Orlando 2020 Abstract

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 using Newton's Second Law. The IVETs, which are based in part on the tutorials created at the University of Pittsburgh, are designed using multimedia principles of learning and research on human learning and memory. The tutorials are adaptive and provide different levels of scaffolding depending on students' needs. They are also affect-adaptive, such that additional guidance is provided to students who indicate they are confused, frustrated, or bored while completing the IVET. This presentation will showcase one of the IVETs and its various design features**. Research results regarding students' behaviors as they engage with the IVET, as well as the impact of the IVET on student problem-solving ability, will also be presented.**

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Promoting Problem-Solving Abilities through Web-based Interactive Video-Enhanced Tutorials

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NSF IUSE DUE 1821396

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%

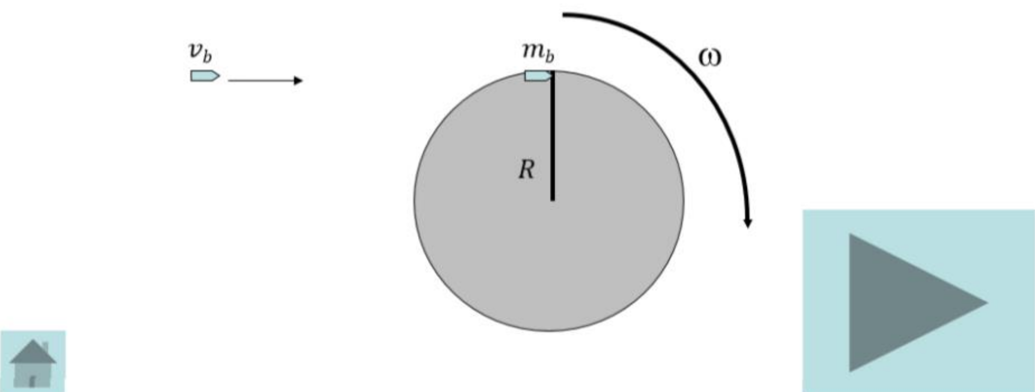
85% of students

See low correlation between student HW scores and exam scores.

Problem Solving Tutorials – Univ of Pittsburgh

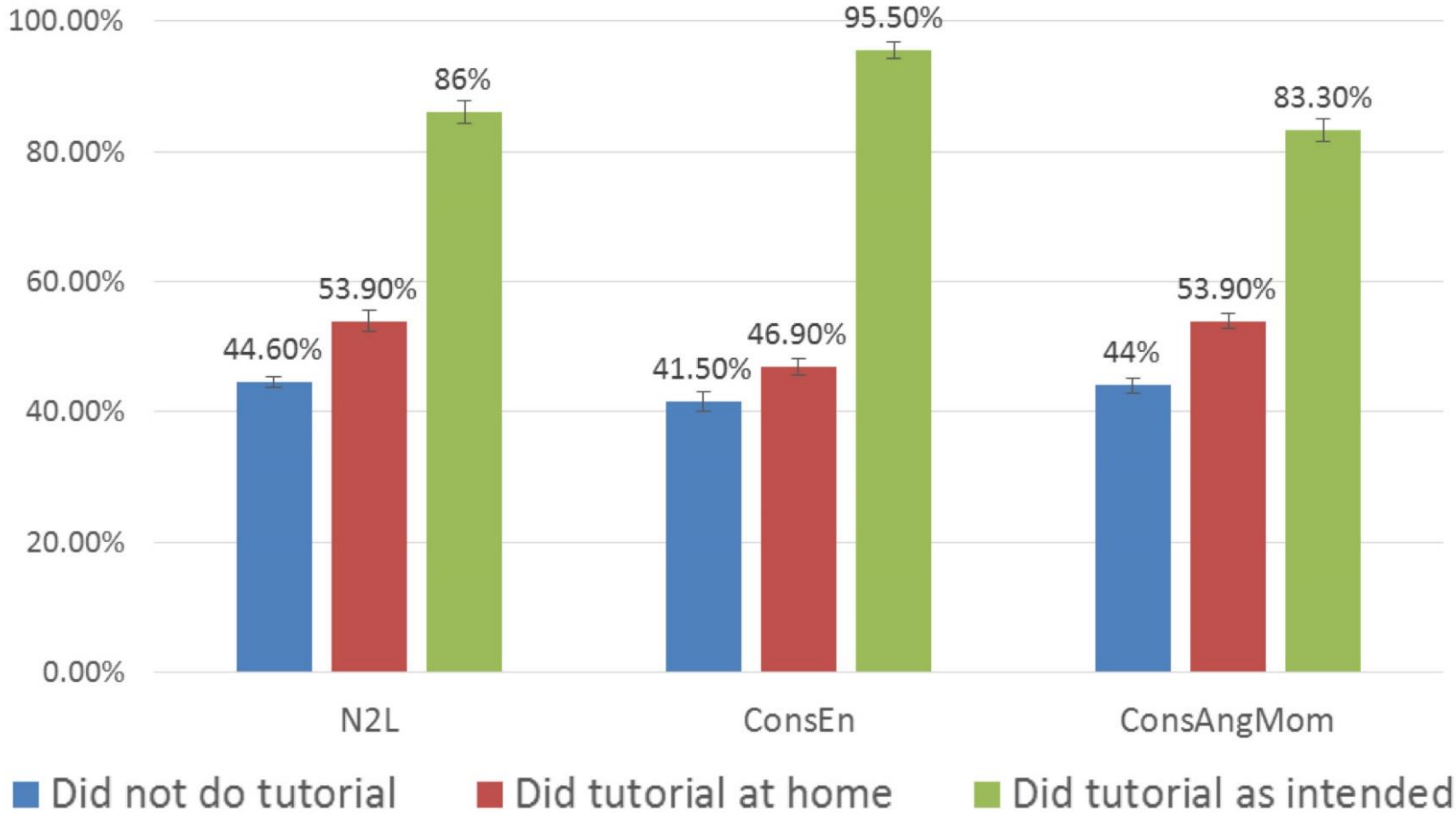
DeVore and Singh developed ~20 tutorials introductory physics.

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?



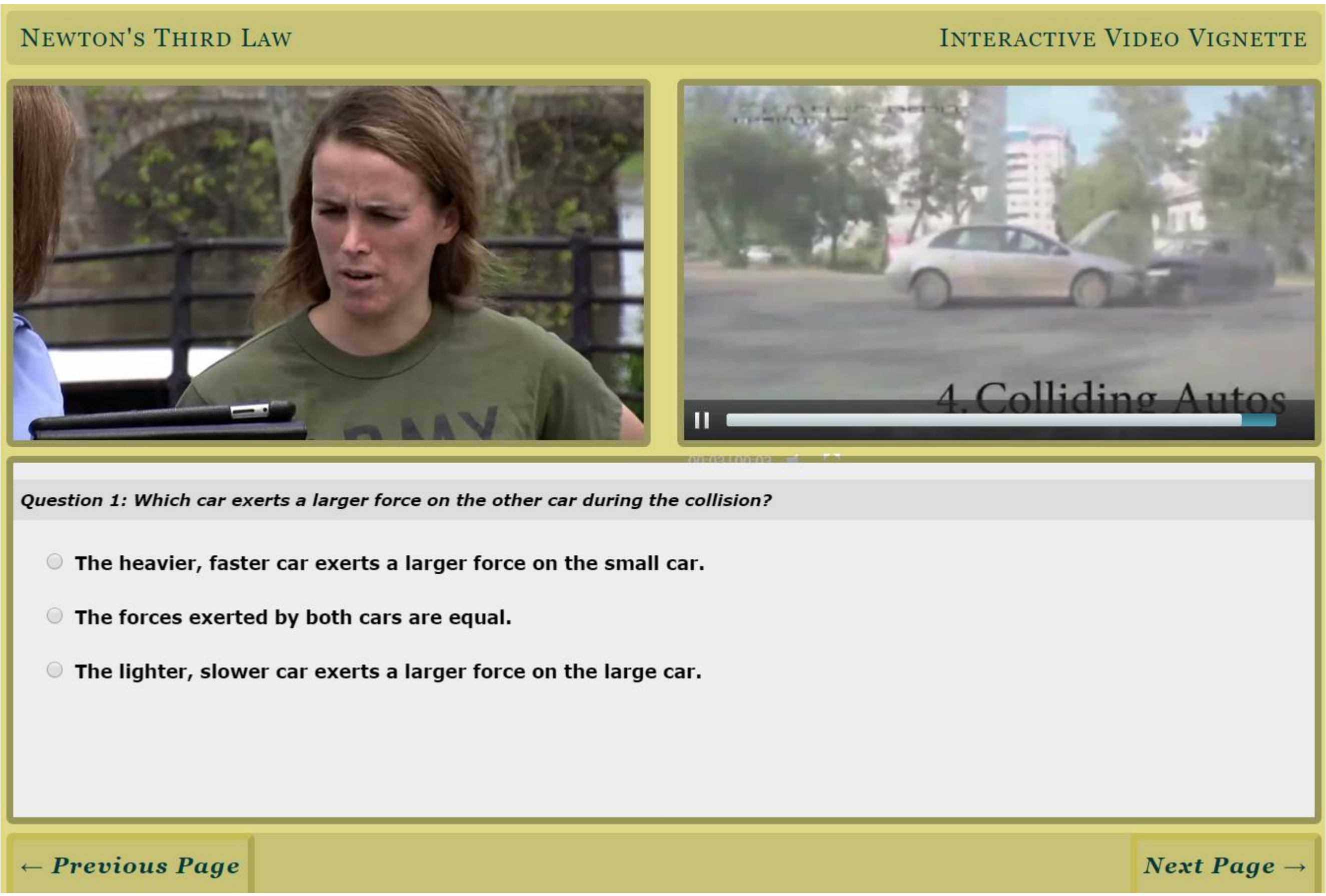
Implemented through Powerpoint and designed to carefully guide students to a solution through the use of branching questions.

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.

