Teaching Problem Solving in One-Dimensional Kinematics Using Interactive Video-enhanced Tutorials (IVETs)

Kathleen Koenig, Alexandru Maries, Lora Sheppard
University of Cincinnati

Robert Teese
Rochester Institute of Technology

NSF IUSE DUE 1821396 and 1821391

Project Goals

- Create and evaluate a set of 30 IVETs (one/chapter)
  - guided problem-solving tutorials
  - enable personalized instruction
- Conduct research on
  - impact of IVETs on student problem solving abilities
  - techniques that motivate appropriate student behavior when using IVETs
- Disseminate IVETs and Java app to create own
  - ivet.rit.edu/IVET

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Features of Design of IVETs

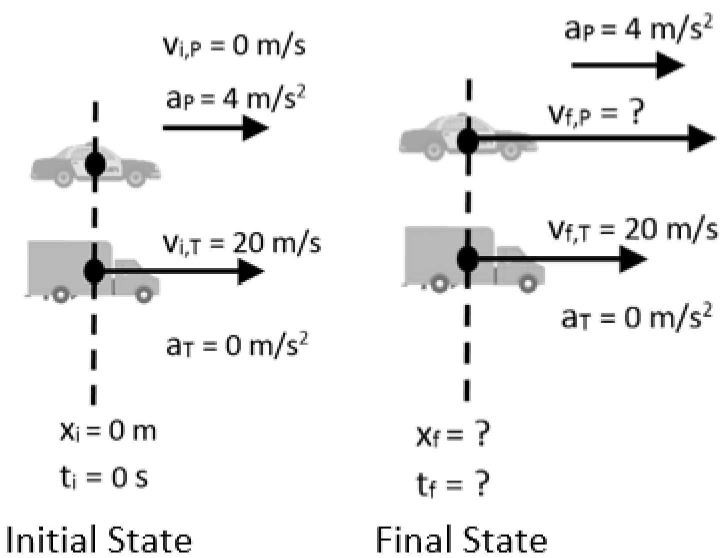
- Developed based on multimedia learning principles (Mayer) and research on human learning and memory (Bransford)
- Mini-lectures, hints, or encouragement (affect) by a tutor (a real person in a video), and multiple-choice questions guide students through an ***effective* problem-solving approach** (e.g.,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

Choose a problem that is challenging to most students

A truck is moving at a constant velocity of 20.0 m/s along a long, straight road for which the legal speed limit is 35 mi/h. At the instant when the truck passes a stationary police car that is parked at rest along the road, the police car begins to accelerate with a constant acceleration of 4.00 m/s^2 in the same direction as the truck. The truck continues to move at its same constant velocity.

At what time and position will the police car catch the truck?

Identify Essential Steps (decision points)



1. Be able to identify and draw the initial and final conditions for solving the problem.
2. Identify what "catch" means (i.e. recognize $x_{f,T} = x_{f,P}$ at time t_f which is same for both).
3. Use Kinematic equations to determine an expression for $x_{f,T}$ at time t_f.
4. Use Kinematic equations to determine an expression for $x_{f,P}$ at time t_f.
5. Recognize need to set expressions equal to one another (i.e. set $x_{f,T} = x_{f,P}$) to solve for t_f.

6. Use quadratic eqn to solve for t_f and choose the appropriate t_f solution.

7. Use the calculated t_f to find x_f for one vehicles. Recognize x_f is same for both vehicles.

This is the problem we are solving:

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Show Problem Statement

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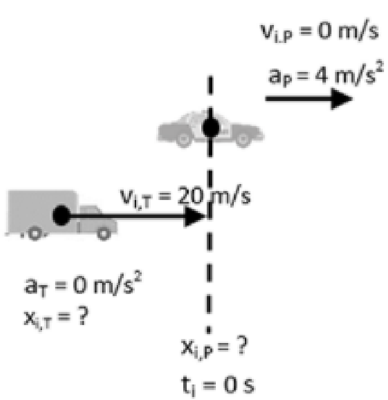
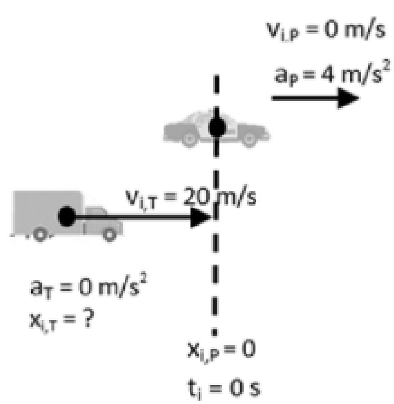
Q1. Which of the following sketches of the initial state (t_i = 0 s) of the problem will be most useful for solving this problem? Subscript T is used for the truck and P is for the police car. The positive x-direction is to the right.

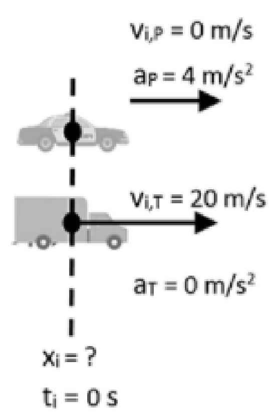
○ A.



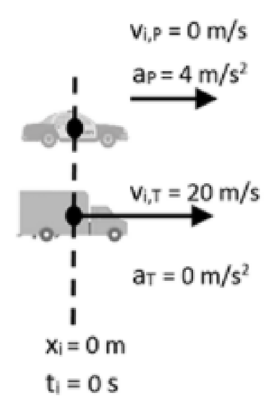
○ B.



○ C.



○ D.

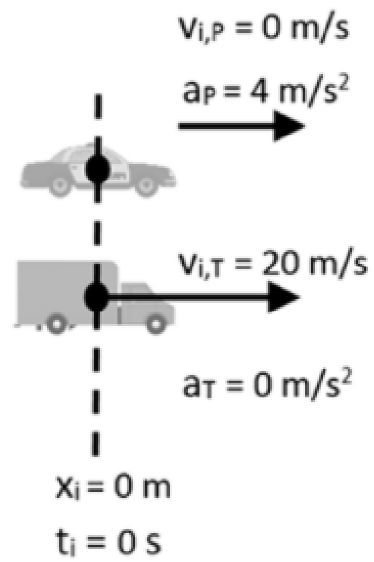


Feedback provided for incorrect and correct responses

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

Correct. Click the Next Page button to continue.

Correct! For the initial state, it makes sense to choose the instant when the truck is passing the police car, which is at rest. It also makes sense to label this position as xi = 0 m. These choices are made to reduce the number of unknowns, making the problem solvable. As shown on the diagram, all of the quantities of the initial position are known. Be sure to update the diagram in your notes before moving on to the next question.



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Show Problem Statement

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Q3. Mathematically, what does it mean for the police car to "catch" the truck?

- ○ A. Both vehicles stop, so our earlier diagram should have $v_{f,T} = 0$ and $v_{f,P} = 0$ at time t.
- ○ B. The police car reaches the same velocity as the truck, so $v_{f,T} = v_{f,P}$ at time t.
- ◉ C. The police car reaches the same location as the truck, so $x_{f,T} = x_{f,P}$ simultaneously at time t.
- ○ D. The police car reaches the same location and velocity as the truck at time t.
- ○ E. The front of the police car reaches the back of the truck, so $x_{f,T}$ = "one vehicle-length" + $x_{f,P}$ at time t.

