Exploring the Integration of Computational Modeling in the ASU Modeling Curriculum

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University of Colorado Boulder · Georgia Institute of Technology · Georgia State University · The Westminster Schools (A co-educational Christian day school for grades Pre -1st - 12)

Overview

The Arizona State University Modeling Instruction paradigm relies on representations of physical models at different levels. We have implemented computational modeling into the ASU curriculum using the high level programming environment VPython in a physics first ninth grade classroom at the Westminster Schools. Students develop computational models that simultaneously employ situational maps, motion maps, interaction maps (force diagrams), and algebraic representations. The student can interact with the model in almost real-time changing different aspects of the algebraic representation through the python code they write and alter and observe how that effects the situational map, motion map, and interaction map through the resulting animation. We utilize the PhysUtil module developed at the Georgia Institute of Technology to allow students an easy method to create timers, graphs, motion maps, and axes. PhysUtil allows less tedious implementations for four of the more detail oriented (but physics-less) coding exercising involved with VPython. In the future we will assess this implementation first using a proctored assignment as well as an open ended essay. We will also assess the student's attitudes towards computation using the Georgia Tech developed Computational Physics Attitudinal Student Survey (COMPASS).

ASU Modeling Curriculum

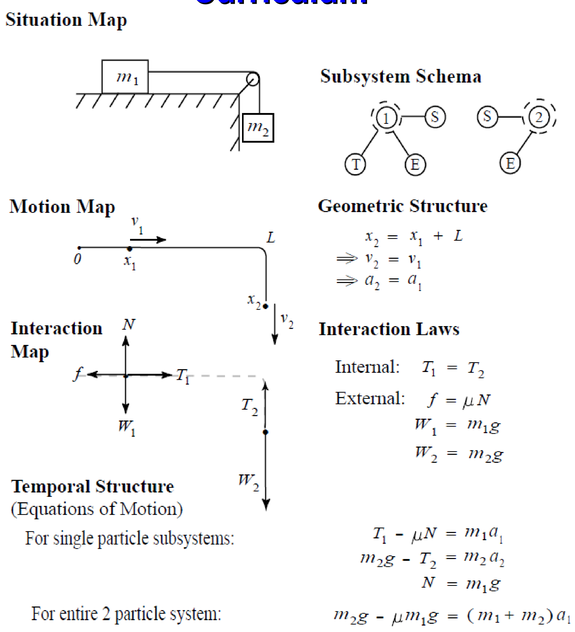

Figure 1. Modeling Instruction uses multiple representations to model physical phenomena. Fig. 1 describes the four representations for the Atwood machine. Each of these four representations is used by the lessons with computational modeling integrated [*Hestenes*, 1996].

References

Hestenes, David, Modeling Methodology for Physics Teachers. *Proceedings of the International Conference on Undergraduate Physics Education*,1996.

Caballero, Marcos D., Evaluating and Extending a Novel Course Reform of Introductory Mechanics, *PhD Dissertation*, 2011.

Computation as Another Representation (Current Implementation)

Constant Velocity Model

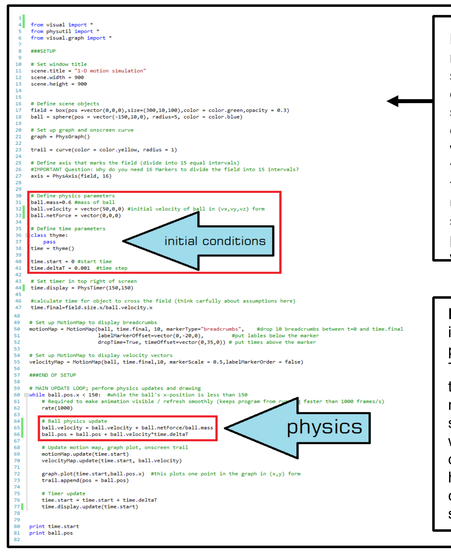

Figure 2. The Constant Velocity model was the first exercise given to students that was integrated with computational modeling. It is a simple exercise to get the students comfortable with the environment while still having them interact with the physics. The arrowed boxes are the initial conditions and the position update. The model produces a simulation of a ball moving across a plane. A motion map is created as well as a position versus time graph.