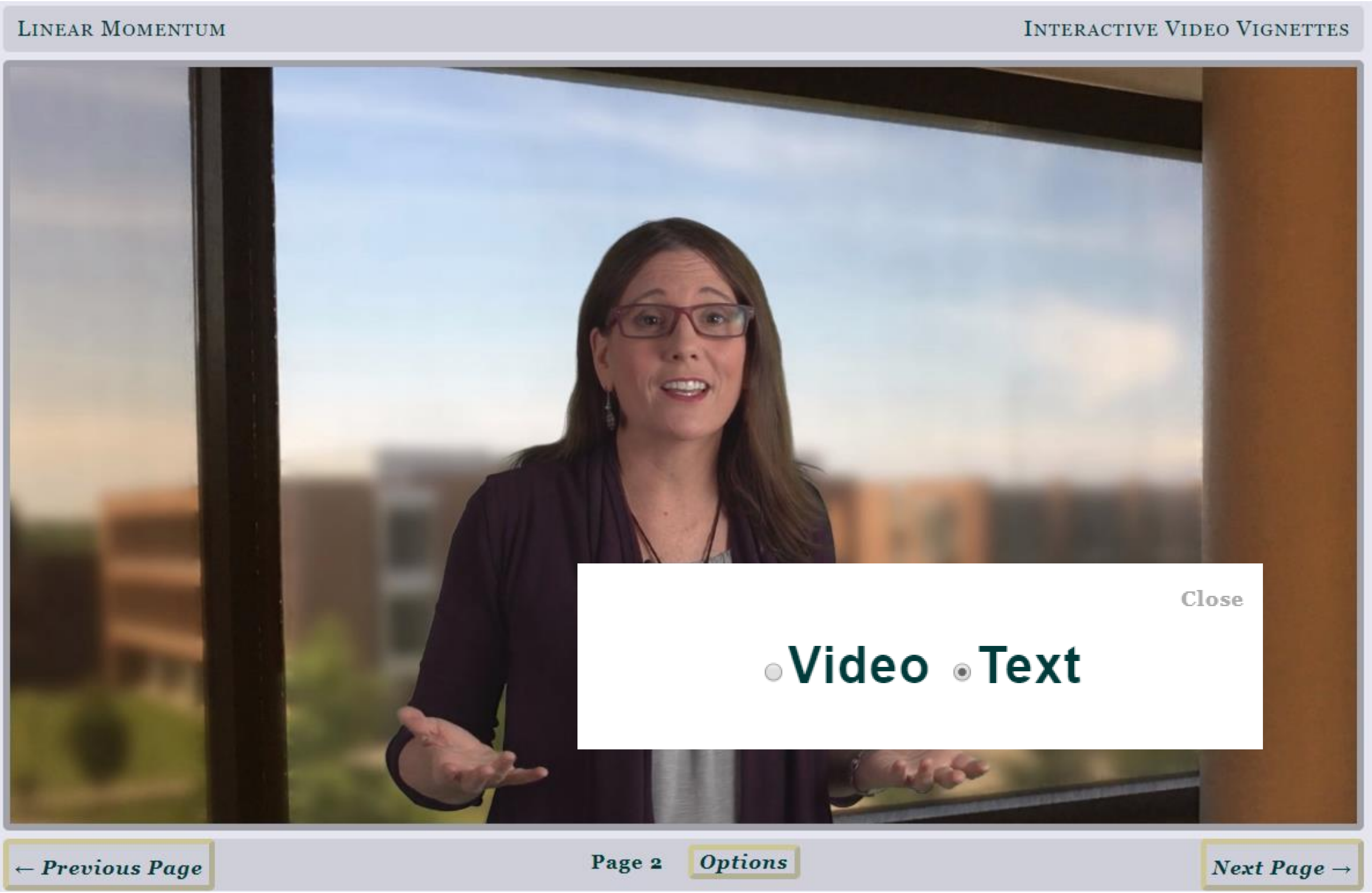
Features of Design of IVETs

- Developed based on multimedia learning principles (Richard Mayer) and research on human learning and memory (Bransford)
- Problems challenge students while providing support designed to stretch students’ zone of proximal development
- Student support delivered through mini-lectures, hints, or encouragement (affect) by a tutor (a real person in a video)

Features of Design of IVETs

- Multiple-choice questions guide students through an ***effective* problem-solving approach** (e.g., define a coordinate system, draw a force diagram, 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

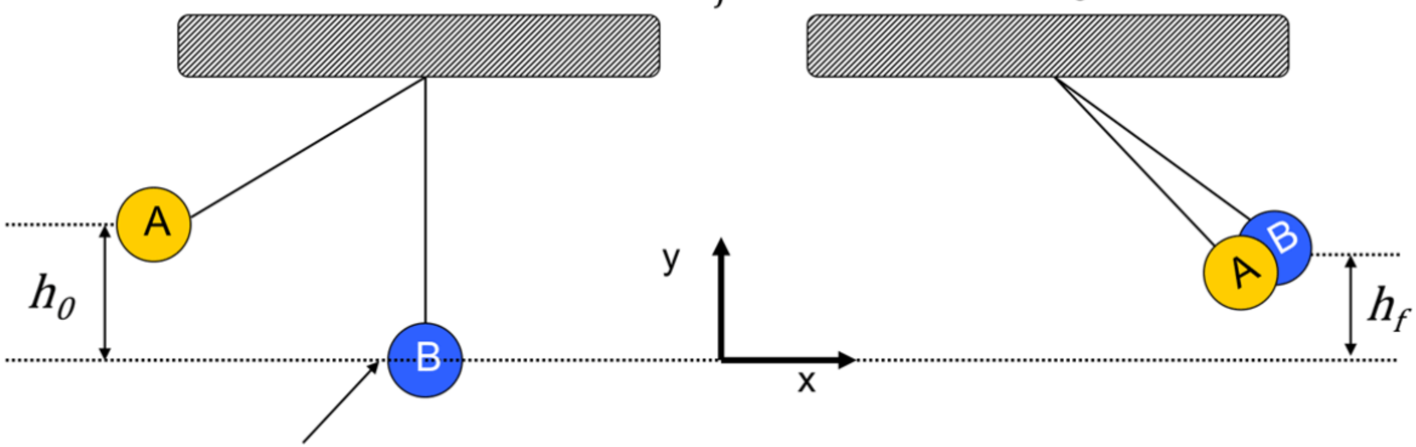
Example IVET – Linear Momentum and Energy



Text option: Page presents problem to be solved.

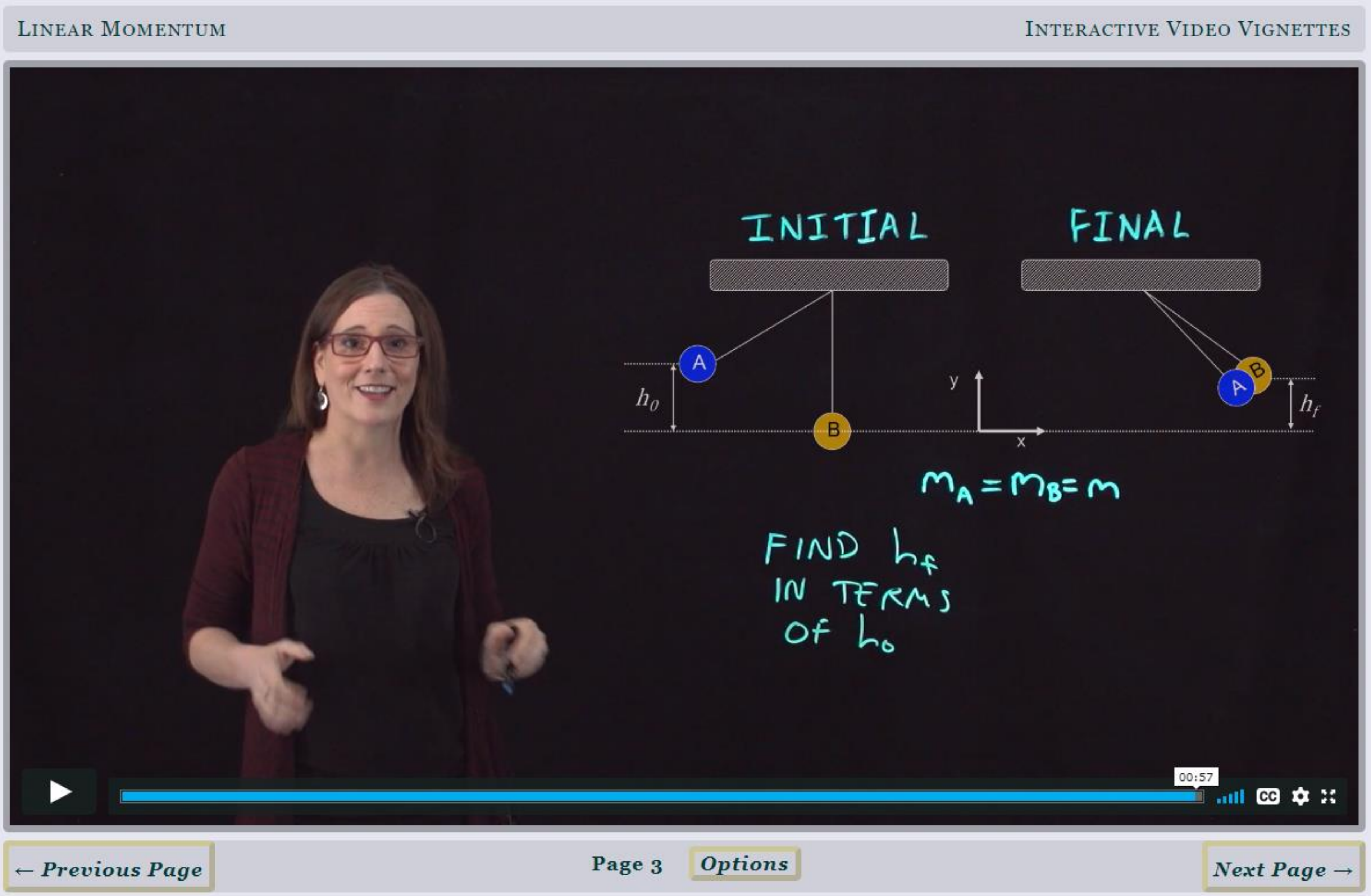
Two small spheres of putty, A and B, of equal mass m, hang from the ceiling on massless strings of equal length. Sphere A is raised to a height h_0 as shown below and released. It collides with sphere B (which is initially at rest). The two spheres stick and swing together to a maximum height h_f. (Assume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

Find the height h_f in terms of h_0.



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

Video option: Narrator presents problem to be solved.