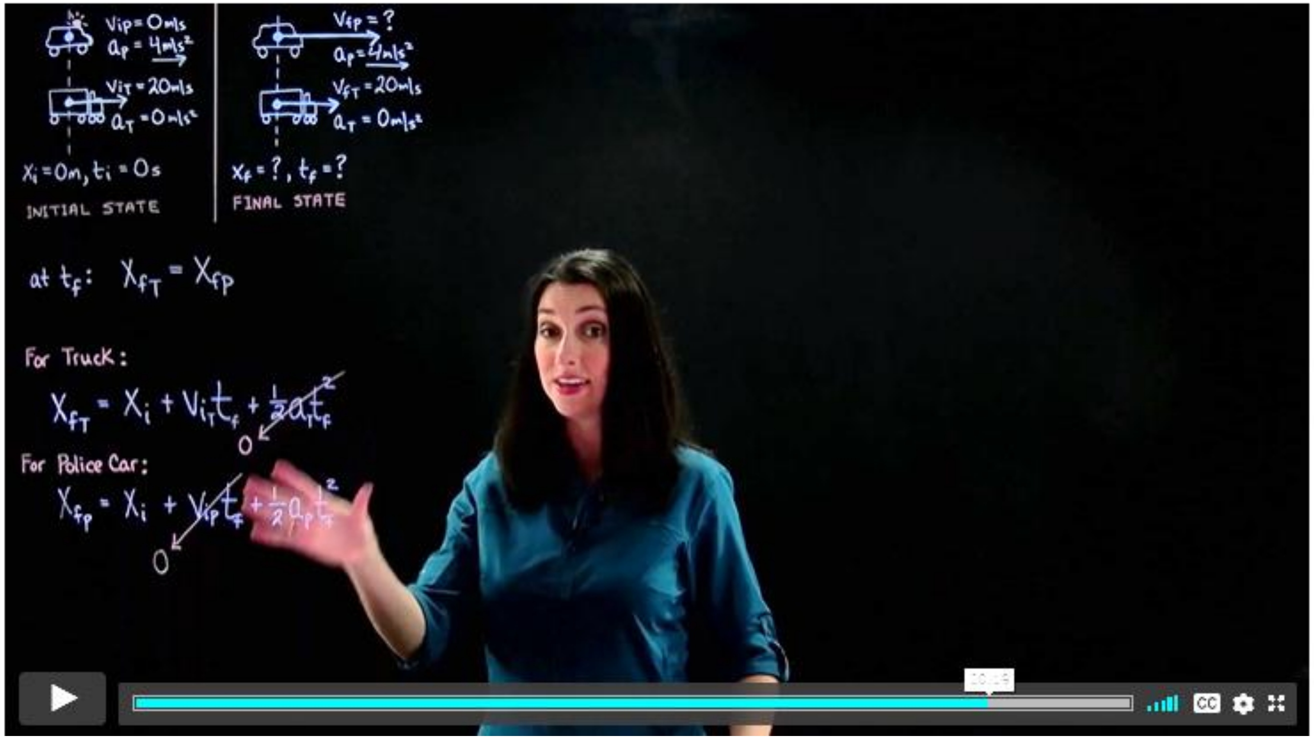
Q4. Which kinematics equation is most likely to be useful for helping us determine the final position of the truck at time t_f?

○ A. $v_f = v_i + at$

○ B. $x_f = x_i + v_i t + ½at^2$

○ C. $v_f^2 = v_i^2 + 2a(x_f - x_i)$

○ D. None of the above because the truck has an acceleration of zero.



Q6. Setting the two kinematic equations for $x_{f,T}$ and $x_{f,P}$ equal to each other at time t_f, and then simplifying, we obtain:

