Reducing the Gender Gap in Introductory Physics using Interactive Tutorials

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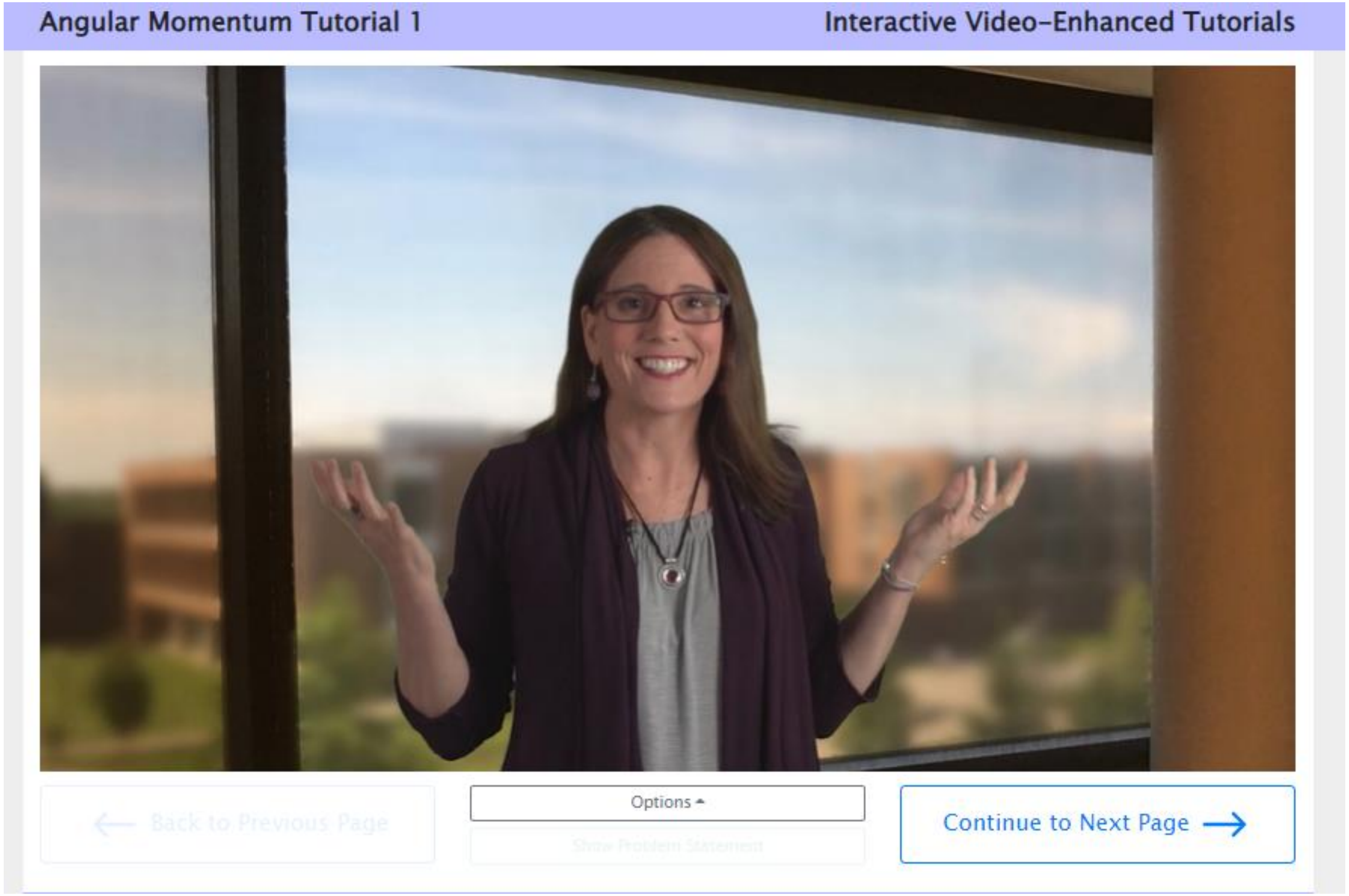
Well-Known Problems

- Students are not learning proper problem-solving skills in Introductory Physics
  - Hake, 1998, students completing a traditional lecture-based physics course, walk away without a good conceptual understanding of the material
- Students are not participating in Online Tutorials
  - Devore et al., 2017, students are not motivated to engage properly with online tutorials when completing them at home
- Women are underperforming in STEM
  - Binning et al., 2020, Stereotype threat causes students to miss important learning opportunities, but there are promising interventions to help mitigate this negative effect
  - Marshman et al., 2018, female students with a grade of A have similar self-efficacy as male students with C+/B- (physics 1) and C (physics 2)

Interactive Video-Enhanced Tutorials (IVETs)

- Using well-established research to create this online tutorial
- Explicit walk-through of a challenging real-world problem,
- Problem is broken down into conceptual subgroups
- Students are guided through the problem to follow an expert-like strategy
- Feedback is provided when an answer is given
  - Wrong answer: corrects students understanding
  - Right answer: reinforce correct reasoning
- Reflection problem at end of tutorial with no guidance to promote self-reliance

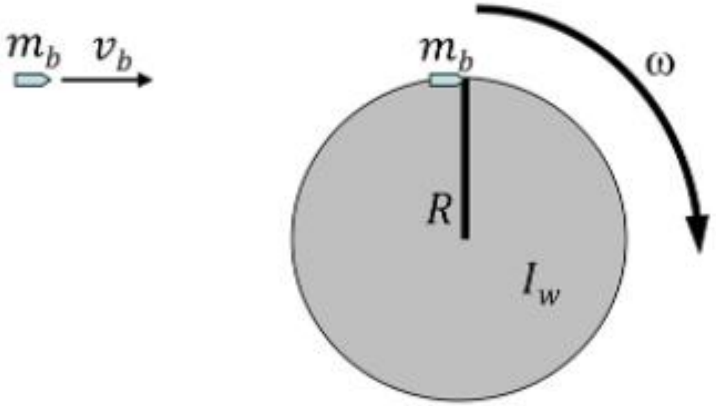
IVET Example Angular Momentum:



IVET Text Option of Problem

Angular Momentum Tutorial 1 Interactive Video-Enhanced Tutorials

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?