Keep good notes as you go though this tutorial. You will need them.
Briefly summarize your plan for solving the problem in the box below:

Solution Plan

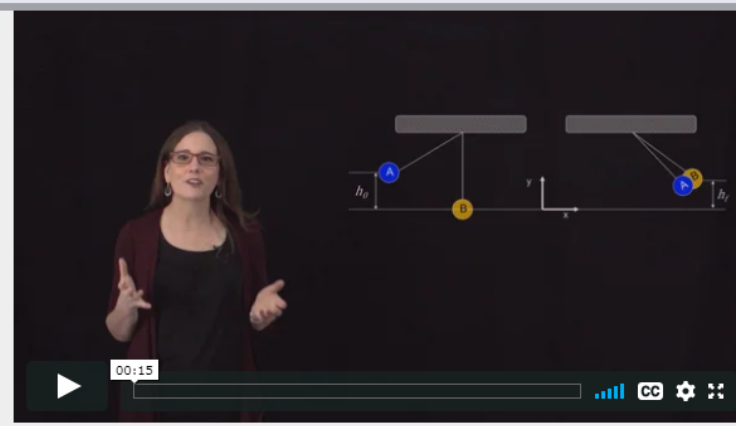
Before starting any physics problem, you should always decide which principles will be needed. If you want to see the problem statement again, click the *Problem Statement* button at the bottom of this window.

Q1: Choose *all* of th

- A. Conservation
- B. Conservation
- C. Newton's 2nd

← Previous Page

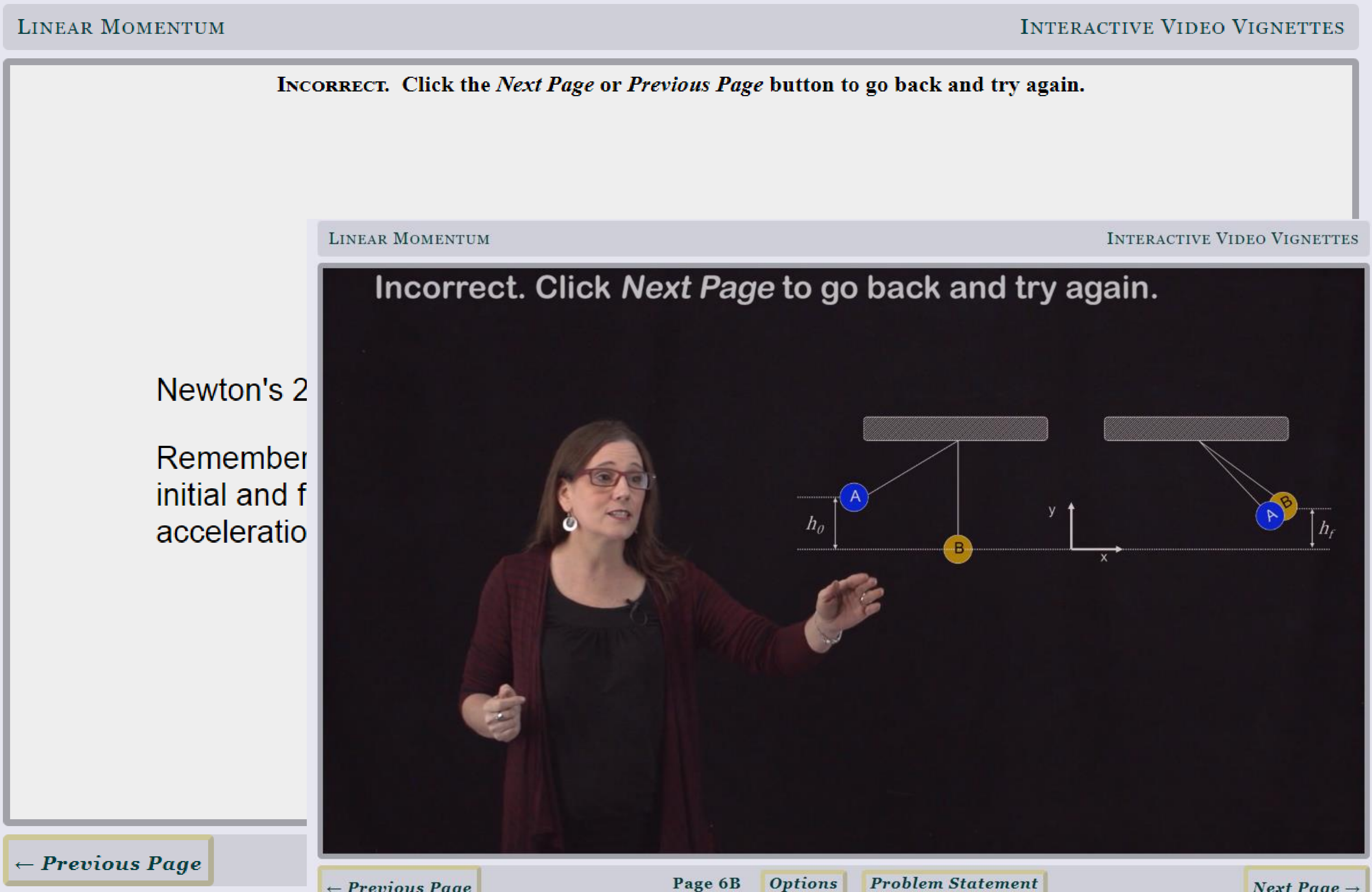
Linear Momentum
Interactive Video Vignettes



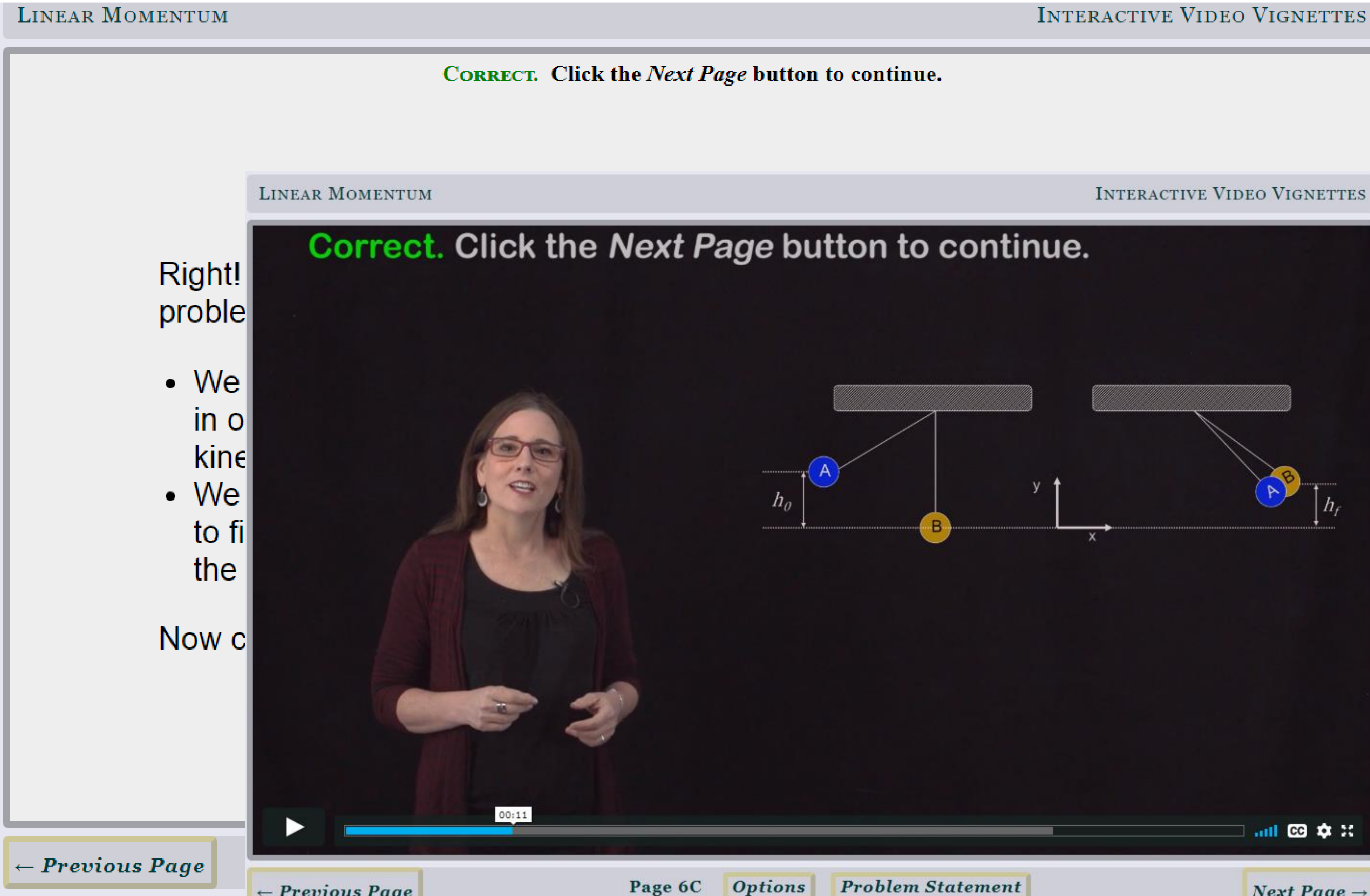
Q1: Choose *all* of the following physics principles we should use to solve this problem:

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

Feedback is provided for all incorrect as well as correct responses.

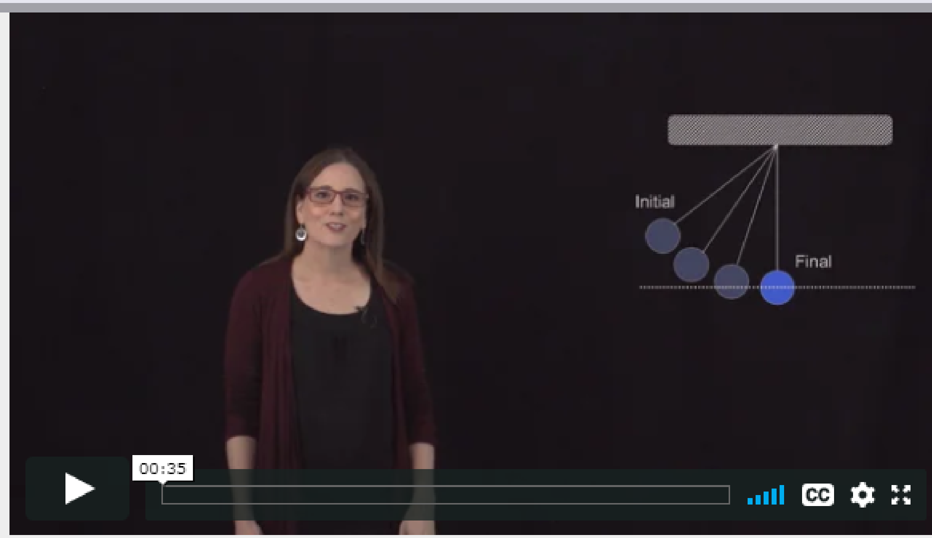


Feedback is provided for all incorrect as well as correct responses.