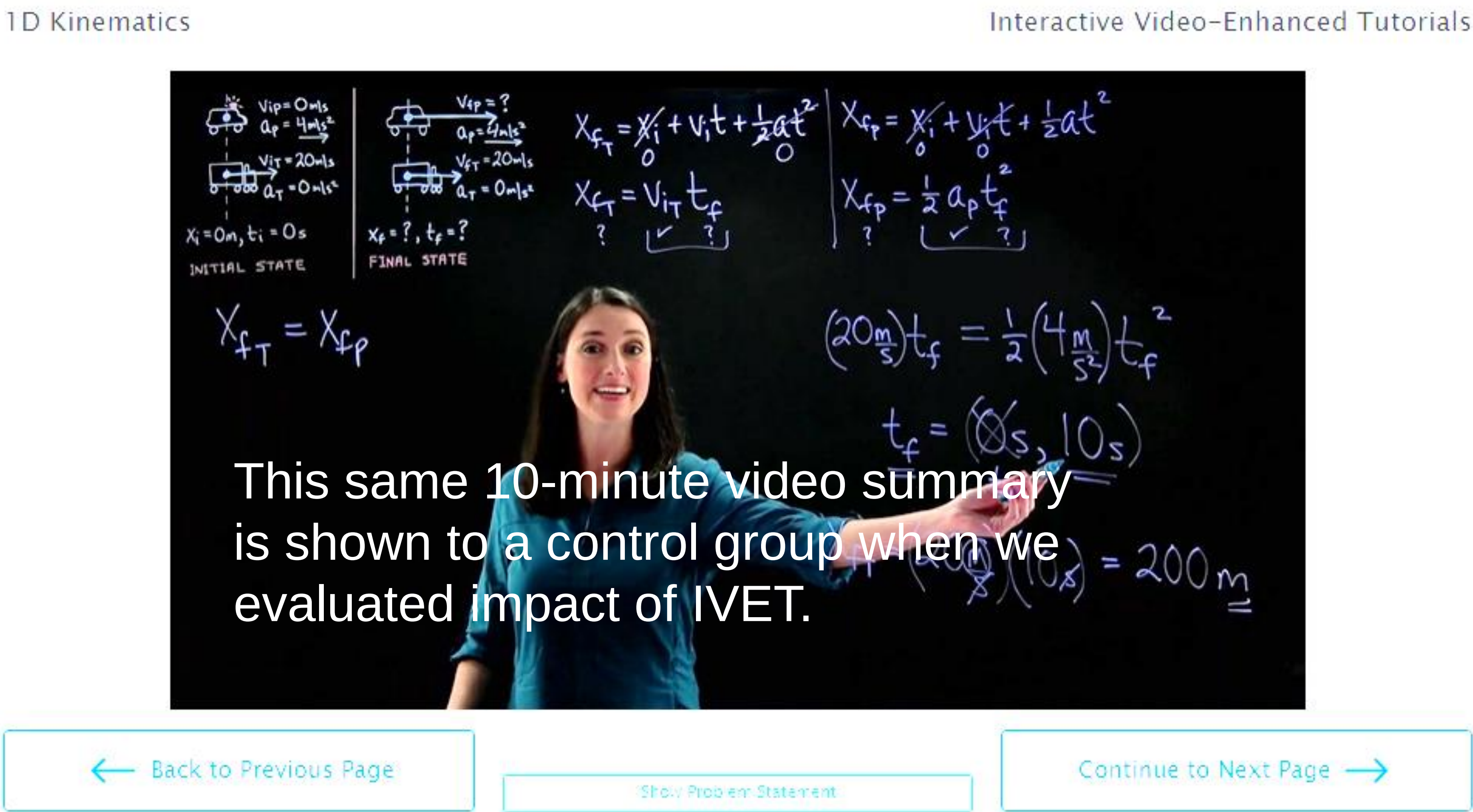
○ A. (20.0 m/s)$t_{f,T}$ = ½(4.00 m/s^2)$t_{f,P}^2$ where $t_{f,T} \neq t_{f,P}$

○ B. (20.0 m/s)$t_{f,T}$ = ½(4.00 m/s^2)$t_{f,P}^2$ where $t_{f,T} = t_{f,P}$

○ C. (4.0 m/s^2)$t_{f,T}$ = ½(20.0 m/s) $t_{f,P}^2$ where $t_{f,T} \neq t_{f,P}$

○ D. (4.0 m/s^2) $t_{f,T}$ = ½(20.0 m/s) $t_{f,P}^2$ where $t_{f,T} = t_{f,P}$

Students given option to watch a video summary before they are given a problem to try on their own.



This same 10-minute video summary is shown to a control group when we evaluated impact of IVET.

