Virtual Reality Experiments in Introductory Physics Laboratories

Dedra Demaree,
Stephen Stonebraker
and Lei Bao,
The Ohio State University

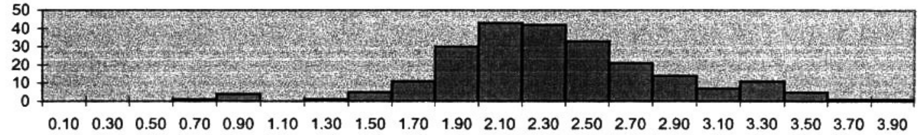
Problems with Traditional Introductory Labs:

- Students rank lab as the least helpful component to the introductory physics courses at The Ohio State University (OSU), despite them being PER-based *

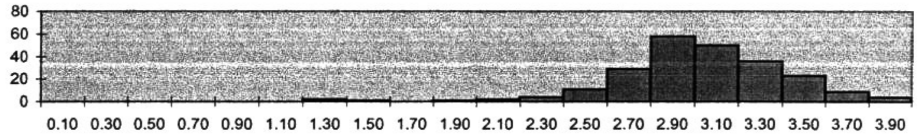
*D. J. VanDomelen and A. Van Heuvelen, *Am. J. Phys.* 70, 7 (2002.)

Average student ratings for various components of 131 from '96 to '02

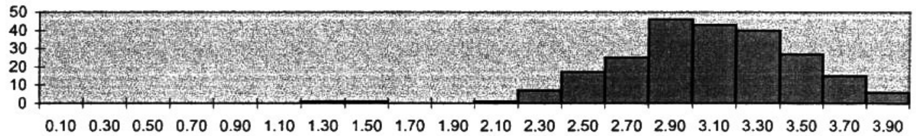
16.) Value of the laboratory as part of this course.



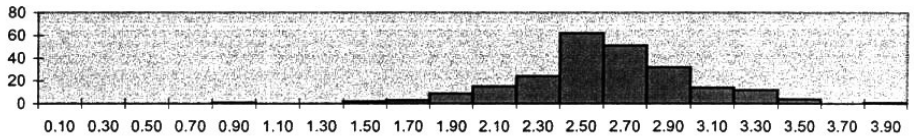
17.) Value of the homework as part of this course.



18.) Value of the recitation section as part of this course.



19.) Quality and value of the textbook.



Problems with Traditional Introductory Labs (continued):

- Traditional lab experiments have inherent error for any measurement, which can cause student frustrations if not properly addressed
- Students tend to be overconfident, despite missing fundamental concepts covered in lab (this is not helped by the fact that lab does not directly relate to exams)

What information do we gain from previous PER activities:

- Active engagement computer-based activities have been shown to be much more effective than passive programs *
- FCI gains can improve significantly with the replacement of only one traditional lab with a PER-based activity **
- One must be careful even when using effective activities to make sure students don't view the output as authoritative ***

* R. K. Thornton and D. R. Sokoloff, *Am. J. Phys*., 58, 9 (1990).
E. F. Redish, J. M. Saul and R. N. Steinberg, *Am. J. Phys*., 65, 1 (1997).
F. Reif and L. A. Scott, *Am. J. Phys. Suppl*., 67, 7 (1999).
** D. S. Abbott, J. M. Saul, G. W. Parker and R. J. Beichner, *Phys. Educ. Res., Am. J. Phys. Supl*. 68, 7 (2000).
*** R. N. Steinberg, *Phys. Educ. Res., Am. J. Phys. Suppl*. 68, 7 (2000).