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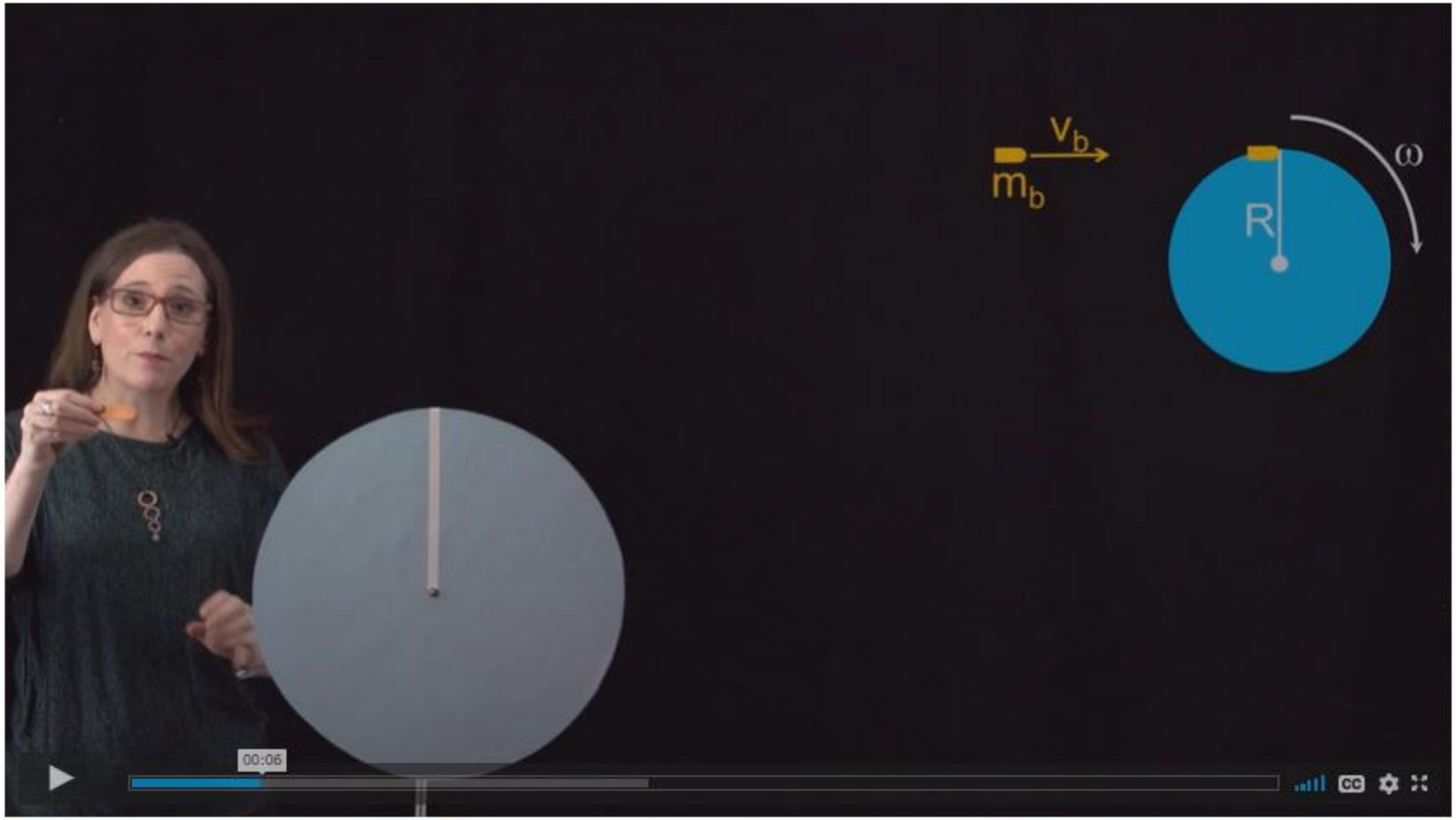
Video Solution: Presenter Walks Through Problem

Angular Momentum Tutorial 1 | **Interactive Video–Enhanced Tutorials**



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Tutorial begins by asking about the system in question

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Q1: What is the system that we want to analyze in this problem?

○ A. Only the wheel.

○ B. Only the bullet.

○ C. Both wheel and bullet taken together.

○ D. All of these are equally good choices.