Multiple select questions used to engage students and reduce guessing.

LINEAR MOMENTUM | INTERACTIVE VIDEO VIGNETTES



Q2: What type(s) of initial mechanical energy does ball A have when it is released? What type(s) of final mechanical energy does ball A have just before it strikes ball B? Choose *all that are not zero*:

- [ ] A. Initial Kinetic Energy
- [x] B. Initial Gravitational Potential Energy
- [x] C. Final Kinetic Energy
- [ ] D. Final Gravitational Potential Energy

Feedback is aligned to choices made.

← *Previous Page* | Page 7 | *Options* | *Problem Statement* | *Next Page* →

Students are expected to work problem out on paper along with IVET.

LINEAR MOMENTUM | INTERACTIVE VIDEO VIGNETTES

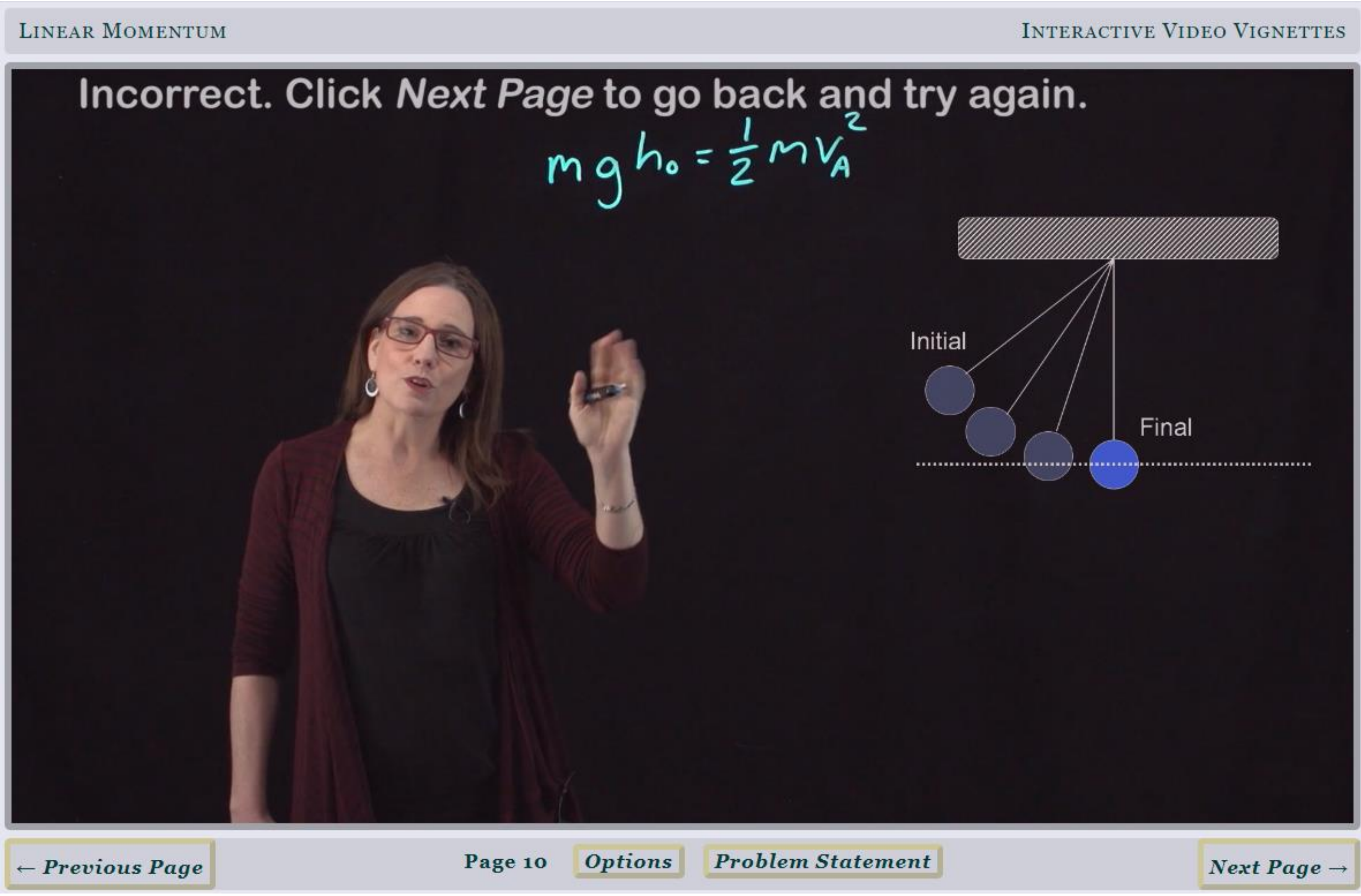
Q3: Which one of the following expressions for the speed v_A of ball A right before it collides with ball B is correct?

- ○ A. $v_A = \sqrt{2gh_0}$
- ◉ B. $v_A = \sqrt{gh_0}$
- ○ C. $v_A = \sqrt{\frac{gh_0}{2}}$

Incorrect answer selected.

← Previous Page | Page 9 | Options | Problem Statement | Next Page →

Feedback is provided to get student started in addressing this part of problem.



Students get brief summary even when correct.

Correct. Click the *Next Page* button to continue.

LINEAR MOMENTUM INTERACTIVE VIDEO VIGNETTES

CORRECT. Click the *Next Page* button to continue.

Reasoning:

Initial gravitational potential energy	=	Final kinetic energy

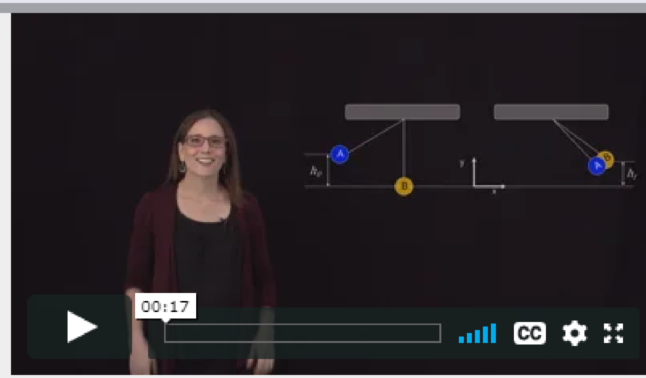
$$\not{m}_A g h_0 = \frac{1}{2}\not{m}_A v_A^{\,2}$$

$$g h_0 = \frac{1}{2} v_A^{\,2}$$

$$2 g h_0 = v_A^{\,2}$$

$$v_A = \sqrt{2 g h_0}$$

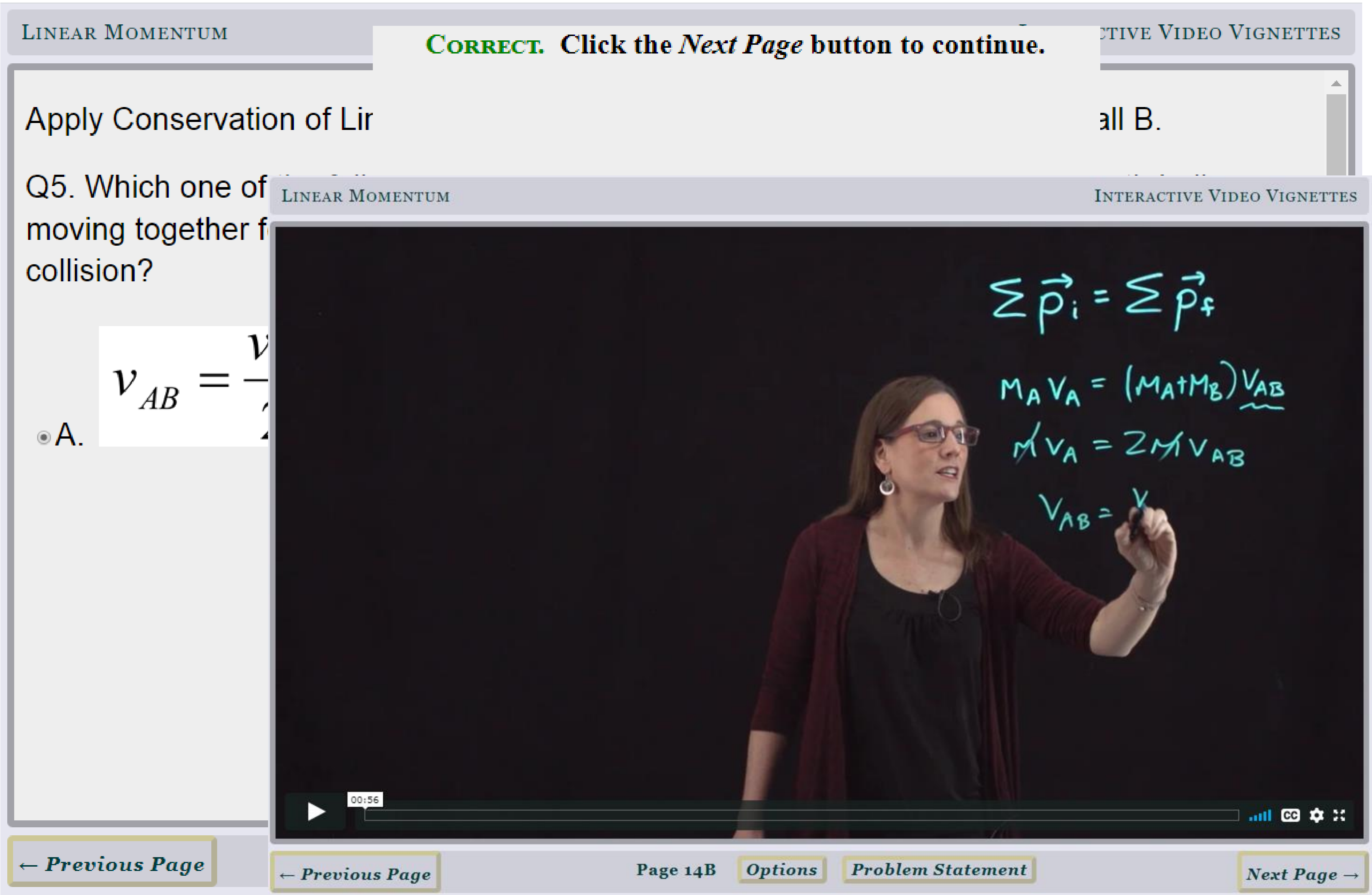
Throughout the IVET, emphasis is placed on solving the problem in parts. Here, the student is moved into the 2nd part of the problem.