Does IVET impact student problem-solving ability?

Two sections of calculus-based physics included in study FS21

- One section assigned Kinematics IVET to complete at home
- One section assigned to watch the same 10-minute video solution in the IVET

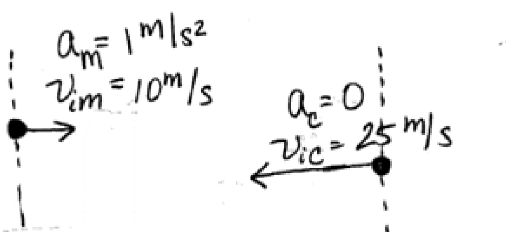
Both the IVET and Video groups were given a follow up problem to complete in class the day the assignment was due.

Assessing Impact: Follow Up Problem

A motorcycle is moving at a constant velocity of 10 m/s to the East (right). A car is moving towards the motorcycle, and the car is moving at a constant velocity of 25 m/s to the West (left). When they are at a distance of 2000 m apart, the motorcycle begins to accelerate at 1 m/s².

a. Where do the two vehicles pass each other?
b. What is the speed of the motorcycle when this happens?

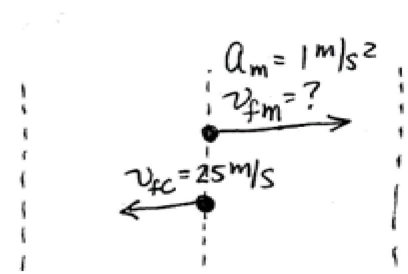
Show your work for both questions below and circle your final answers.



$x_{i,M} = 0$ $x_{i,C} = 2000$ m

$t_i=0$

Initial State

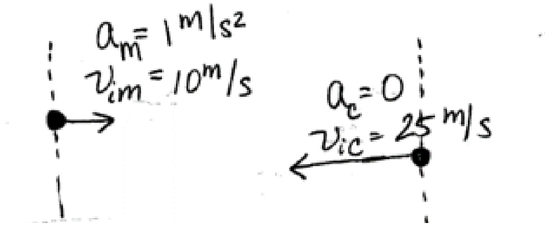


$x_f = ?$

$t_f = ?$

Final State

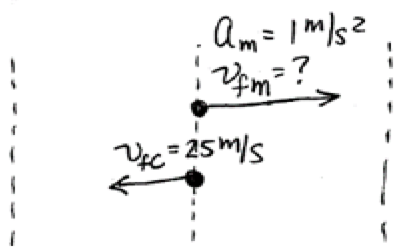
Identify Essential Steps & Create Rubric