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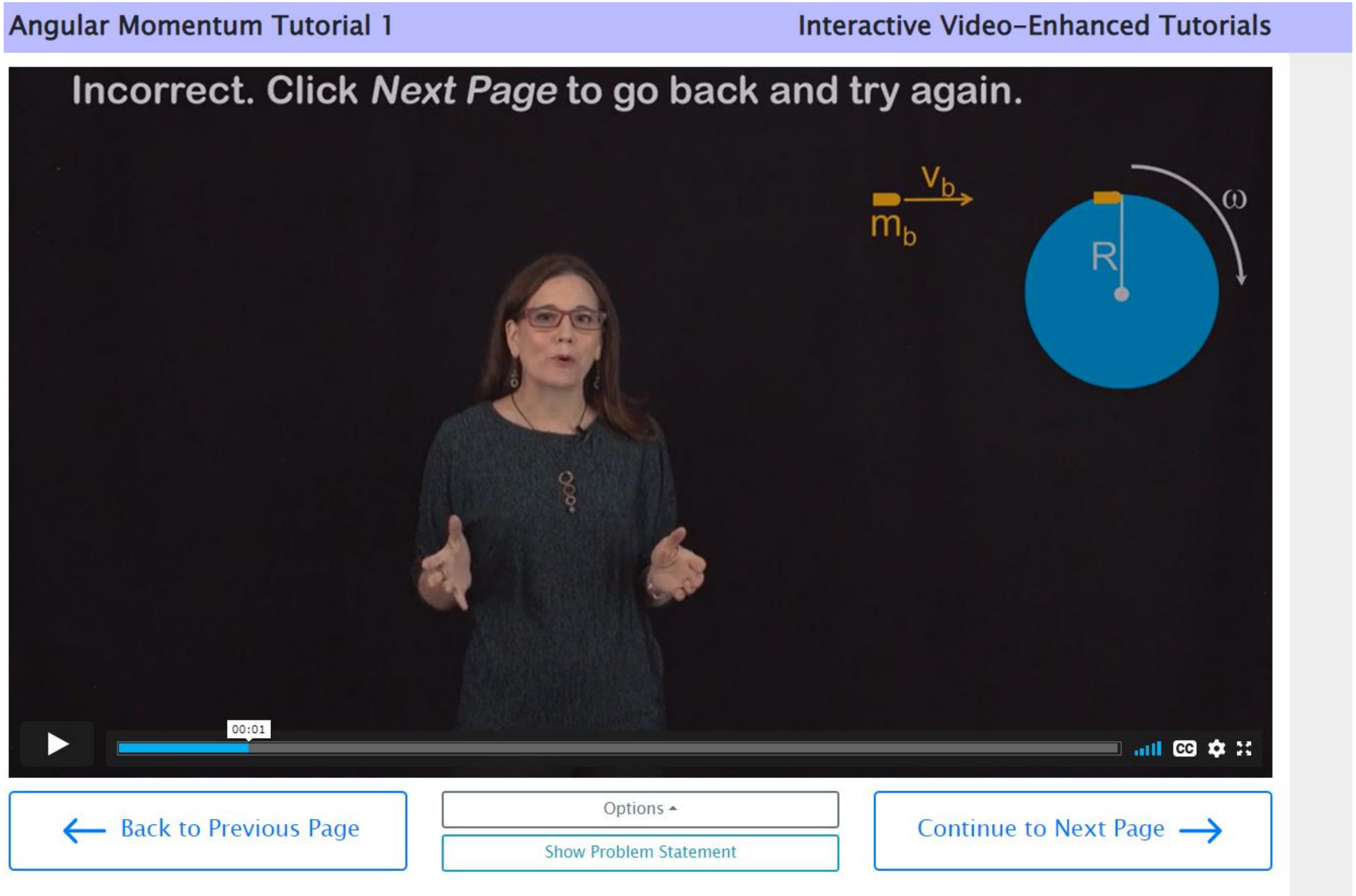
Correct and Incorrect response prompt feedback



Next: Tutorial asks which physics principles are applicable

Angular Momentum Tutorial 1 — **Interactive Video-Enhanced Tutorials**

Q2: Which physics principle can be used to solve this problem? (All symbols have their usual meaning.)

- ○ A. Conservation of Mechanical Energy $E_i = E_f$
- ○ B. Conservation of Linear Momentum $\vec{p}_i = \vec{p}_f$
- ○ C. Conservation of Angular Momentum $\vec{L}_i = \vec{L}_f$
- ○ D. Work-Energy Theorem $W_{total} = K_f - K_i$

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Incorrect answer choices based on common student difficulties

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Q4: What is the magnitude of the angular momentum (L_i) of the system of wheel and bullet about a point on the axle just before the collision between the bullet and wheel in terms of given quantities?

- ○ A. $L_i = 0$ ← No initial angular momentum because nothing is spinning
- ◉ B. $L_i = m_b v_b$ ← Confusing angular momentum with linear momentum
- ○ C. $L_i = m_b v_b R$ ← Correct answer obtained from $\vec{L} = \vec{r} \times \vec{p}$
- ○ D. $L_i = m_b \omega_i$ ← Making superficial connection between linear and angular momentum

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Tutorial responds to student affective states to help with motivation to engage

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How are you feeling right now?

What is this? Why should I answer?

- ○ I feel fine.
- ○ I feel confused.

Please choose the most appropriate response from this list.

- ○ The tutorial is moving too quickly.
- ○ I am having trouble staying focused so I'm not getting the most out of this tutorial.
- ○ This tutorial uses terms that I do not understand.
- ○ The problem-solving approach used here is different from what I learned in class.

- ○ I feel frustrated.
- ○ I feel bored.
- ○ I feel worried.

- ○ None of the choices apply to me.
- ○ I prefer not to answer.