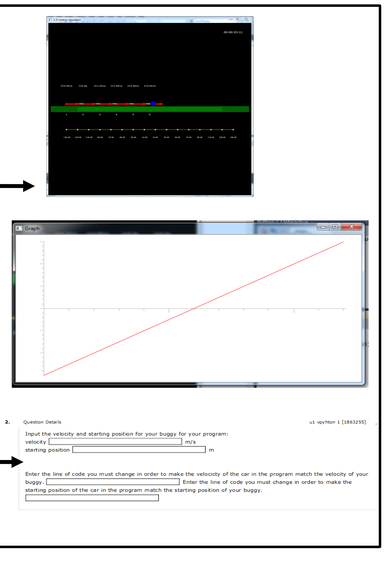

Figure 3. A WebAssign assignment in which students re-factored their programs to model new situations This assignment asked the students to re-factor their programs to model new situations. It also asked the students to explain a new situation where the buggy travels a long distance. The student has to explain how they think they will alter their code and then they alter their code to see if they are correct.

Balanced Forces Model

Figure 4. The Balanced Forces assignment increased the complexity of the physical models that the student can work with. The students had to play with the model to make it have a net force of zero over all time. It also introduced the computational concept of a function. The students were tasked with changing the model to reduce the code complexity with functions.

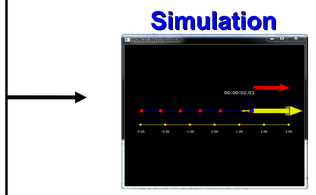

Figure 5. The model produces an acceleration graph that the students can immediately see update as the cart moves. When a force is put on the cart the student sees the graph change. This all aids students in answering the question, "How can you tell, based only on the motion of an object, whether the net force acting on the object is zero?"

PhysUtil Faciliates Building Highly Visual Simulations with Little Excess Code

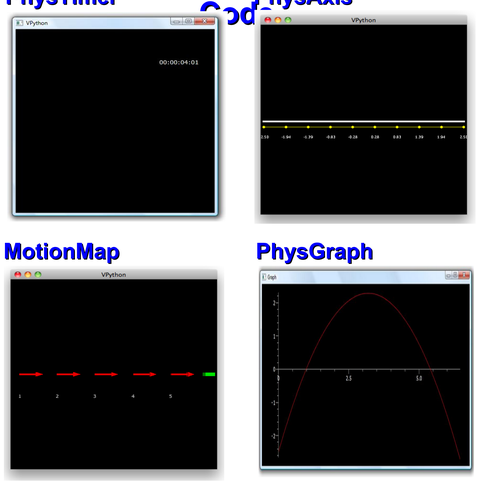

Figure 6. PhysUtil is an add-on module for VPython. It includes four additional classes that allow students to create graphs, motion maps, timers, and axes with very little coding effort. This is key to implementing computational modeling at lower levels including middle and high schools. None of these classes obfuscates any of the physics involved in the model, they only abstract the code used to create the important but non-physical code so that the student's attention is on the physics.

Want to try out PhysUtil?
http://code.google.com/p/python-physutil

PhysUtil

Planned Assessments of Student's Skills and Attitudes

Proctored Assignment

Figure 7. The proctored assignment will be given to the students in class. They will be given the text of the problem and asked to complete the computational model below by adding the lines marked by red dots. We will then compare all students response and code these responses to find patterns of student answers.

Open Ended Essay

Figure 8. The open ended essay asks students to explain how they solve the posed problem but are not expected to solve the problem itself. The problem will be posed in WebAssign and the students will write a short essay in response explaining how they would solve the problem. These answers will be coded for their responses and analyzed for matching patterns between the responses. This analysis will give us insight into how students would use computation, if at all, to solve a physical problem.