How can Virtual Reality (VR) help with these problems:

- VR allows for the study of things not easily possible with traditional equipment
  - Fast processes can be slowed down
  - Very large and very small scales can be observed
- The VR environment can be fully controlled – all parameters are adjustable
  - This allows for careful exploration of phenomenon
  - Parameters such as friction can be turned off and on allowing students to clearly contrast the resulting behavior

How can Virtual Reality (VR) help with these problems (continued):

- Using a joystick mimics playing a video game, which prompts students to use the VR
  - Overconfident students will repeat exercises using VR because they are fun – this may help them catch their misconceptions
  - Students often challenge each other to see who can best control the motion of an object, or try to get a strange effect to occur – this adds to the learning experience
- VR is fun and engaging, while providing a learning experience for the students
  - This can improve student attitudes towards labs
  - This may also improve student attitudes towards physics, which can lead to increased learning *

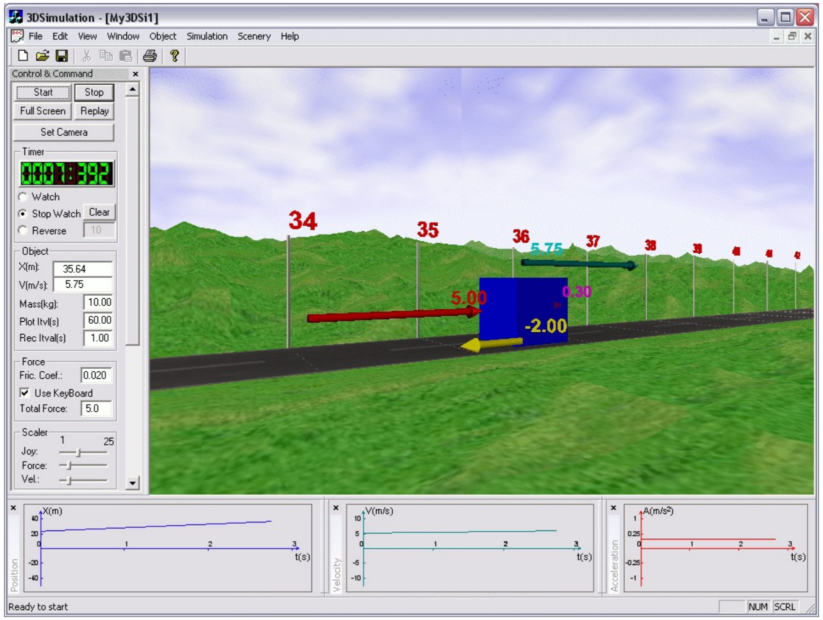
* E. F. Redish, J. M. Saul and R. N. Steinberg, Am. J. Phys. 66, 3 (1998).

How is OSU’s VR different from other computer-based experiments?

- The VR program is manipulated using a touch-sensitive joystick
  - If the student pushes harder a larger force is applied to the object in the simulation
  - Students can apply a controlled force at a distance and instantly see how their force affects the motion of an object
  - The VR output is direct physical reactions to student input, it is not authoritative

The Linear Motion VR lab:

- Students probe Newton's 2nd law using a joystick to exert an external force on the block
- The initial conditions, mass of the block and coefficient of friction can all be easily adjusted by the user
- The force diagram, velocity and acceleration vectors, and motion graphs for the block can all be displayed in real time
- Exercises using the software were integrated into the existing lab on Newton's 2nd law that uses physical carts on tracks



Screen shot of the Linear Motion VR interface

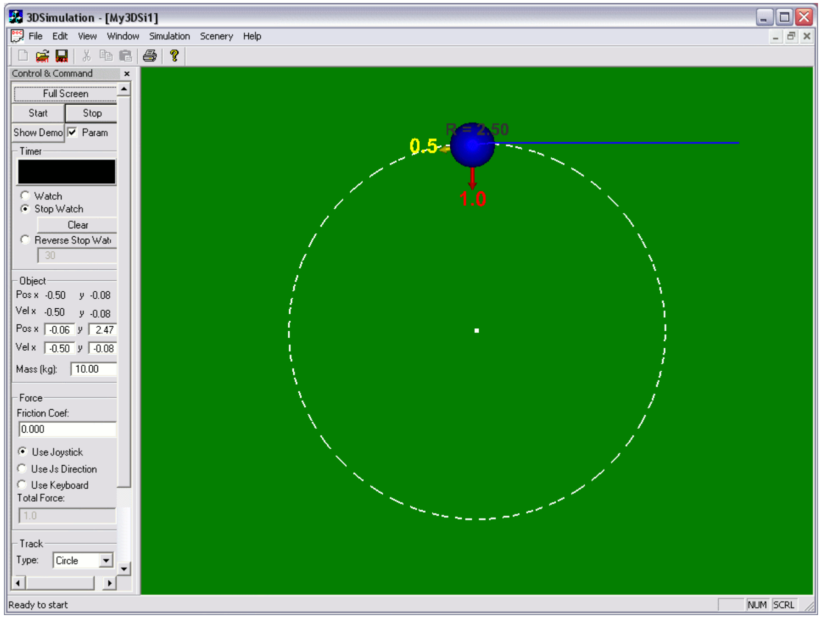
The Circular Motion VR lab:

• Students probe central forces by exerting the appropriate external force necessary to cause the ball to execute uniform circular motion

•The radius of the desired circular path and the coefficient of friction can be adjusted

•The external force, velocity, and acceleration vectors are displayed in real time

•Since no previous circular motion lab was in use, a completely new lab was developed making use of this software



Screen shot of the Circular Motion VR interface

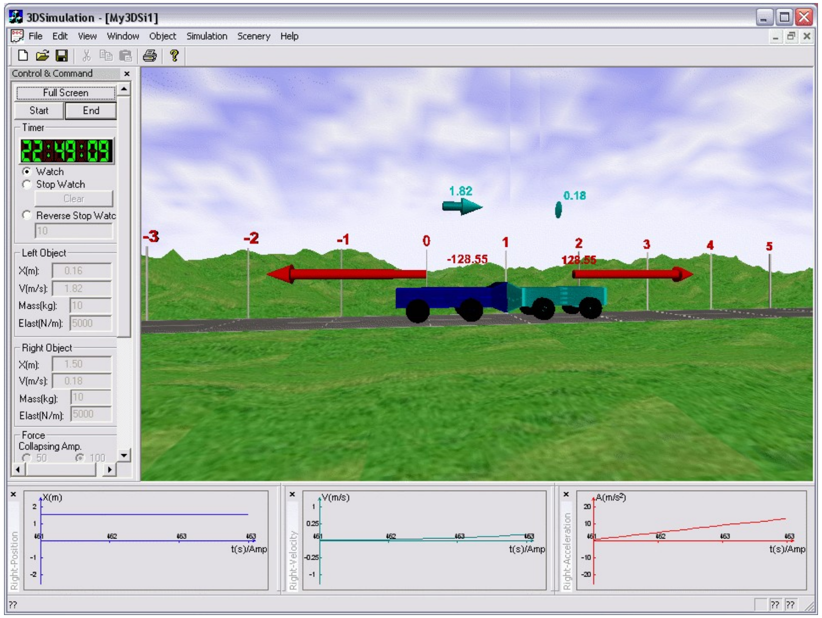
The Collisions VR lab:

• Students study impulse and momentum using the collisions VR software

• The initial conditions, the coefficient of friction and the elasticity of the bumpers can be set by the user

•The force diagram, velocity and acceleration vectors, and motion graphs for both carts can be displayed in real time

•A completely new lab was developed to make use of the explicit view of the forces during the collision provided by the software *



Screen shot of the Collisions VR interface

* Many ideas for this lab came from "Five Easy Lessons " by R. D. Knight

Testing the effectiveness of the new VR labs:

- Students were split into two groups: the Linear VR group and the Collisions VR group
  - The Linear VR group did the new Linear Motion VR lab and the old collisions lab – this group contained 136 students
  - The Collisions VR group did the new Collisions VR lab and the old linear motion lab – this group contained 118 students
  - Both groups also did the Circular Motion VR lab
- The FCI was given as a pre- and post-test
- Three sets of 3 additional problems were given at the start of the quarter and again the week after each respective lab
- A qualitative feedback questionnaire was given at the end of the quarter

Preliminary quantitative results:

- The Linear VR group had an average 11% higher normalized gain on questions 25 and 26 (these are very similar to activities performed with the joystick)
- The Collisions VR group had an average 12% higher normalized gain on FCI questions 4, 15, 16 and 28 (all pertaining to Newton's 3rd law)
  - This last result may very well be caused in part by the completely new structure of the VR lab, and not just the VR software

Preliminary qualitative results:

- 95% of students in the Linear VR group found the joystick more helpful than traditional lab equipment for understanding how force affects motion
- 80% of the students in the Collision VR group also preferred the joystick, despite using it much less than the other group
- Many students voluntarily suggested that increasing the amount of VR labs would be a good way to improve the course
- Lab instructors noticed a higher level of excitement in the students when they used the VR equipment

Preliminary qualitative results (continued):

- Students were asked about their preference between traditional and VR labs
  - Students only slightly prefer the VR labs; *however*, students strongly prefer a small specific subset of the traditional labs called “experiment problems” (designing their own experiment to determine an unknown quantity)
  - The VR labs are a close second in preference after the experiment problem labs, and are far preferable to the standard traditional labs

Motivations for a mix of traditional labs with VR experiments:

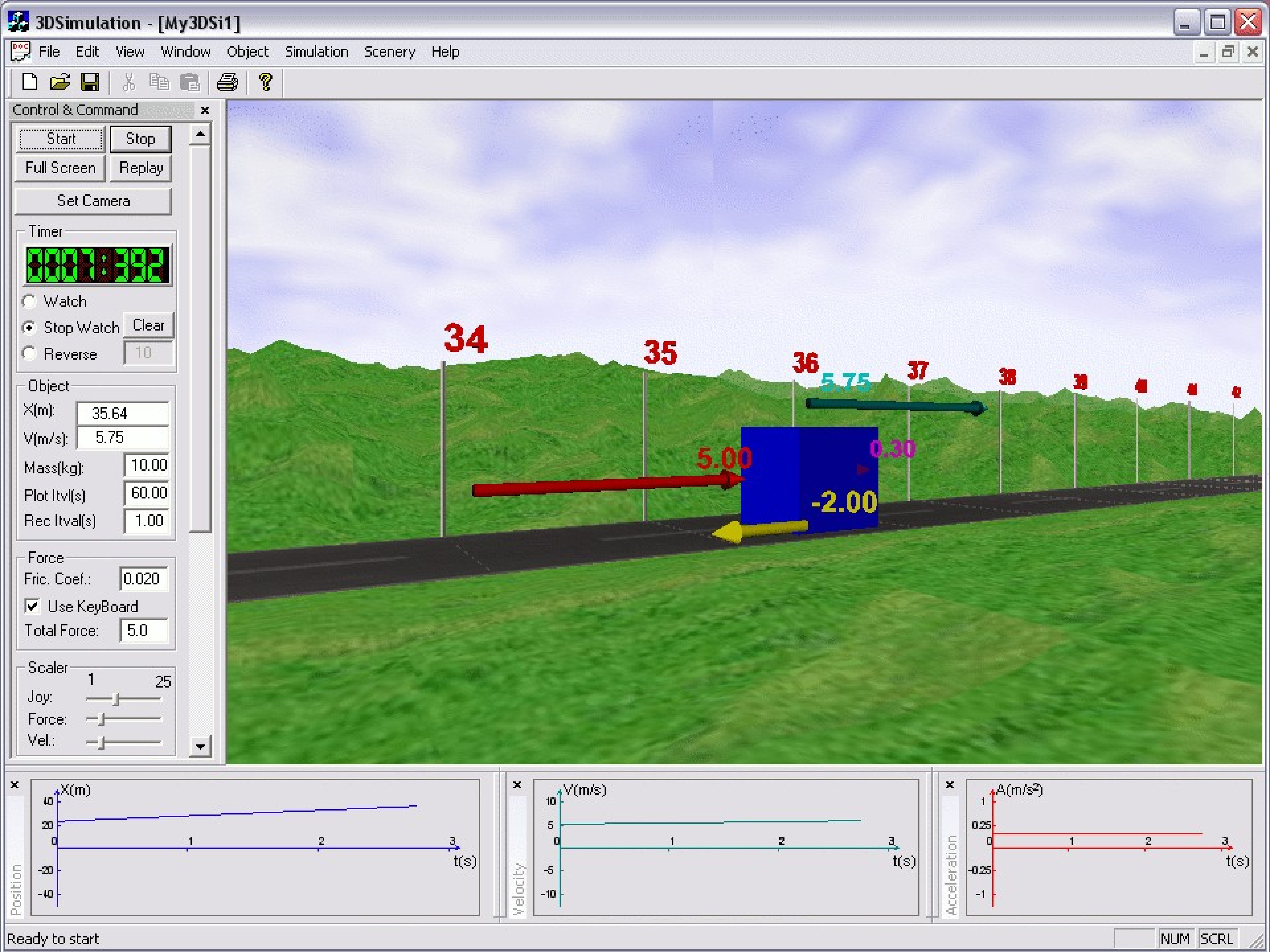
- Students prefer traditional labs for:
  - having hands-on experimentation (21%)
  - exploring a “real” phenomenon (11%)
- Students prefer VR labs for:
  - being able to explore the physics in an “exact” environment (19%)
- Students appreciate both lab types, and valuable experiences can be created when the two are integrated

