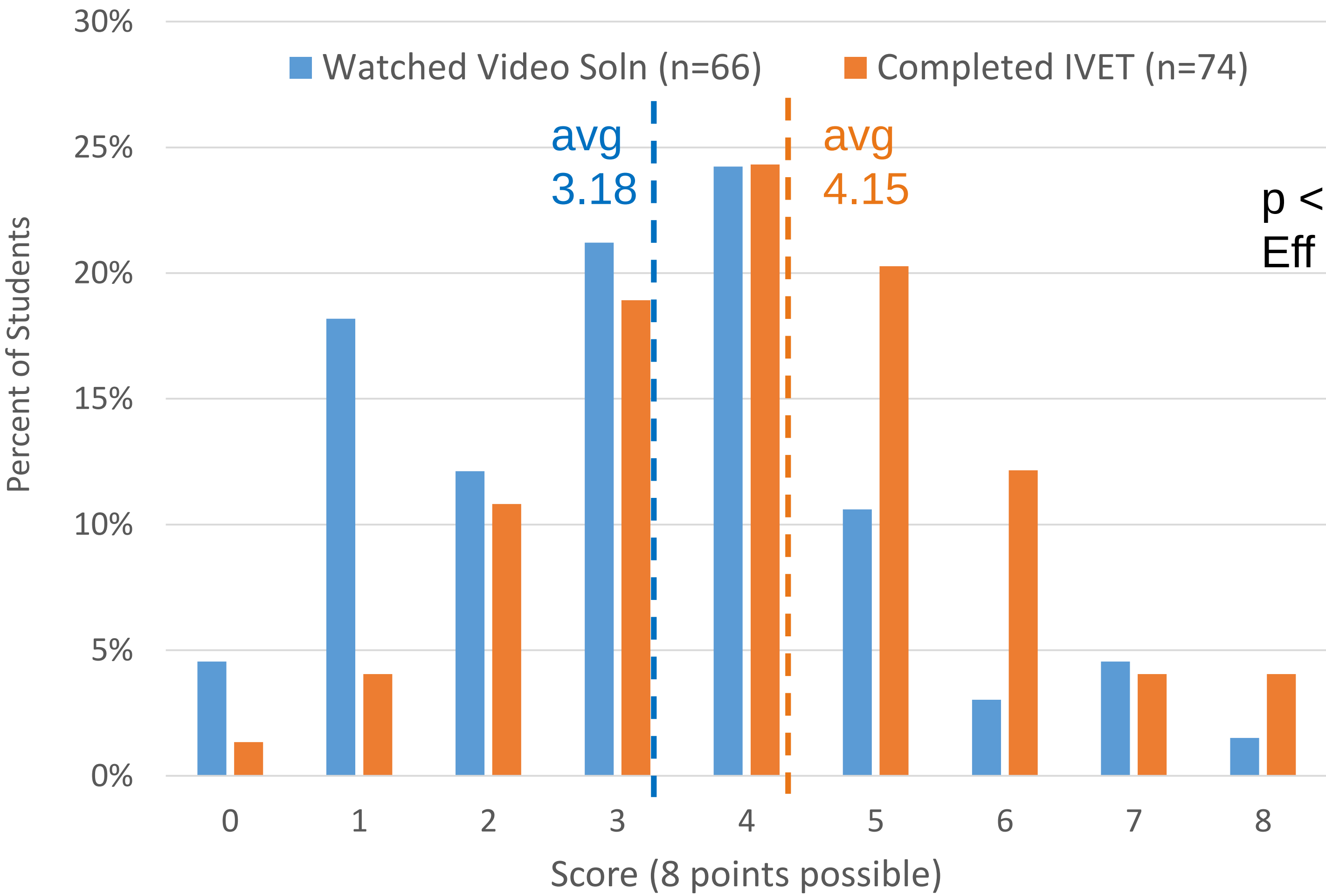
Based on the problem solving strategies emphasized in the IVET and video solution, we expected students to:

(1) Draw a free body diagram for the block shown above

(2) Recognize that the block would accelerate down the ramp

(3) Apply Newton's 2nd Law separately to block and pulley to generate two equations with two unknowns as part of their solution process.

Torque and Rotation IVET:
Results of Scoring Follow Up Problem



p < 0.001
Eff Size = 0.55

Torque and Rotation IVET: Range of solutions presented by students

Video N=66	IVET N=74	Code Description
6%	10%	Correct solution (includes minor math errors or unit omission)
41%	47%	Correct force diagram included for box on ramp
18%	30%	Recognized need to solve using 2 eqns with 2 unknowns but made mistake in application
24%	10%	Incorrectly assumed a=0 for box, solved using $\tau = I\alpha$ only
27%	8%	Appeared to have no plan

Torque and Rotation IVET:
Range of solutions presented by students

This study also involved a "no treatment" group, which included students in both sections of the course who didn't complete the video or IVET assignment.

No Treatment N=65	Video N=66	IVET N=74	Code Description
3%	6%	10%	Correct solution (includes minor math errors or unit omission)
20%	41%	47%	Correct force diagram included for box on ramp
8%	18%	30%	Recognized need to solve using 2 eqns with 2 unknowns but made mistake in application
16%	24%	10%	Incorrectly assumed a=0 for box, used $\tau = I\alpha$ only
42%	27%	8%	Appeared to have no plan

Mean score (of 8 pts) for no treatment group = 2.52 vs 3.18 (video) and 4.15 (IVET).

Conclusion

Students who did IVET were more likely to:

1. Recognize and apply the physics principles needed to solve the problem.
2. Solve the problem in parts rather than attempt to solve in a single step.
3. Make correct assumptions about problem (such as $a \neq 0$).
4. Approach the problem with a plan rather than writing down random equations.

Our outcomes suggest that the interactive nature of the IVETs better engages students in the learning process over video.

Should video never be used?

In several smaller studies we found that use of video improved learning when compared to *no treatment*.

To increase the effectiveness of video, it is important to consider <u>how</u> students engage, particularly given our increased dependency on video for supporting online instruction, flipped classrooms, etc.

Suggestions for motivating students to mentally engage with video…

1. Make it interactive, where students have to submit responses throughout (ex. course LMS can help here).
2. Provide an assignment with the video, such as complete a list of questions or take notes that are submitted.
3. Follow the video with a quiz, but be sure students know what they need to take from the video in preparation.

We have found that putting points on an assignment, even a small amount, is a significant motivator. The tough part is designing the assignment such that it is **mentally engaging**!

List of available IVETs:

- **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** (Atwood problem)

Seven more to be produced in Summer 2021, including:

- **Monkey Gun** (demonstration and problem)
- **Thermal Equilibrium** (temperature and phase changes)
- **Thermal Processes** (PV diagrams)

If you wish to assign IVETs to your students, please contact **Robert Teese (rbtsps@rit.edu)**.

More information about IVVs can be found at:

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

Teese, R., Koenig, K., & Jackson, D. (2020). Interactive Video Vignettes for Teaching Science. In J.J. Mintzes and E.M.Walter, Eds. *Active learning in college science: The case for evidence based practice*. Berlin: Springer Nature.

Laws, P., Willis, M., Jackson, D., Koenig, K. and Teese, R. (2015). Using Research-Based Interactive Video Vignettes to Enhance Out-of-Class Learning in Introductory Physics. *The Physics Teacher*, 53(2), 114-117.

More information about IVETs can be found at:

https://ivet.rit.edu/IVET

Koenig, K., Maries, A., and Teese, R. (in press). Promoting Problem Solving through Interactive Video-Enhanced Tutorials, *The Physics Teacher*.

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