Q4: Which of the following principles is most convenient to find an expression for the speed of the merged balls (v_{AB}), in terms of the speed that ball A had immediately before the collision (v_A)?

- A. Conservation of Linear Momentum
- B. Newton's Second Law
- C. Conservation of Total Mechanical Energy

Students are led to an equation which wraps up the collision part of the problem.



How are you feeling right now?

What is this? Why should I answer?

Your instructor will NOT see your answer to this question.

There are two reasons for answering the question.

1. You may find the response helpful.

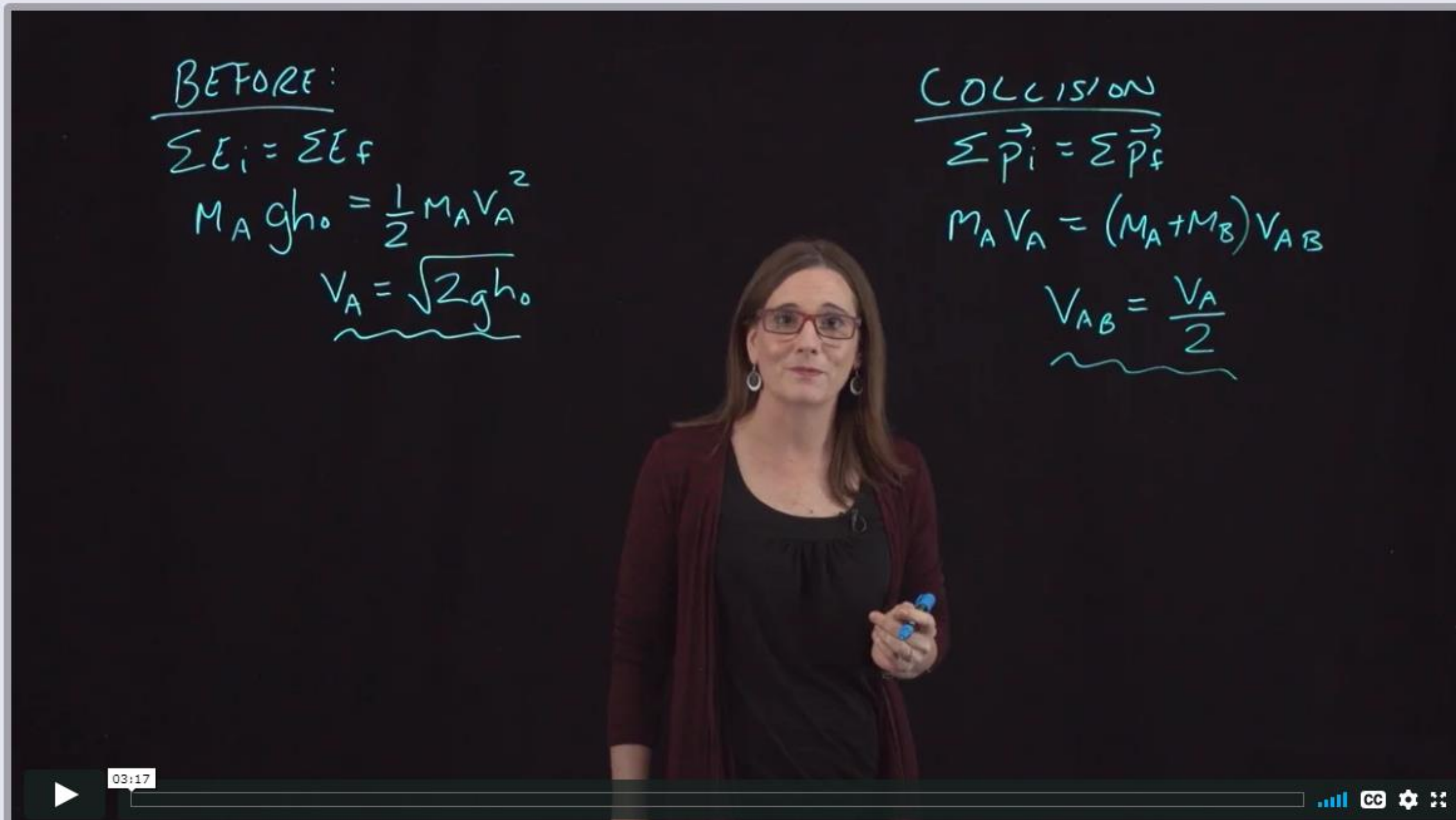
2. The answer will be sent anonymously to the authors of the tutorial, and they will use the class-averaged data to improve the tutorial. If you do not wish to let the authors know how you are feeling, you can choose not to answer this question.

Fine	
Confused	
Frustrated	
Bored	
Worried	I worry that I will not do well in this course. I am just feeling kind of stressed today.
Other	None of the choices applies to me. Continue with the tutorial.
I Prefer Not To Answer	Continue with the tutorial.

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

- Watch a video summary.
- Continue with the tutorial.

Linear Momentum
Interactive Video Vignettes



Throughout the IVET, emphasis is placed on solving the problem in parts. Here, the student is moved into the 3rd (last) part of the problem.

Now that we have found the speed of the two balls stuck together, once again, use the law of conservation of mechanical energy assuming the initial point is right after the collision and the final point is when balls that are stuck together reach the maximum height h_f.

Q6. Which one of the following expressions is correct for h_f?

○ A. $h_f = \frac{v_{AB}^2}{4g}$

○ B. $h_f = \frac{2v_{AB}^2}{g}$

◉ C. $h_f = \frac{v_{AB}^2}{2g}$

This step is the end of the problem.

Use the relations we found in previous questions to find an expression for the maximum height of the two balls together (h_f) in terms of the initial height of ball A (h_0).

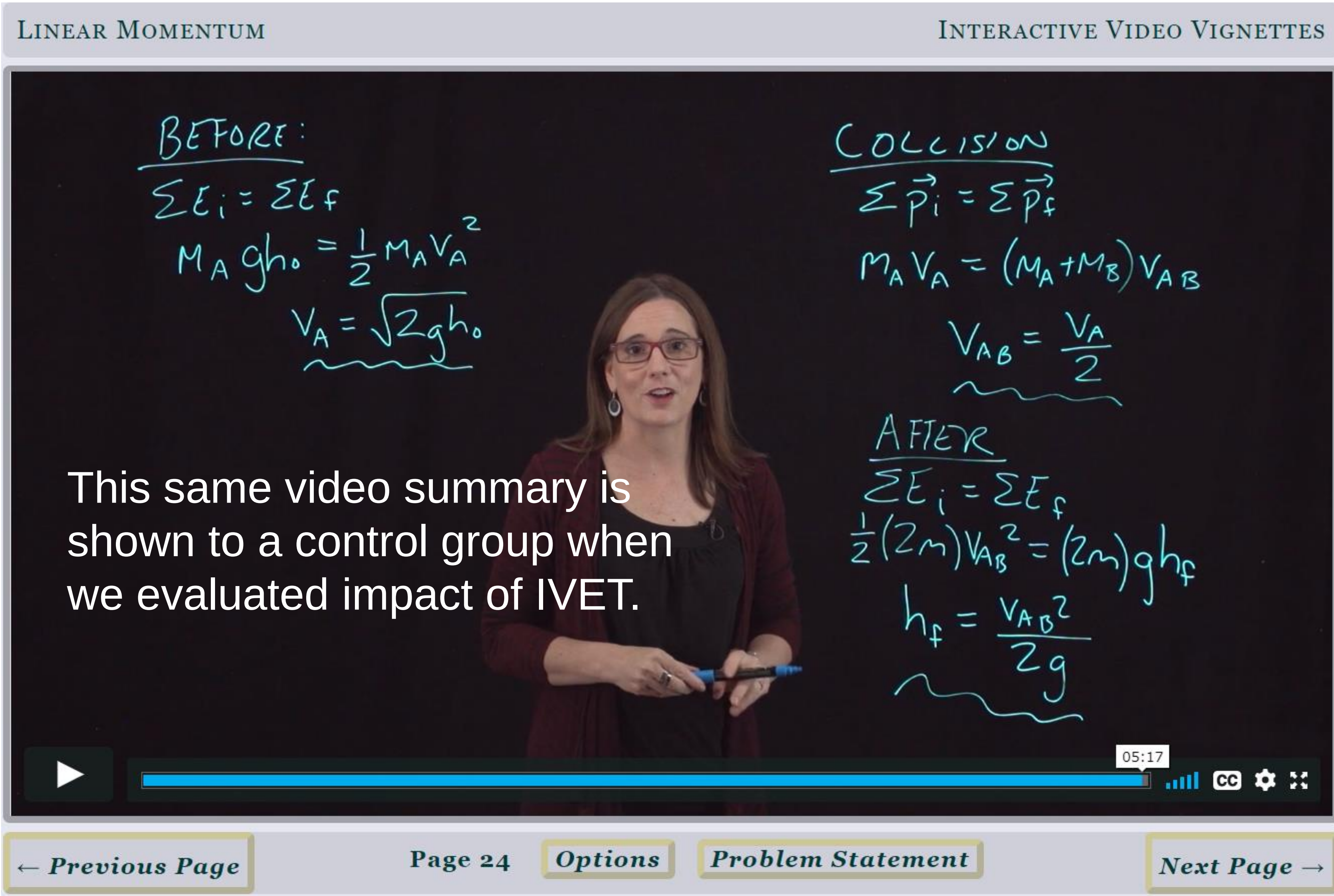
Q7. Which of the following expressions is correct for the maximum height h_f of the two balls together?

- ○ A. $h_f = 2h_0$
- ◉ B. $h_f = \frac{h_0}{4}$
- ○ C. $h_f = \frac{h_0}{2}$

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.

Reflection

To test your understanding of this type of problem, try solving it again using $m_B = \frac{1}{2} m_A$.

The result you should get is $h_f = (4/9)\ h_0$.

List what things you learned from this tutorial.

Also, the developers would appreciate any feedback about how well the activity worked (technical problems, for example).

Then click the *Next Page* button in the lower right corner to finish.

Preliminary Version

Does IVET impact student problem solving ability?