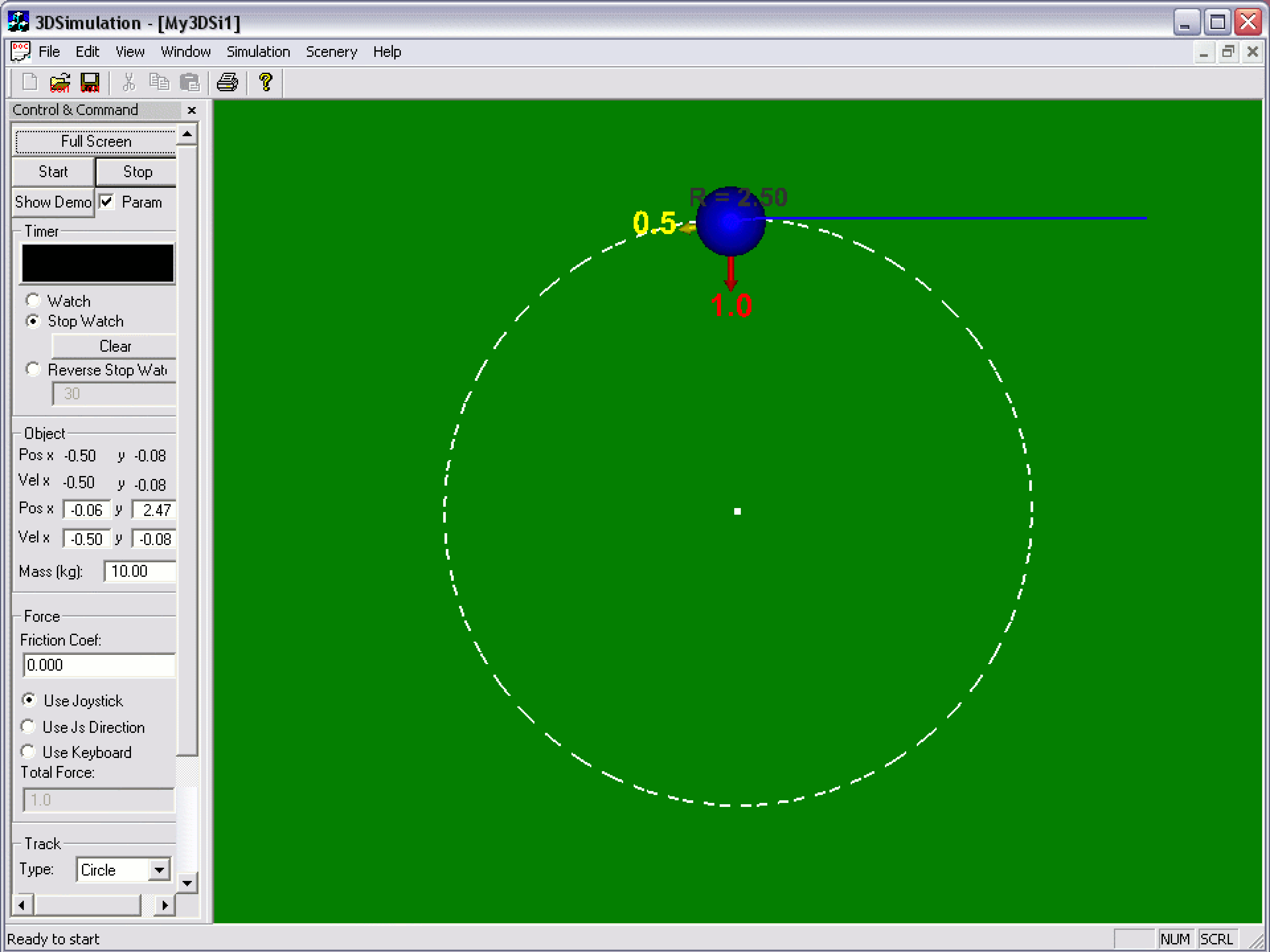
Conclusions:

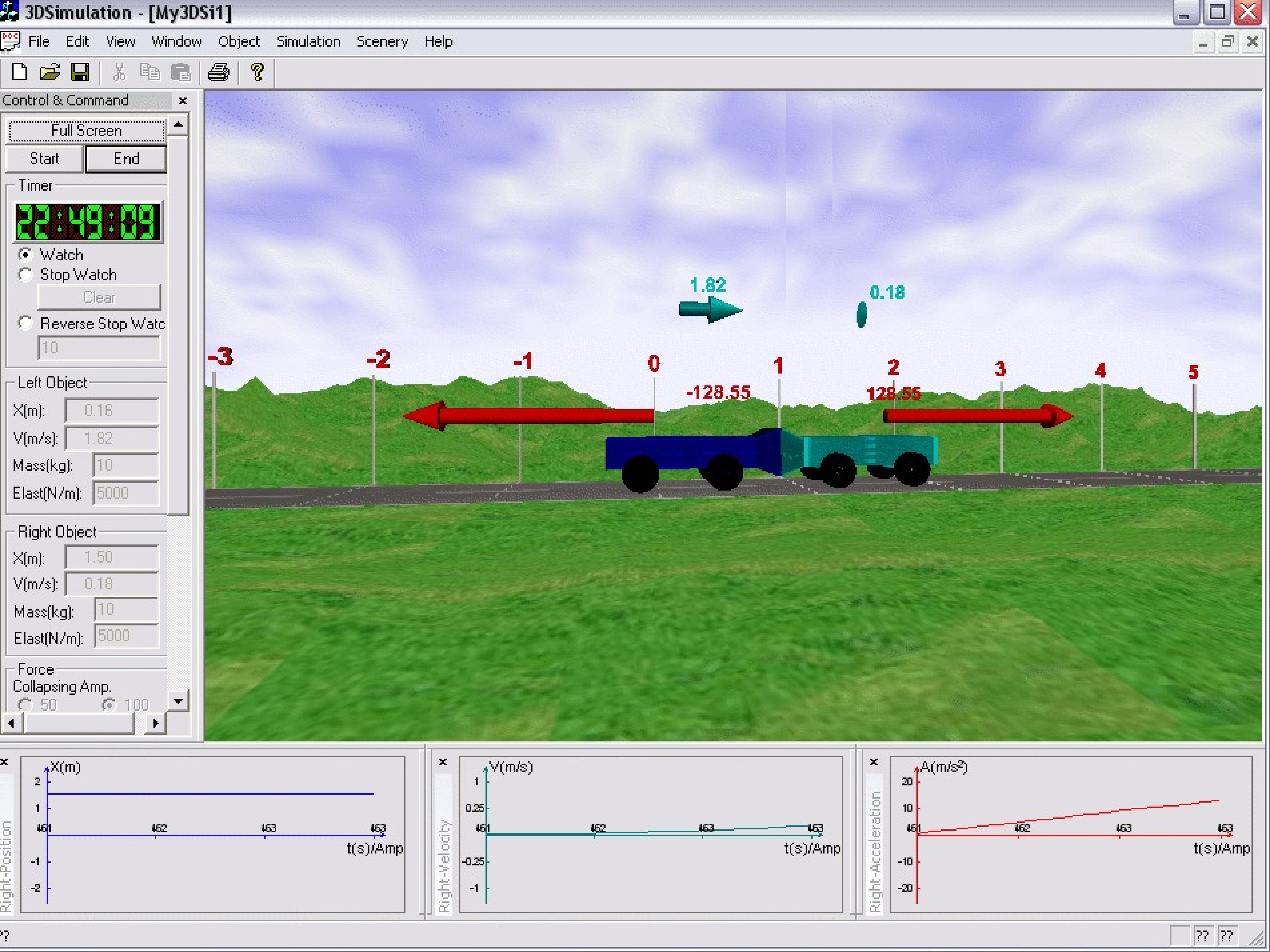
- The VR software has the potential to be a powerful educational tool for improving labs when:
  - Combined with physical experiments to allow for both hands-on and ideal environments to be explored and contrasted
  - Combined with PER findings to best make use of the additional features gained by the software
- Preliminary results indicate that the VR experiments (and specifically use of the joystick) increases student understanding
- Students enjoy VR, and may enjoy lab more as a result