$x_{i,M} = 0$ $x_{i,C} = 2000$ m

$t_i=0$

Initial State



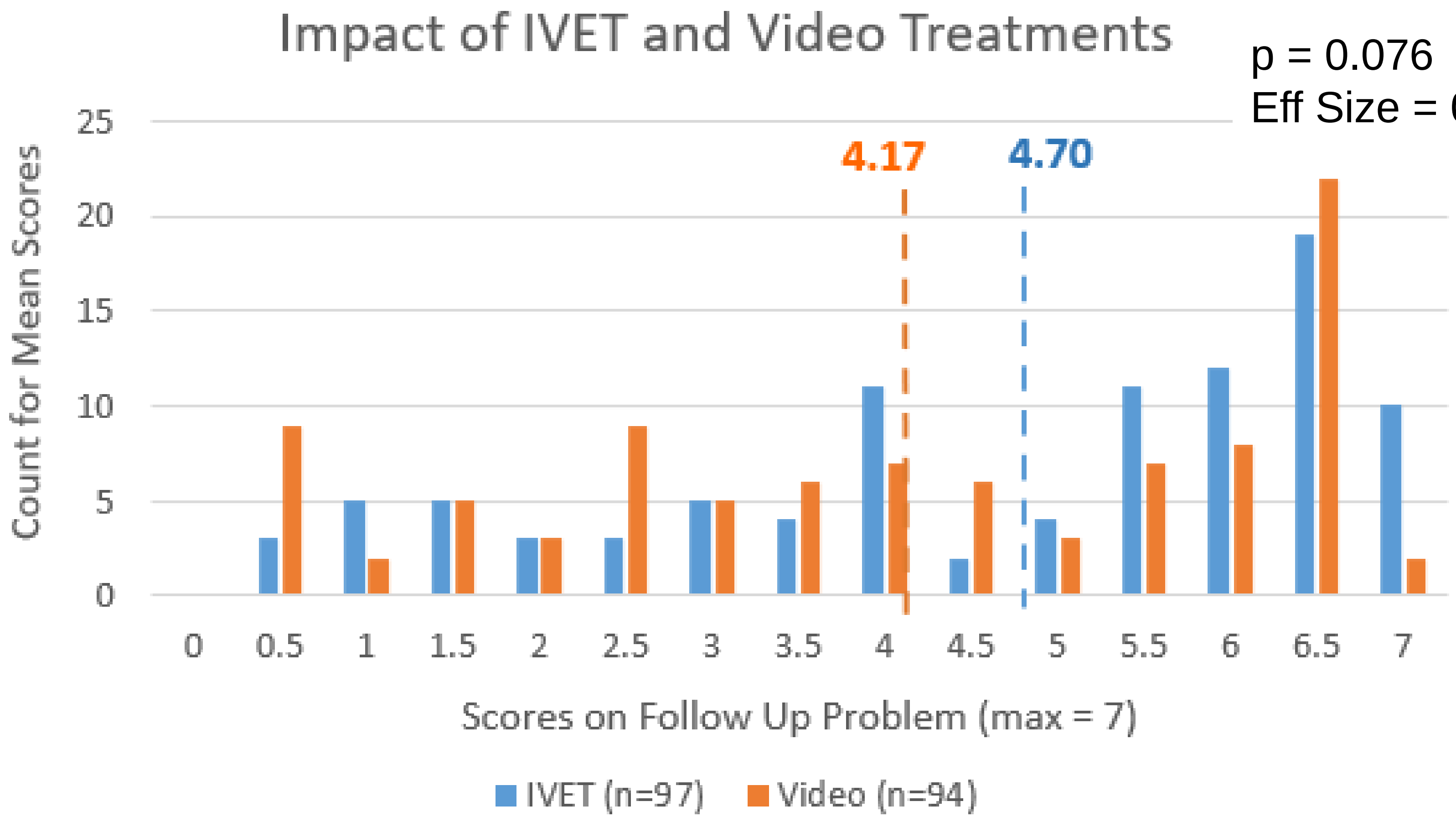
$x_f = ?$

$t_f = ?$

Final State

1. Be able to identify and draw the initial and final conditions for solving the problem.
2. Identify what "pass" means (i.e. recognize $x_{f,M} = x_{f,C}$ at time t_f which is same for both).
3. Use Kinematic equations to determine an expressions for $x_{f,M}$ and $x_{f,C}$ at time t_f.
4. Recognize need to set expressions equal to one another (i.e. set $x_{f,M} = x_{f,C}$) to solve for t_f.
5. Use quadratic eqn to solve for t_f and choose the appropriate t_f solution.
6. Use calculated t_f to find x_f for where vehicles pass.
7. Use calculated t_f or $x_{f,m}$ to determine $v_{f,m}$.

Results of Scoring Follow Up Problem



p = 0.076
Eff Size = 0.259

Note: Exam 1 Avg IVET group = 75.2%
Exam 1 Avg Video group = 84.5%

p < 0.001
Eff Size = -0.602 (favors Video group)

Range of solutions presented

IVET (n=97)	Video (n=94)	None (n=46)	Code Description
40%	32%	26%	Correct (includes minor math errors)
95%	93%	89%	Drew/indicated initial state for problem
31%	4%	9%	Drew/indicated final state for problem
93%	98%	63%	Recognized x(f,m) = x(f,car)
5%	19%	13%	Selected kinematic equation w/too many unknowns
9%	15%	33%	Appeared to have no idea (not included in line above)

Not included in table:
32% of IVET group struggled with how to handle the 2000 m distance between the two vehicles moving towards one another.