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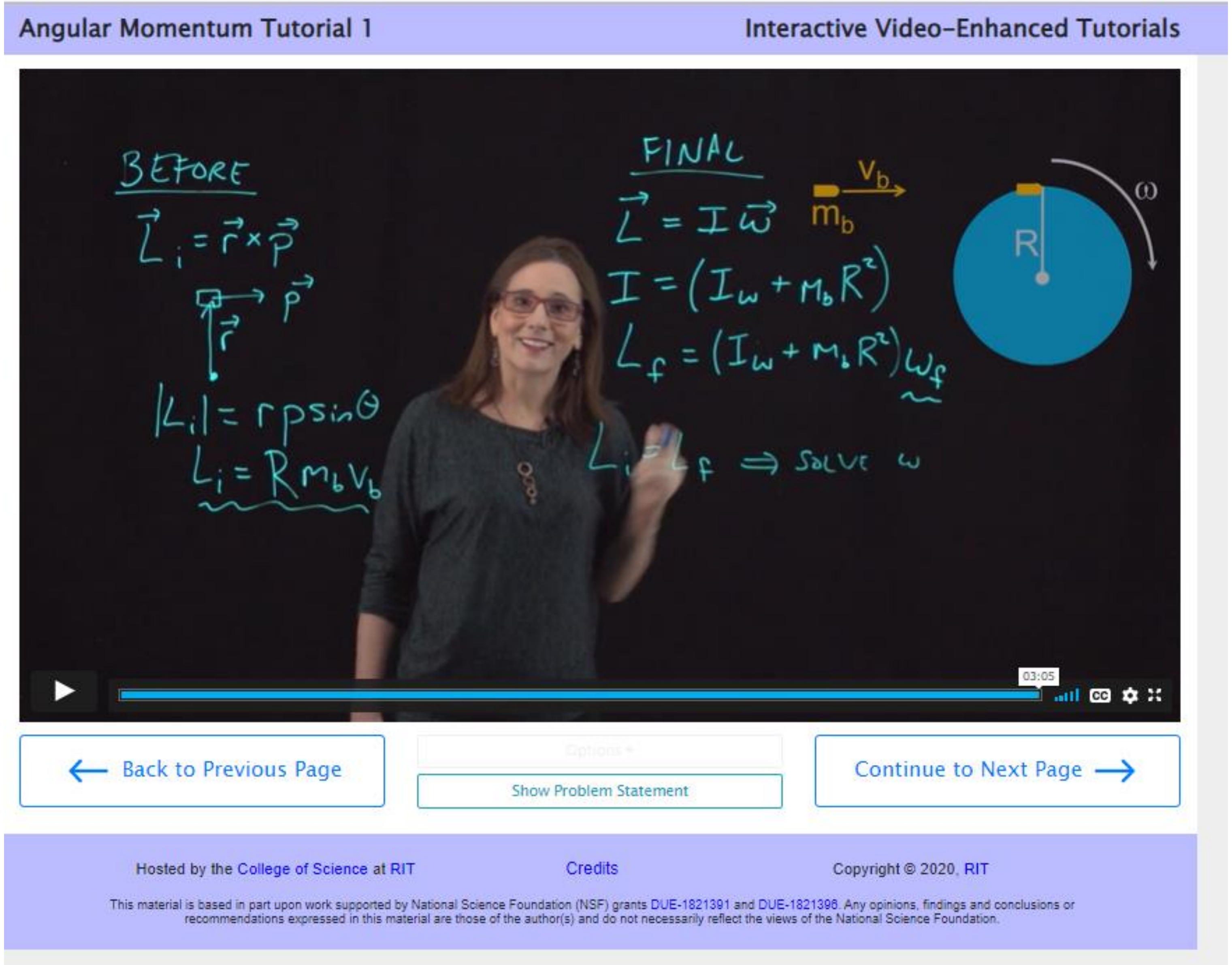
After working through the problem, the tutorial provides one last summary of the solution