Student Quotes Regarding the VR labs:

- “They are a great complement (to regular labs)”
- “(They) allow us to see the inner workings of a system”
- “There is more control over the environment”
- “(They) give instant data feedback”
- “It is kind of like a game”


3DSimulation - [My3DSi1]
File Edit View Window Object Simulation Scenery Help
Control & Command
Start
Stop
Full Screen
Replay
Set Camera
Timer
Watch
Stop Watch
Clear
Reverse
10
Object
X(m): 35.64
V(m/s): 5.75
Mass(kg): 10.00
Plot Itvl(s) 60.00
Rec Itval(s) 1.00
Force
Fric. Coef.: 0.020
Use KeyBoard
Total Force: 5.0
Scaler
1
25
Joy:
Force:
Vel.:
34
35
36
37
5.75
5.00
0.30
-2.00
X(m)
Position
t(s)
V(m/s)
Velocity
A(m/s2)
Acceleration
Ready to start
NUM
SCRL


3DSimulation - [My3DSi1]
File
Edit
View
Window
Simulation
Scenery
Help
Control & Command
Full Screen
Start
Stop
Show Demo
Param
Timer
Watch
Stop Watch
Clear
Reverse Stop Wat
30
Object
Pos x -0.50 y -0.08
Vel x -0.50 y -0.08
Pos x -0.06 y 2.47
Vel x -0.50 y -0.08
Mass (kg): 10.00
Force
Friction Coef:
0.000
Use Joystick
Use Js Direction
Use Keyboard
Total Force:
1.0
Track
Type: Circle
R = 2.50
0.5
1.0
Ready to start
NUM
SCRL


3DSimulation - [My3DSi1]
File
Edit
View
Window
Object
Simulation
Scenery
Help
Control & Command
Full Screen
Start
End
Timer
22:49:09
Watch
Stop Watch
Clear
Reverse Stop Watc
10
Left Object
X(m): 0.16
V(m/s): 1.82
Mass(kg): 10
Elast(N/m): 5000
Right Object
X(m): 1.50
V(m/s): 0.18
Mass(kg): 10
Elast(N/m): 5000
Force
Collapsing Amp.
50
100
1.82
0.18
-3
-2
-1
0
1
2
3
4
5
-128.55
128.55
X(m)
V(m/s)
A(m/s2)
t(s)/Amp
Right-Position
Right-Velocity
Right-Acceleration

Abstract:

- Physicists consider laboratories to be a vital part of any introductory course, yet students consistently rate them as having low value. The Ohio State University (OSU) Physics Department has modified the current introductory calculus based Physics laboratories to include Virtual Reality (VR) experiments developed by the PER group at OSU. These VR experiments, when implemented as a mix with traditional experiments, have the potential to improve upon many of the difficulties with traditional labs which cause student frustration. This poster explores some of the specific reasons that standard introductory physics laboratories are not having the expected impact, and describes how the implementation of Virtual Reality based experiments improves upon these issues. Student response to these experiments and preliminary results regarding their impact on student learning will also be discussed.

Implementation of the VR experiments:

- 3 VR programs were ready for full implementation at the start of this investigation
- The 3 programs were integrated into the introductory calculus-based mechanics lab at OSU during spring quarter, 2004
- More programs are currently ready for implementation, and others are being developed