Solving the Hard Problem of Educational Video Game Design with Modeling Instruction

Eric Keylor, Arizona State University

The Hard Problem of Educational Video Game Design

Modeling instruction is a pedagogical method for teaching physics developed by David Hestenes and colleagues at Arizona State University (Hestenes, 2010) that has profound implications for educational game design. Modeling instruction has been little explored by game designers. (SURGE (Clark, Sengupta, Biswas, & Nelson, 2011) is a rare example of a physics video game that attempts to incorporate modeling instruction.) Research on modeling instruction shows that the practice of modeling is one of the few paths to robust conceptual understanding for physics and other subjects. As Hestenes says, "Modeling is the name of the game" (Hestenes, 1992; Hestenes, 1993). If educational game designers want to achieve similar results, modeling pedagogy implies real constraints that cannot be ignored. Effective game designs must fulfill model assumptions or risk being ineffective. This leads to what I call the Hard Problem of Educational Video Game Design: How do educational video game designers create game mechanics, which are mostly rooted in player actions, that allow players to instantiate models, especially when so much of the modeling process is discursive? Some following questions: Are educational video game designers forever dependent on activities outside the game to achieve learning outcomes? What implications does this have for production and video game genres, especially for subjects such as Newtonian mechanics? Are effective educational casual (small-scale) games even possible? I submit that no educational video game worth playing for a subject, where modeling instruction is effective, will have a large impact without resolving the tension between game mechanics and modeling discourse. Educational game designers must be able to identify and articulate the model for the phenomenon they want to teach in their designs. Models are necessary, if not sufficient, for educational game design, and learners must be able to instantiate those models in the game.

If discourse, which includes relevant practices, is a necessary condition for conceptual change in areas such as physics—and modeling research and socio-cultural learning science strongly suggest this is the case (Gee, 2007a; Gee, 2007b)—, what are the options for game designers? When making a video game, designers have to make decisions in at least two categories: creating a single player versus a multiplayer game and creating a standalone experience versus an integrated experience. Single player games are most likely easier to release because multiplayer games typically have administrative and production issues that single player games do not have such as personal security, networking, hosting and maintaining servers, having too few or too many players, etc. Single player games may be harder to design for educational outcomes because modeling discourse must be handled by the game engine. In a multiplayer game, however, discourse must still be guided by either the game engine (like a single player game) or by someone who is knowledgeable enough to guide the players, which creates a dependency since an expert must always be in the game for it to work. Designing standalone experiences means that most, if not all, support and all scaffolding (help) must be part of the game engine. Although a community may grow around a video game, this is most likely beyond developers' control, and dependency on a community for a learning outcome is a very big dependency that could be indicative of a major design flaw. Educational video games to be integrated into a larger instruction experience are also at the mercy of the environment where they will be used, which may include things like class duration, fitting into state standards, the instructor's comfort with technology, etc. This adds more dependencies that could lead to failure. No matter what type of educational video game the designers intend and which problems the designers accept, however, a model must be at the heart of the design.

An Example Model

Models have structure (Hestenes, 1997; Hestenes, 2008; Hestenes, 2010), and a basic model is presented as an example. The model is *particle moving with constant velocity* (Hestenes, 1992). Particle does not mean an atom or molecule. Particle means an object that can be modeled as a single, rigid (solid) object, where the internal structure does not matter. Although the specification for a model evolved in Hestenes's writings, a model has the following substructures although not all may be present. Here is a model using a spaceship as the particle in an educational video game for Newtonian mechanics.

1. Systemic Structure: What is the structure of the system?

   a. Composition: The object is a spaceship which we model as a particle.

   b. Environment: The spaceship flies in space. We assume there are no large massive objects nearby, so we do not have to consider gravity (force).

   c. Connections: None. There are no interactions with other objects necessary for the model.

2. Object Structure: What are the things in the system?

   a. Intrinsic properties: Position is the only spaceship attribute (variable) that changes.

3. Geometric Structure: How are things placed?

   a. Location: The spaceship moves on a 2D Cartesian grid with the origin in the left corner.

   b. Configuration: None because no other objects are needed in the model.

4. Temporal Structure: How do things change over time?

   a. Descriptive Structure: The spaceship changes position on the grid, which is a graph.

   b. Dynamic Structure: The only spaceship state variable that changes is position:

      $x = x_0 + vt$ for horizontal motion

      $y = y_0 + vt$ for vertical motion

   Subscript 0 means initial position (when time equals zero seconds).

   Time (t) is in seconds. Velocity (v) is constant in the horizontal and vertical directions.

5. Interaction Structure:

   a. None as there are no forces or the forces sum to 0. There are no collisions either.

This specifies a model to describe a particle moving with constant velocity. If we wish to design a game to teach a player about constant velocity accurately, this model describes what the player must learn. Surface details may be changed. For example, instead of a grid, a number line could be used where the player only must consider one dimension. The larger point is that this model puts constraints on the design of the video game. The temporal structure is especially important because it is, in a sense, where the action is. The model, unfortunately, does not give us a prescription for teaching the model. That is for the designer to decide, and there is a wealth of research in modeling instruction and other areas to help with this. (To learn more about the structure of models and implementing modeling instruction cycles, the American Modeling Teachers Association provides a wealth of materials.)

Modeling instruction is a topic worthy of study by educational game designers. For creating deep conceptual change in introductory natural science subjects, it may be necessary. Pedagogy matters for educational game design. Modeling instruction suggests that there may be a scientific foundation for educational video game design waiting to be created since models are objective and imply constraints on game designs. Game designs that use models and emulate the model cycle, the process by which students construct and test models, should have a higher chance for success.

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