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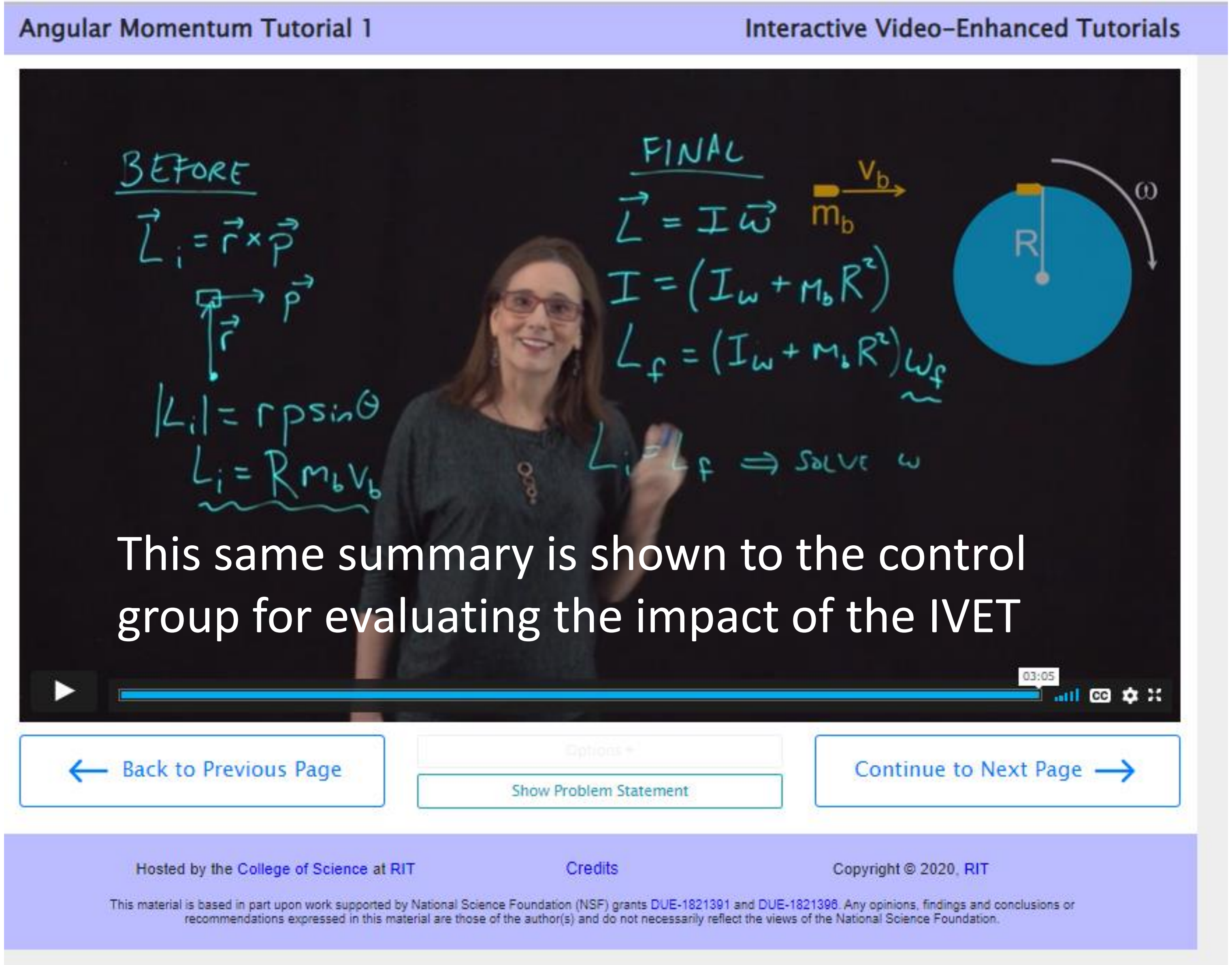


This same summary is shown to the control group for evaluating the impact of the IVET

IVET Implementation

- IVETs were given to students in Introductory Physics at the University of Cincinnati
- Fall Semester 2019 – Algebra Based
  - Two Sections
  - Two Teachers
  - One section is assigned IVET, one section is assigned Video Tutorial
- Fall Semester 2021 – Calculus Based
  - Two Sections
  - One Teacher
  - One section is assigned IVET, one section is assigned Video Tutorial
- Assignment is to complete the tutorial, then a problem is given (as a quiz) in the next class that uses the same principles as the tutorial
- Paired problems are graded with a rubric that accounts for following the steps of the problem-solving strategy

Paired Problem

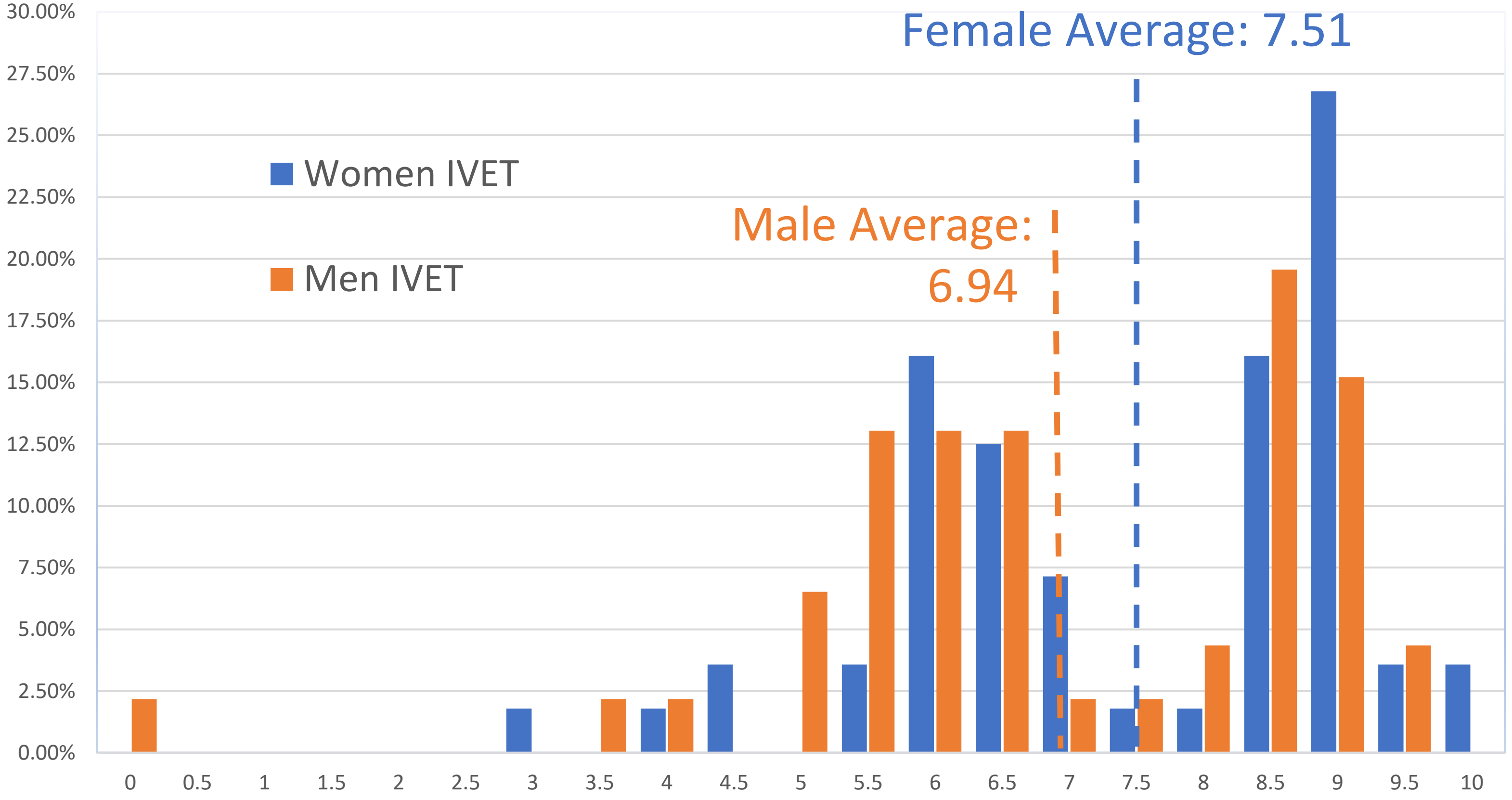
A 20 kg boy stands at the edge of a small stationary (at rest) merry-go-round of radius 2.0 m. The total moment of inertia of the system including the merry-go-round with a fixed axis at the center and the boy standing on the edge is 120 kg m^2. While the merry-go-round is at rest, the boy jumps off in a tangential direction with a linear speed of 1.5 m/s.