A small asteroid is seen through telescopes and is headed towards earth. How will scientists model the asteroids path? Explain the steps and tools scientists will use to solve this problem. How would you determine whether the asteroid was going to hit the earth or not? How would you model the forces on the asteroid?

A baseball player hits a ball with enough force to send the ball out of the park. If the wall is 122 meters from home plate, model the forces on the ball immediately after the batter hits the ball (you can assume the bat gave the ball some initial velocity) and the forces on the ball as it flies through the air (you can assume it was hit at a 45 degree angle). What is the final velocity of the baseball? You will need to create the initial conditions, define the forces, and update the forces and the motion in a while loop.

Computational Physics Attitudinal Student Survey (COMPASS)

A significant problem in learning computer modeling is being able to memorize all the information I need to know.
1) When using a computer to solve a problem, I try to decide what would be a reasonable value for the answer.
2) It is useful for me to solve lots of problems when learning computer modeling.
3) After I solve a problem using a computer model, I feel that I understand how the model works.
4) I find that I can use a computer model that I've written to solve a related problem.
5) There is usually only one correct approach to solving a problem using a computer.
6) I am not satisfied until I understand how my working computer model connects to physical situation that I am modeling.
7) I cannot learn computer modeling if the teacher does not explain things well in class.
8) I do not expect computer modeling to help my understanding of the ideas; it is just for doing calculations.
9) If I get stuck on a computer modeling problem my first try, I usually try to figure out a different way that works.
10) Nearly everyone is capable of using a computer to solve problems if they work at it.
11) To understand how to use a computer to solve a problem I discuss it with friends and other students.
12) I do not spend more than 30 minutes stuck on a computer-modeling problem before giving up or seeking help from someone else.
13) If I want to apply a computer modeling method used for solving one problem to another problem, the problems must involve very similar situations.
14) In doing a computer modeling problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.
15) It is important for me to understand how to express physics concepts in a computer model.
• I enjoy solving computer modeling problems.
1) To learn how to solve problems with a computer, I only need to see and to memorize examples that are solved using a computer.
2) Spending a lot of time understanding how computer modeling methods work is a waste of time.
3) I find carefully analyzing only a few problems in detail is a good way for me to learn computer modeling.
4) I can usually figure out a way to solve physics problems.
5) If I have trouble solving a problem with pencil and paper, I will try using a computer.
6) Computer models have little relation to the real world.
7) Reasoning skills used to understand a computer model could be helpful to me in my everyday life.
8) When I solve a computer modeling problem, I explicitly think about which physics concepts apply to the problem.
9) When I solve a computer modeling problem, I explicitly think about the limitations of my model.
10) We use this statement to discard the survey of people who are not reading the questions. Please select agree-option D (not strongly agree) for this question to preserve your answers.
11) If I get stuck on a computer modeling problem, there is no chance I'll figure it out on my own.
12) When studying computer modeling, I relate the important information to what I already know rather than just memorizing it the way it is presented.
13) I would rather have someone give me the solution to a difficult computer modeling problem than to have to work it out for myself.
14) I expect to have little use for solving problems using a computer when I get out of school.
15) I'll need to solve problems using a computer for my future work.
• When my computer model does not work immediately, I stick with it until I have the solution.
1) When I solve a problem using a computer, I have a better understanding of the solution than if I solve it with pencil and paper.
2) Computer models are useful for solving science and engineering problems.
3) Watching a computer model helps me understand the solution to a problem.
4) The results of the computer model are more important than the computer modeling method.

Figure 9. Each question is rated on a five step Likert scale with the options being Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree. This will be given only as a post assessment because students struggled with understanding some of the questions when used as a pre-assessment for attitudinal shift. If you would like to learn more about the COMPASS, please visit:
http://per.gatech.edu/compass

Summary

- We have integrated computational modeling into the ASU modeling curriculum for constant velocity and balanced forces.
- Students are exposed to all four representations, situation map, motion map, interaction map, and the algebraic representation simultaneously using VPython.
- We will be assessing students ability to use computation as a tool with a proctored assignment and an open ended essay question. We will assess their attitude towards computation with the COMPASS.