Two sections of algebra-based physics included in study

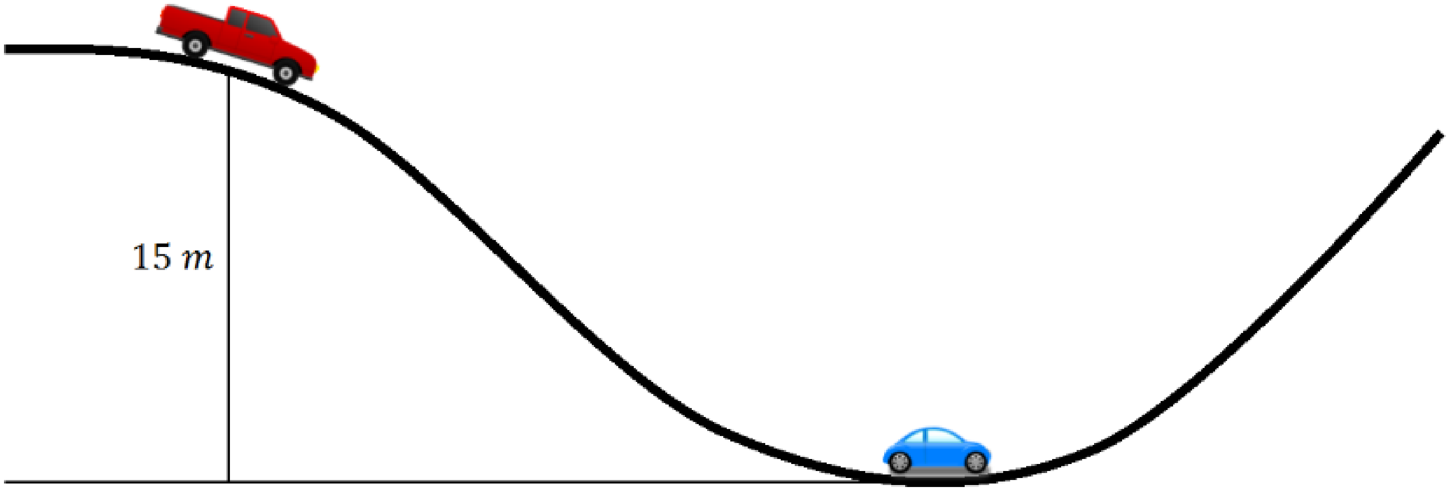
- One section given the Linear Momentum IVET to complete at home
- One section asked to watch the same ~5 minute solution showcased in the IVET

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?

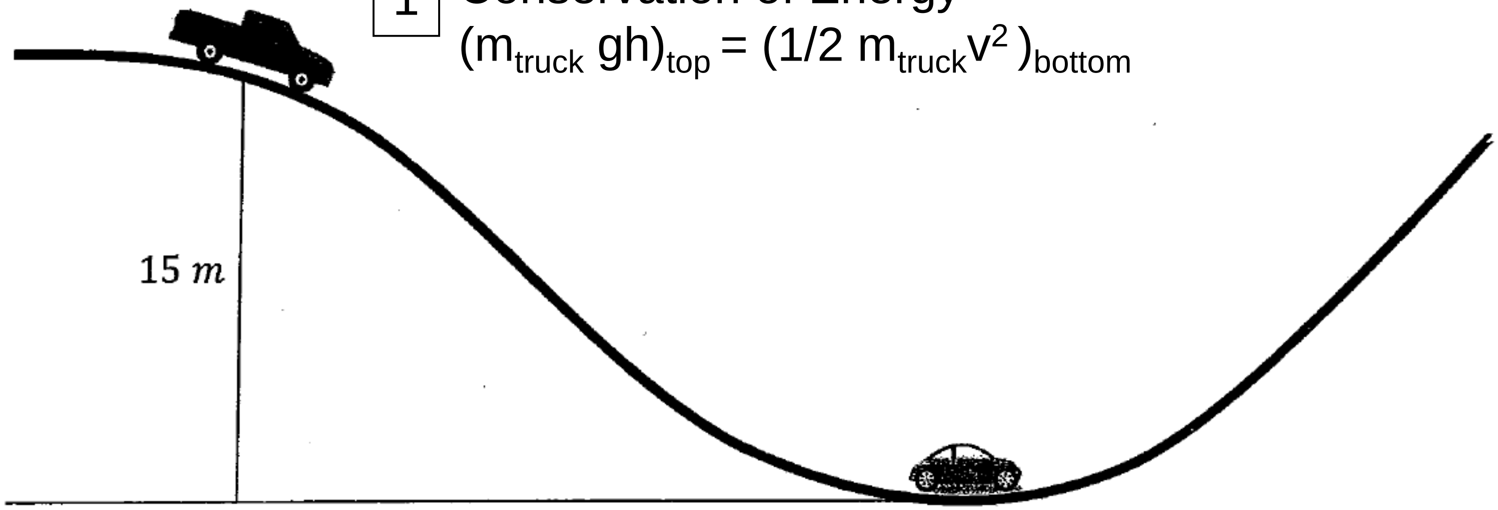


Paired Problem – post-assessment

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?

1 Conservation of Energy

$(m_{truck}\ gh)_{top} = (1/2\ m_{truck} v^2)_{bottom}$

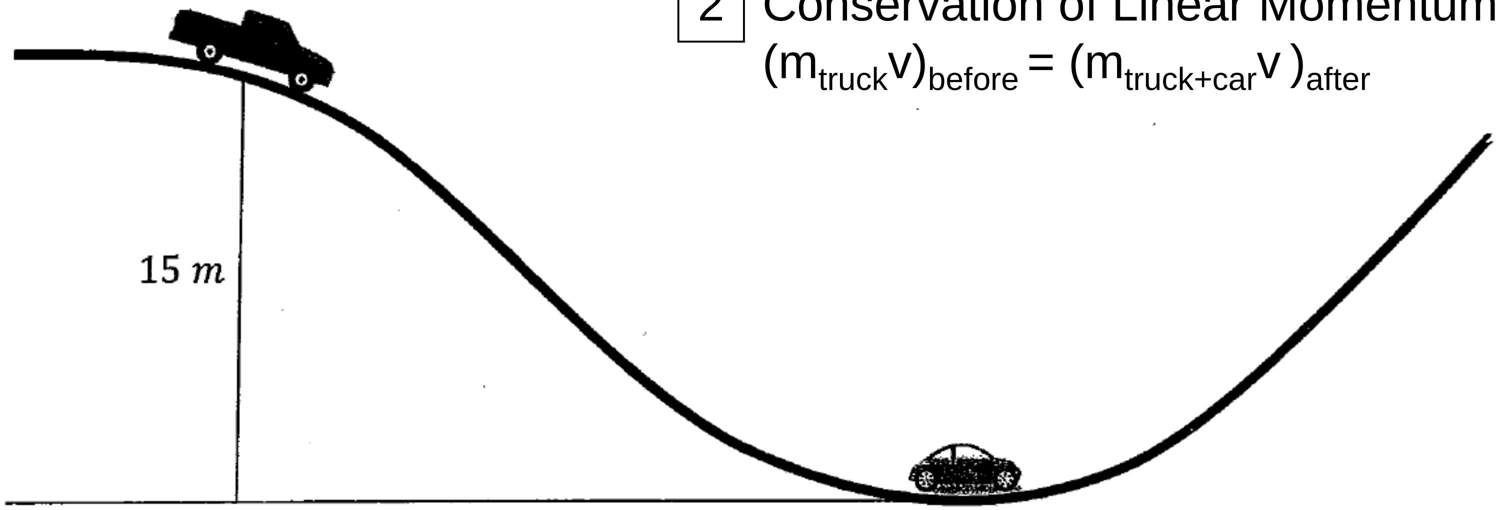


Paired Problem – post-assessment

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?

2 Conservation of Linear Momentum (collision)

$(m_{truck}v)_{before} = (m_{truck+car}v)_{after}$



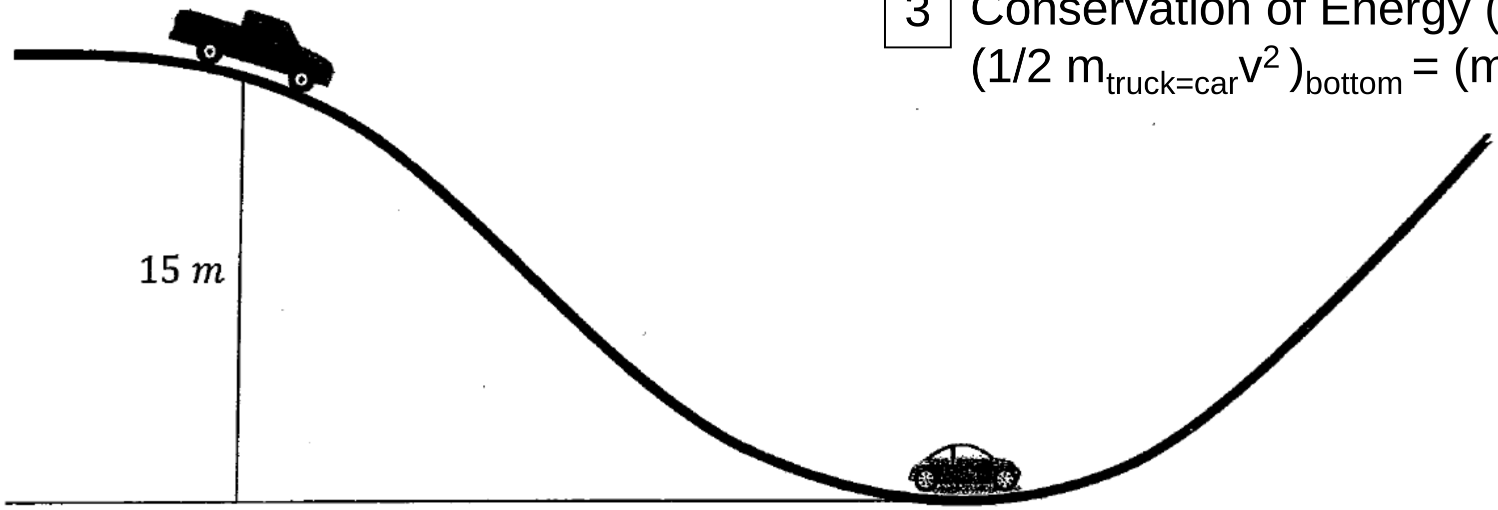
Paired Problem – post-assessment

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?