Determine the angular speed of the merry-go-round at the instant the boy jumps off

Rubric Used

Problem part/mistake	#of points to add/sub
1. Use conservation of angular momentum	+1 points
1.1 Did not use conservation of angular momentum	-1 point
2. Find initial angular momentum	+1.5 points
2.1 Did not determine that $L_i = 0$	-1.5 points
3. Find final angular momentum	+6 points
3.1 Angular momentum of child	+2 points
3.1.1 Misstates $L_c = r \times p$	-1 point
3.1.2 Misstates $L_c = rmv$	-1 point
3.2 Angular momentum of merry-go-round	+4 points
3.2.1 Misstates $L_{mgr} = I_{mgr}\omega_f$	-1 point
3.2.2 Misstates $I_{total} = I_{mgr} + I_{child}$	-1 point
3.2.3 Misstates $I_{child} = m_{child}R^2$	-1 point
3.2.4 Has incorrect signs	-1 point
4. Find the answer	+1.5 points
4.1 Incorrect ω_f	-1 point
4.2 Incorrect/no units for ω_f	-0.5 point

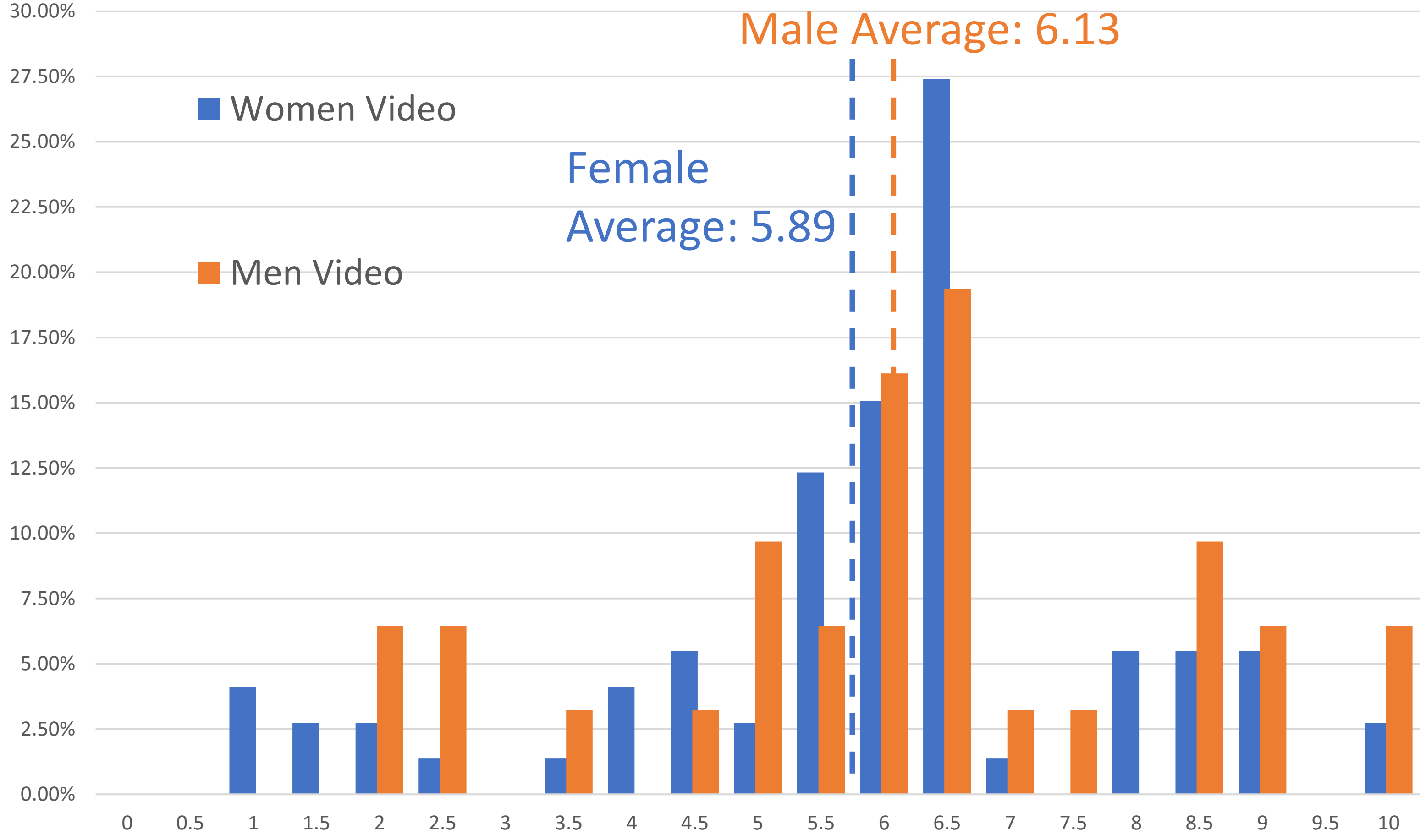
Fall 2019 Results: Students Given IVET



Exam 3 Average
Male 78.45%
Female 64.84%
Effect Size .789 (Favors Male)
P-Value 0.016

P-Value: .120
Effect Size: - 0.315 (Favors Female)

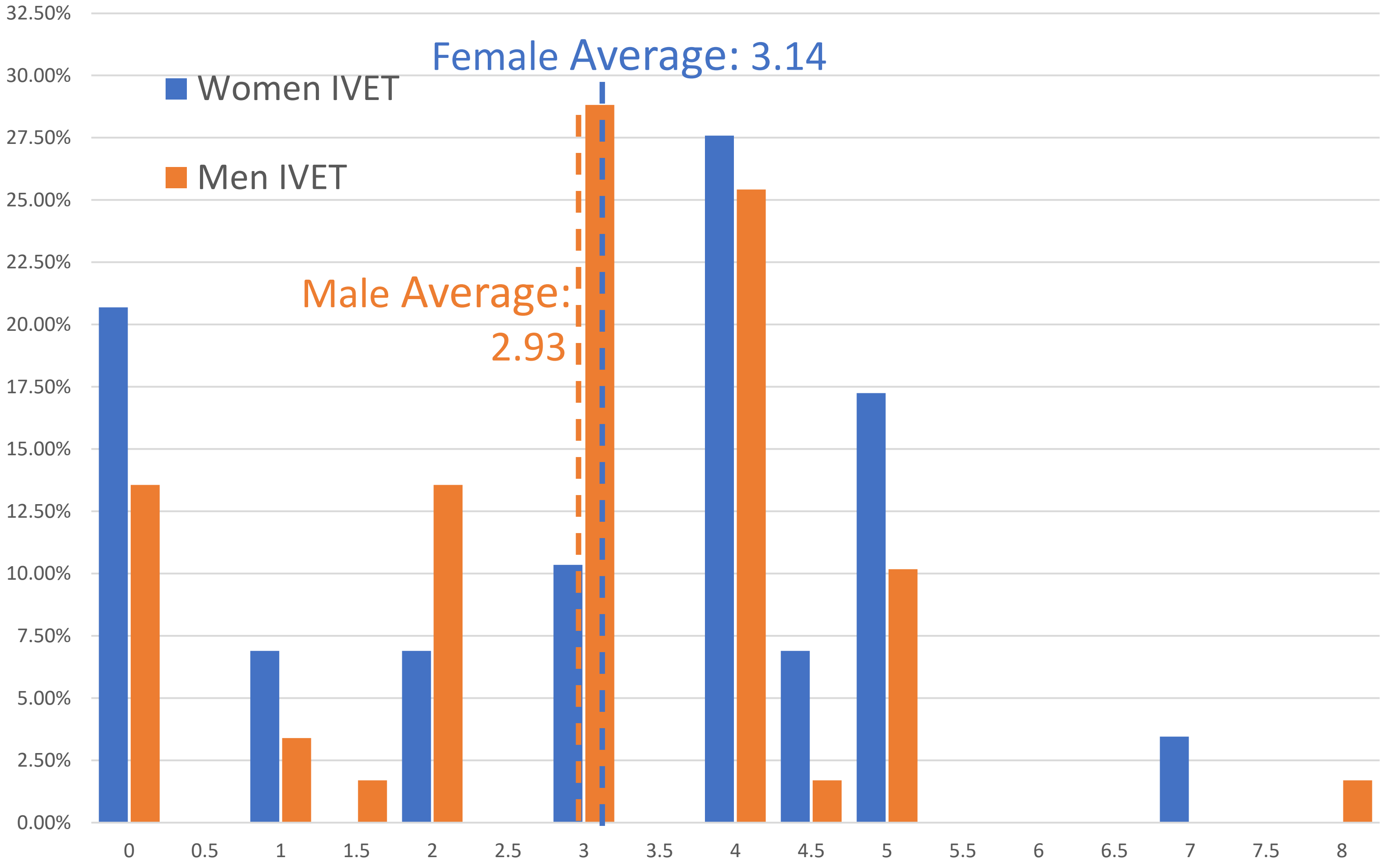
Fall 2019 Results: Students Given Video



P-Value: 0.747
Effect Size: 0.116 (Favors Male)