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)
- Angular Momentum (bullet shot into wheel)
- Torque and Rotation
- Thermal energy transfer

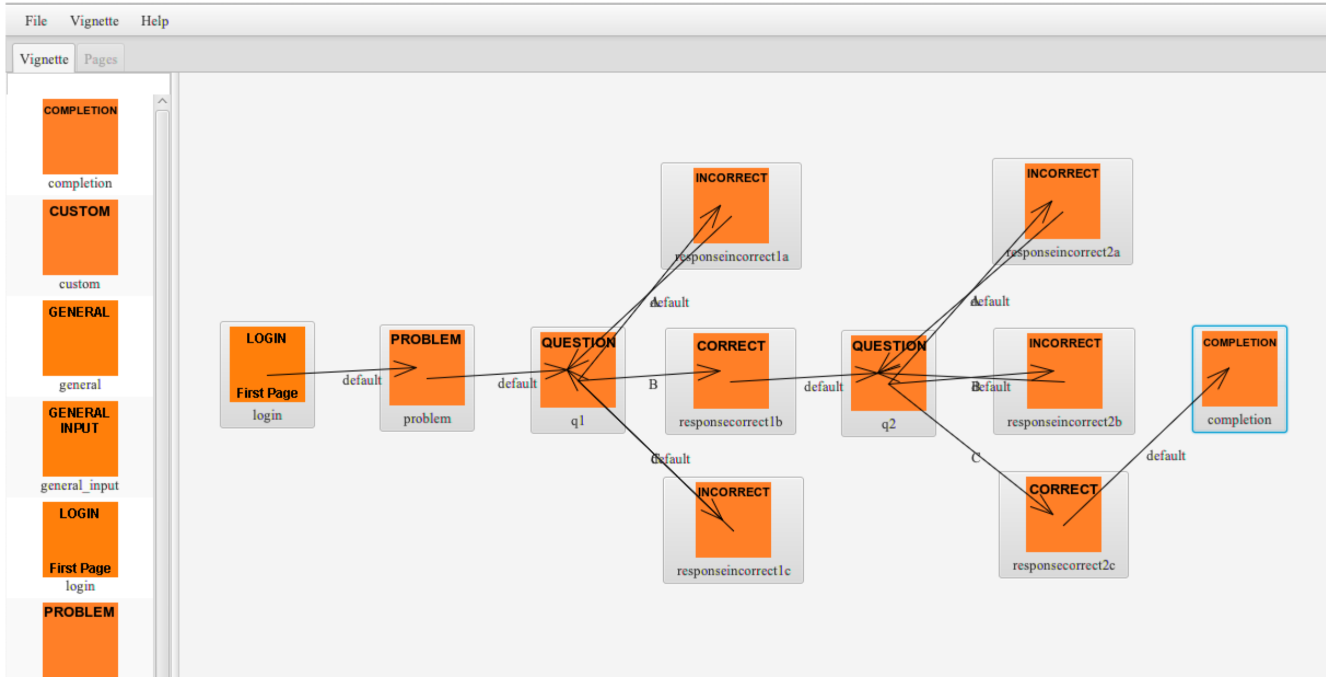
ivet.rit.edu/IVET

Under development:

- Adding vectors
- Projectile Motion ("monkey gun" demonstration)
- Conservation of Energy (use of energy 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.

Vignette Studio II



- A desktop application for authoring IVETs and similar online activities
- Easy to use if you know a little about HTML
- Activities you make with Vignette Studio II can be uploaded to most Learning Management Systems (Blackboard, Canvas, Moodle…)
- Free to download and use:

ivet.rit.edu/IVET

Thank you! Any Questions? kathy.koenig@uc.edu