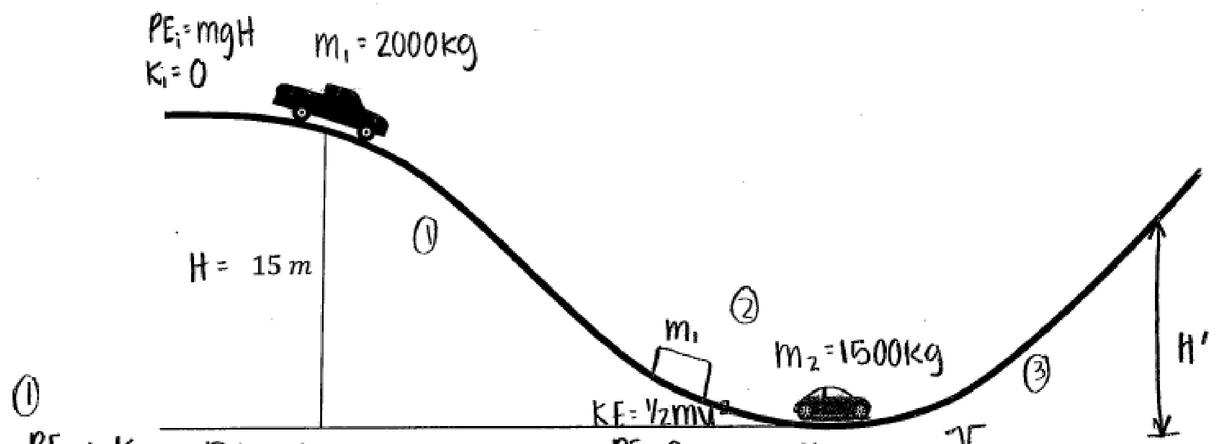
3

Conservation of Energy (up the hill)

$(1/2\ m_{truck=car} v^2)_{bottom} = (m_{truck+car} gh)_{top}$



Correct Solution



+3

$$PE_i + K_i = PE_f + K_f$$

$$mgH + 0 = 0 + \frac{1}{2}mu_1^2$$

$$\cancel{m}gH = \frac{1}{2}\cancel{m_1}u_1^2$$

$$u_1 = (2gH)^{1/2}$$

+3

② $$m_1u_1 + m_2\cancel{u_2}^{\,0} = V(m_1+m_2)$$

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

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

$$34292.856399 = 3500V$$

$$V = 9.79796\,m/s$$

③

+4

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

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

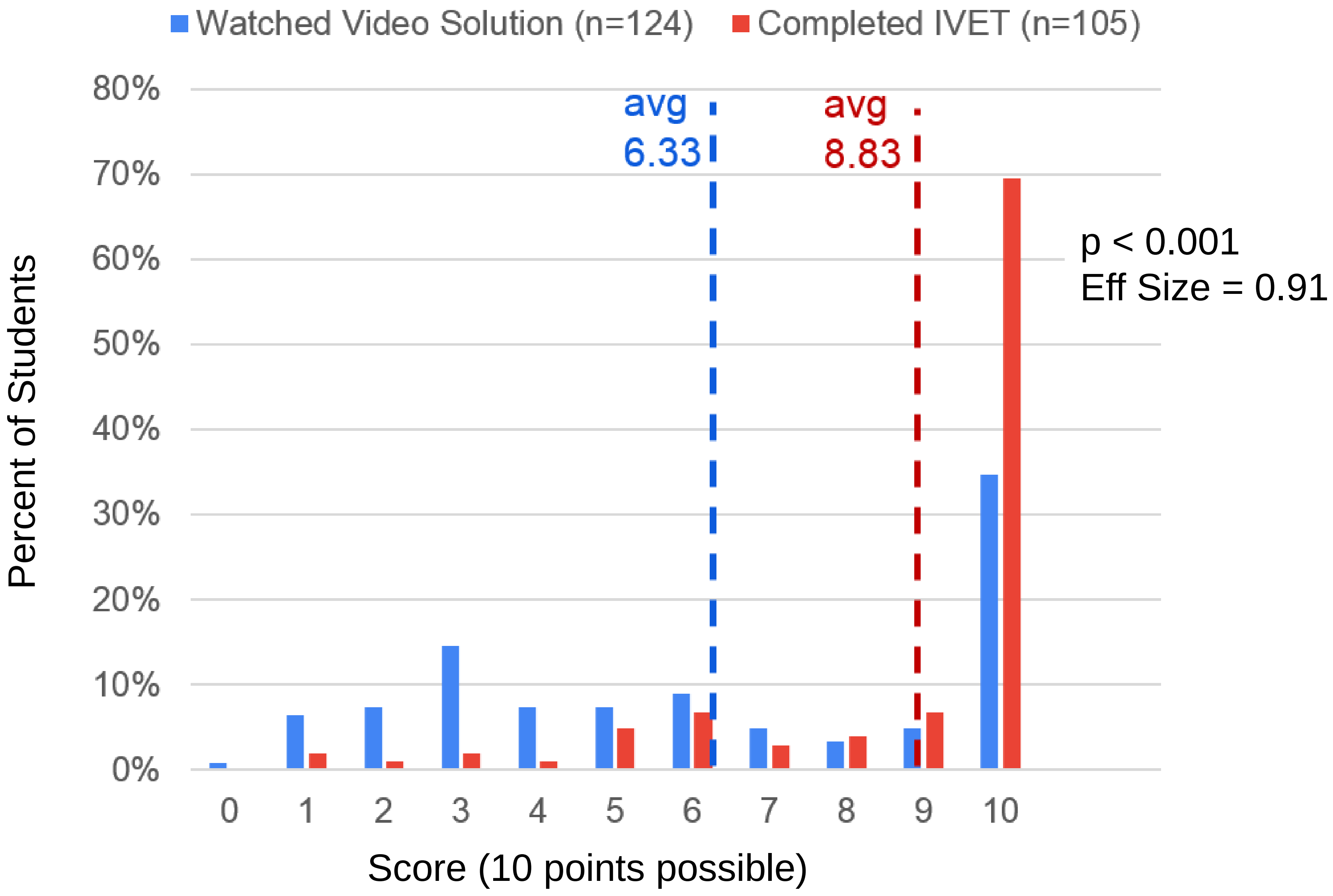
$$1750\,(96.0003) = 34300H'$$

$$168\,000.58397 = 34300H'$$

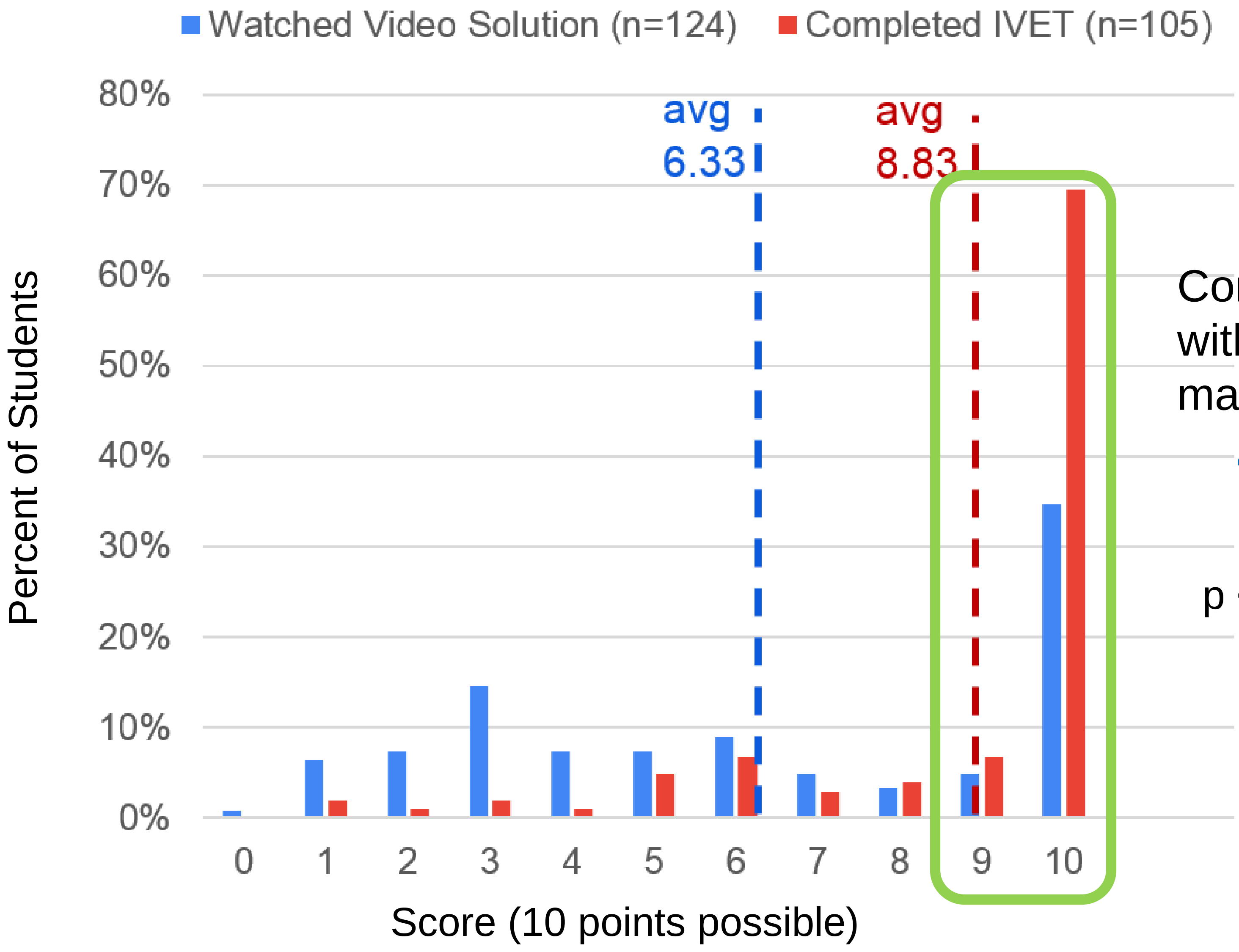
$$H' = 4.897976\,m$$

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

Results of Scoring Paired Problem



Results of Scoring Paired Problem



Correct (or with simple math error):

43%

77%

$p < 0.001$

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; few mentioned LM
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