Exam 3 Average
Male 78.39%
Female 76.45%
Effect Size 0.117 (Favors Male)
P-Value 0.600

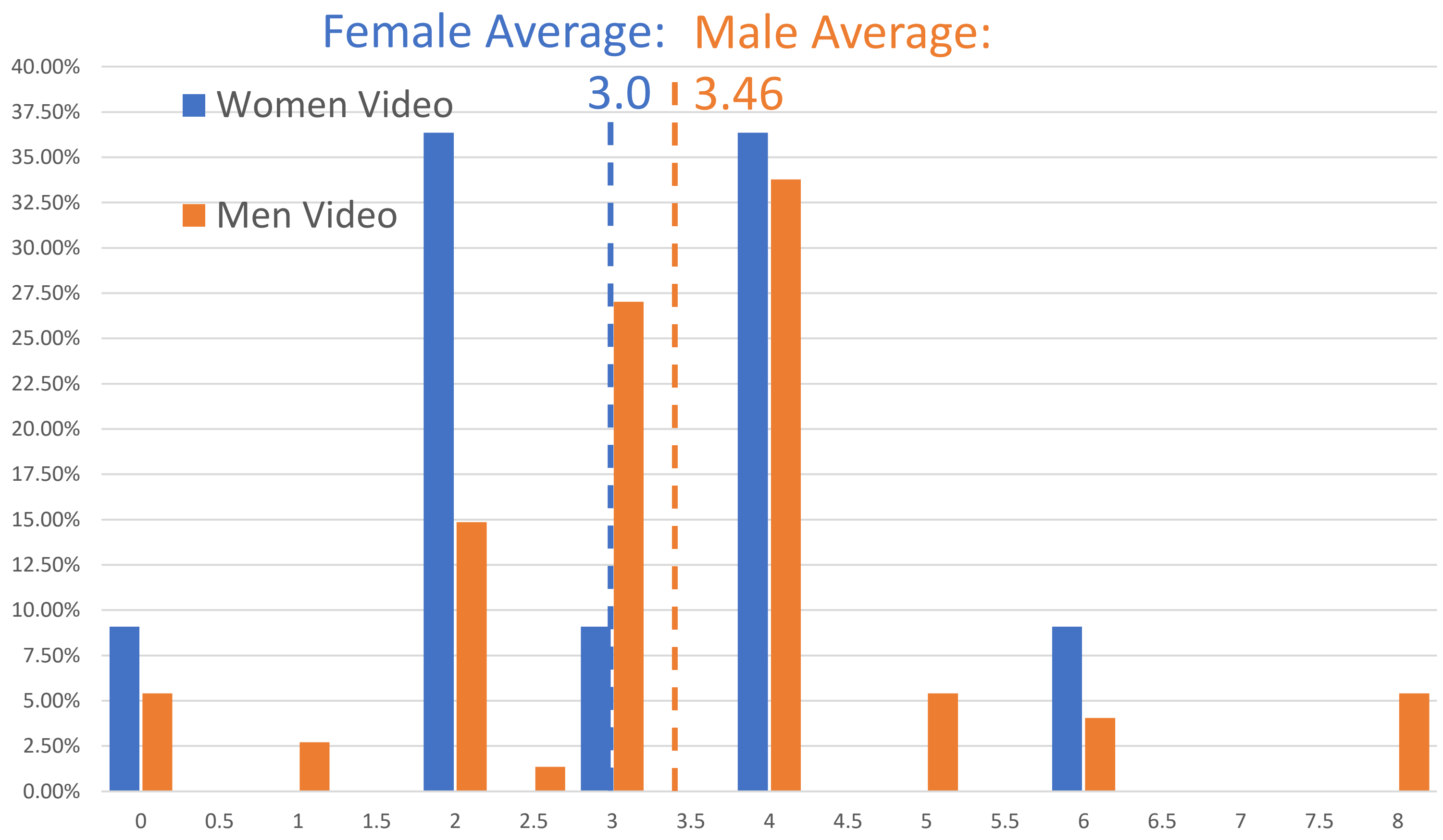
Fall 2021 Results: Students Given IVET



Exam 3 Average
Male: 73.11%
Female: 73.01%
Effect Size: .023 (Favors Male)
P-Value: 0.918

P-Value: 0.813
Effect Size: - 0.117 (Favors Female)

Fall 2021 Results: Students Given Video



Exam 3 Average
Male: 81.29%
Female: 78.77%
Effect Size: 0.174 (Favors Male)
P-Value: 0.575

Only 11 female students watched the video

P-Value: 0.390
Effect Size: 0.283 (Favors Male)

We have developed and evaluated IVETs involving

- 1D Kinematics
- 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)
- Torque and Rotation
- Thermal Energy Transfer

Ivet.rit.edu/IVET

Under Development

- Adding Vectors
- Projectile Motion ("monkey gun" demonstration)
- Conservation of Energy (use of bar charts)
- Circular Motion
- Fluid Mechanics
- Thermal Processes and Laws of Thermodynamics

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

Conclusions

- On exam following IVET, male students performed better than female students (moderate effect size)
- On IVET this effect size flipped showing women performing slightly better on the paired problem
- In Video group, the effect size remains about the same (slightly favoring male students)
- This suggests that IVET helped address the gender gap

Questions?