Rationale: Why Teach Students to Code Computer Simulations?

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(1) Computer modeling emphasizes the creation and evaluation of physical models over the application of those models to arbitrary scenarios.

> *A ball is launched on level ground with a speed of 25 m/s at a 30º angle above the horizontal. Neglecting air drag, (a) how far does it go, (b) how much time does it spend in the air, and (c) what maximum height does it achieve?*

This type of projectile-motion problem shows up in almost every introductory physics class. To solve it, students must apply vector mathematics, constant velocity kinematics, and constant acceleration kinematics. However, the problem itself is completely arbitrary. The numbers were randomly chosen and even if the question was given in terms of variables instead of numbers, there is very little emphasis placed on actually understanding the physical models that are must be applied to solve it. For many students, problems like this often become about choosing the right equations and doing algebra until they get a right answer. It's not about really understanding why a particular combination of mathematical equations accurately model the system's behavior.

The goal of this unit is to move the emphasis to the creation of physical models, through crafting computer simulations of physical systems. Rather than asking students to solve arbitrary, special-case scenarios, students are asked to create computer models of physical systems. Rather than students thinking "how do I solve this problem?" they will be thinking, "How do I model this type of system?" Once a computer model for a system is developed, solving a specific scenario, becomes as simple as changing a single number in their code or adding a couple more lines.

This approach also emphasizes understanding of physical models over seeking tricks/shortcuts that allow students to find right answers, but completely bypass the skills and understandings we hope them to achieve. When tasked with creating a working computer simulation, students must think primarily about the mathematical model and all of its interlocking parts. Having students craft a computer simulation of a physical system forces them to actually put together a mathematical model of that system which leads to full understanding of how that system works. This is a more reliable way to ensure students achieve undrestanding of a system than conventional pencil and paper problem solving.

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(2) Through time-iterative programming, even algebra-based physics allows students to model systems with non-constant force.

Without the application of calculus, students cannot build complete mathematical models of systems where objects undergo non-constant forces. This is extremely problematic from a pedagogical point of view because most intro physics classes include analysis of some non-constant force systems (like mass-spring oscillators and pendula). Introducing equations that model these systems is typically problematic for teachers because calculus is required to derive them from more basic equations.

Through computer simulations, we can take a system like this and “cheat” by assuming the force on objects *IS* constant, but over very small time intervals. Then we update the force value appropriately over each small interval. Essentially, time-iterative programming allows us to turn a non-constant force problem into many neighboring constant force problems. The same idea can be applied to other systems with non-constant force, like projectiles with air drag.

(3) Physics modeling through computer programming provides students with an opportunity to develop basic coding skills.

Need I say more?