Applied Conservation of Energy Only
(one step solution)

$$\sum E_i = \sum E_f$$

KE_i, U_{gi}, U_{gf}, W_{ext} =

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

$$(1500)(9.8)(10) + (2000)(9.8)(15) = (2000 + 1500) \cdot (9.8) \cdot h_f$$

$$294000 = 34300 h_f$$

$$\boxed{h_f = 8.57\ m}$$

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 $KE_i = U_g$

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

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

$294000 = 34300 h_2$

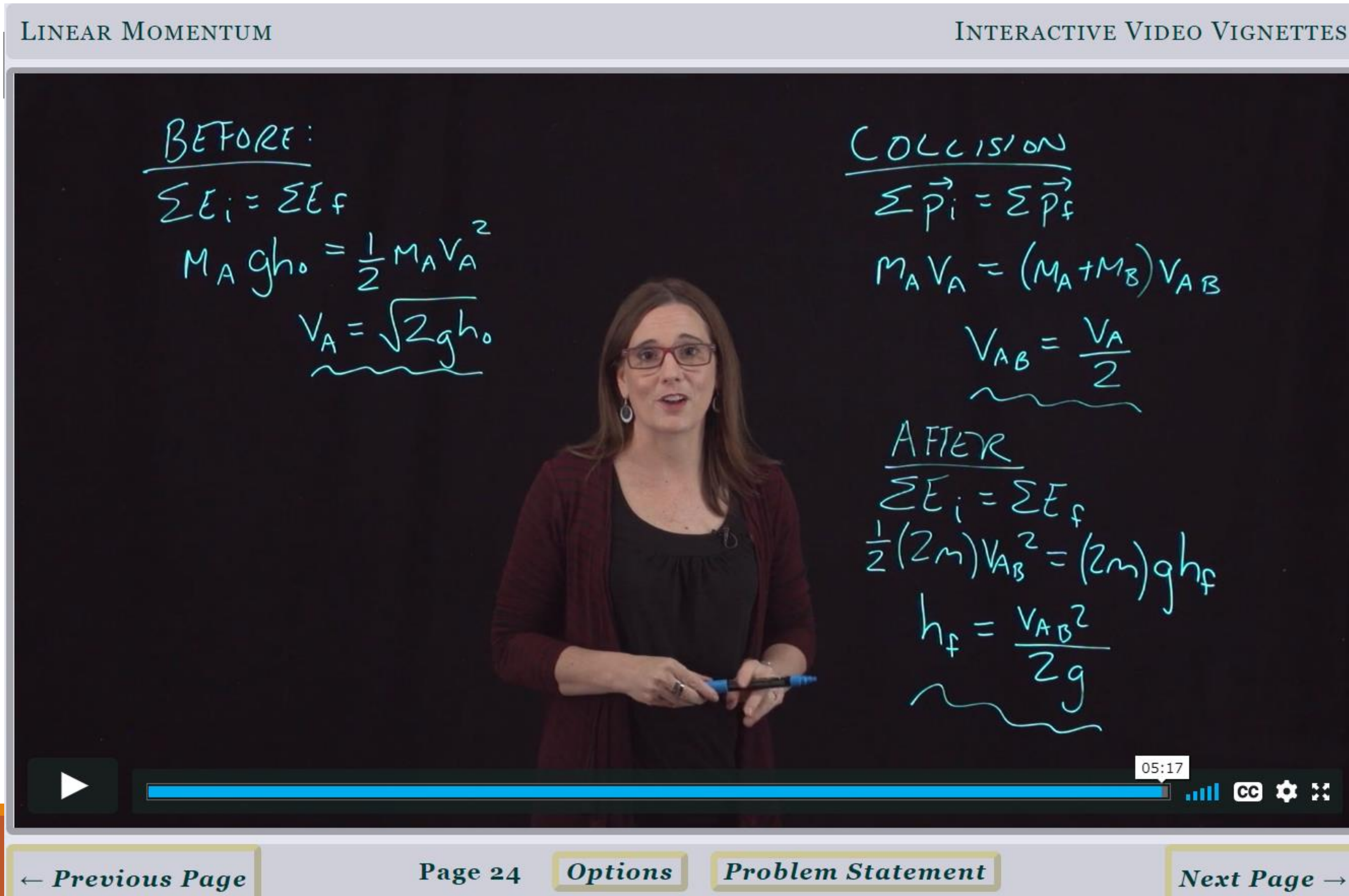
$h_2 = 8.57 \text{ m}$

11% 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



Incorrectly transferred ideas from Video/IVET

1. $V_a = \sqrt{2gh_0}$

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

   $V_a = 17.15$ m/s

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

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

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

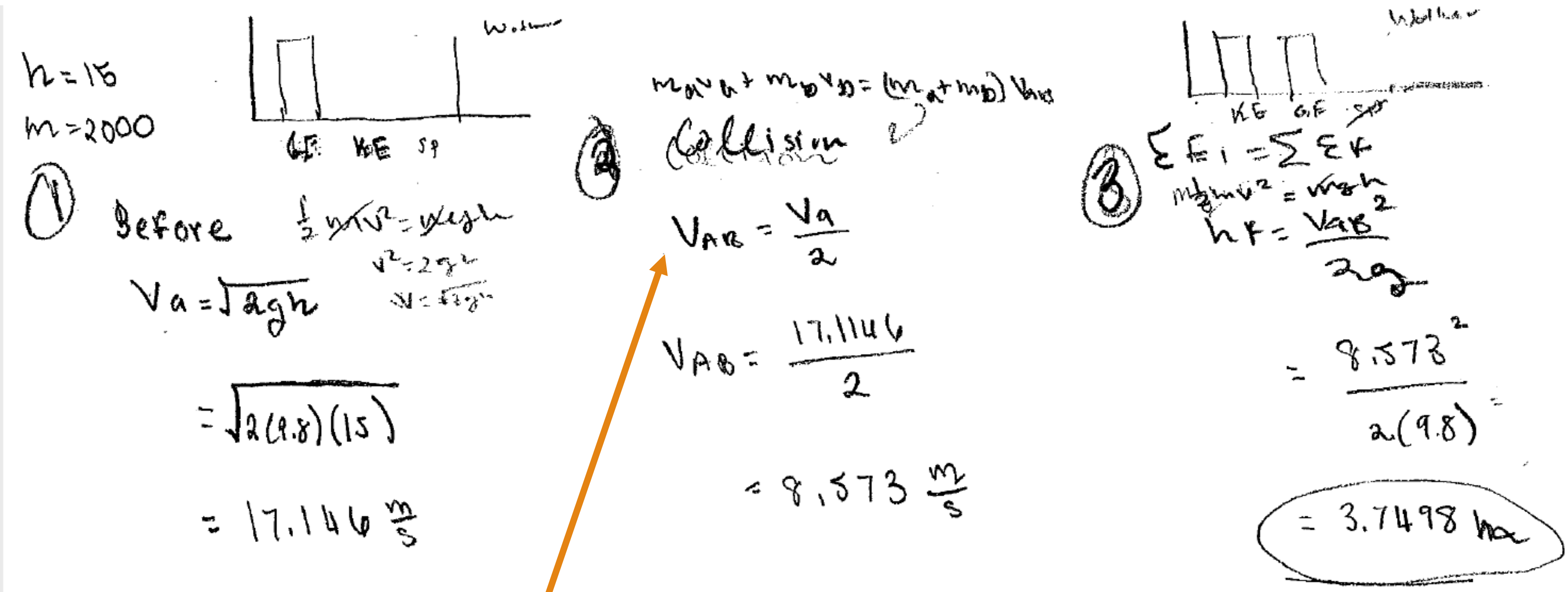
   $h_f = 3.76$ m

Memorized eqns used in video/IVET:

5% Video

6% IVET

Incorrectly Transferred Ideas from Video/IVET



3% Video

5% IVET

Considered truck and car as same mass

Video vs Text Option

Did you use the video or text option for the online video tutorial?

	Linear Momentum
Mainly Video	47%
Mainly Text	24%
Same of each	12%
Didn't realize an option	10%
Didn't do tutorial	7%

Starting in Spring 2020 we can track this behavior.

Video vs Text Option

Did you use the video or text option for the online video tutorial?

	Linear Momentum	Conservation of Energy	Newton's 2^{nd} Law
Mainly Video	47%	38%	54%
Mainly Text	24%	46%	30%
Same of each	12%	14%	9%
Didn't realize an option	10%	2%	4%
Didn't do tutorial	7%	0%	2%

Each survey above is from a different section; students not necessarily similar.

Thoughts about guidance in IVET

What did you think of the guidance in the tutorial (such as hints when you got a question wrong)?

	Linear Momentum
Very Helpful	25%
Mostly Helpful	39%
Helpful Half the Time	18%
Rarely Helpful	5%
Didn't look at hints	14%

Thoughts about guidance in IVET

What did you think of the guidance in the tutorial (such as hints when you got a question wrong)?

	Linear Momentum	Conservation of Energy	Newton's 2nd Law
Very Helpful	25%	43%	41%
Mostly Helpful	39%	35%	33%
Helpful Half the Time	18%	12%	15%
Rarely Helpful	5%	5%	3%
Didn't look at hints	14%	5%	9%

Each survey above is from a different section; students not necessarily similar.

Rate IVET

Overall, how would you rate the tutorial with regards to helping you learn how to apply the (problem solving strategy)?

	Linear Momentum
Excellent	5%
Pretty good	34%
Average	50%
Below average	10%
Terrible	2%

Rate IVET

Overall, how would you rate the tutorial with regards to helping you learn how to apply the (problem solving strategy)?

	Linear Momentum	Conservation of Energy	Newton's 2nd Law
Excellent	5%	22%	10%
Pretty good	34%	40%	52%
Average	50%	32%	32%
Below average	10%	6%	6%
Terrible	2%	0%	1%

Each survey above is from a different section; students not necessarily similar.

Student comments about IVET logistics

The activity worked well, and I liked how you could access the problem statement whenever you needed to.

I liked how it gave feedback to correct or incorrect answers.

The only technical problem was it taking a little longer than I expected to load each page. (7 of 120 mentioned loading time)

Student comments about 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.

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

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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

Identify techniques that motivate appropriate student behavior when using IVETs

- How do we get them to slow down? Mentally engage?
- How do we address boredom, confusion, frustration?

Ask a direct question: *How are you feeling right now?*

Have a pop-up with some feedback (text or real person)

Fall 2019, we evaluated 5 IVETs with videos:

- 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)

New for spring 2020

- Torque and rotation

Questions?

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