Designing Digital Objects to Scaffold Learning

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Abstract. Digital objects in learning games provide opportunities to scaffold teacher and student learning toward deeper epistemological understanding of the concepts they represent. Representations encapsulated in digital objects, however, have the potential to misrepresent the concepts they stand in place of. Using student and teacher interview data after playing a physics learning game, analysis of the role of representations in students' epistemological development led to two design recommendations. When designing digital objects to effectively scaffold concepts, designers should pay attention to the ways in which learning environments explore the nature of core concepts represented by digital objects and explicitly model the meaning of the representations in the learning environment.

Keywords: Digital learning environments, representation, scaffolding, epistemology, science education

1 Introduction

In their review of the literature on digital games and simulations for science education, Clark, et al [1] propose a shift in research agenda away from an exploratory phase that furnishes mere proofs of concept and instead calls on researchers to focus on ascertaining the design principles that best support learning and conceptual change. Design principles in digital learning environments necessarily rely on the use of representations that interact with players in order to model core concepts. These representations then have the power to scaffold the learning trajectory of both teachers and students as they play the game. Representations, however, have the ability to take on a life of their own as a teacher or student appropriates them as tools for learning. Using interview data collected from a four-day classroom implementation of the SURGE: EPIGAME physics learning game, this paper will explore two questions central to the interplay between design, representation, and epistemology:

- How do representations in the SURGE learning environment interact with teachers and students?
- How do these representations scaffold the development of teachers' and students' epistemology of force?

1.1 Theoretical Framework

When thinking about how to use representations to scaffold concepts in a digital learning environment, Ball and Cohen's [2] educative curriculum framework provides an orientation that positions the learning environment to scaffold learning not only for students, but also their teachers. Using learning games to develop deeper content knowledge in teachers, however, will only be effective insofar as 1) the representations in the learning environment properly embody the focus concept(s) and 2) if the correct scaffolds are in place to bridge teachers' intuitive understanding of their content with the concepts represented in the game.

1.2 Representations in the Learning Environment

In order to discuss the potential for learning games to educate students, and the importance of representations to accomplish this task, this analysis will focus on a key representation in the SURGE: EPIGAME learning environment: force. In SURGE, players must navigate a spaceship around obstacles while staying on a set path. This is accomplished by issuing commands to the ship as to the magnitude and direction the ship should fire forces to achieve the desired path. Within the game, these representations are represented by force tiles placed on a timeline delineated in one-second increments.

As representations in the game, force tiles are intended to represent a command given to the ship to fire a force of a specific magnitude and direction at a certain time. This representation is not the actual force being applied, but rather a command to the ship to fire the desired force. Force tiles are placed within the timeline at the bottom of the simulation space, representing when the ship should issue the command to fire the force indicated on the force tile. The timeline is thus intended to represent and visualize the amount of time between commands to fire forces.

2 Impact of Representations on Scaffolding Learning

Lehrer and Schauble [3] have shown that representations edit concepts insofar as they reduce or enhance the information they contain. In the best case scenario, these reductions and enhancements effectively scaffold student and teacher understanding toward the concept embodied in the representation. These representations, however, also have the potential to misrepresent the concept to such an extent that, despite the best design intentions, students and teachers emerge from interaction with the representation holding a fundamentally different concept than intended by designer.

2.1 Force

Throughout student interviews, force tiles take on independent ontological status as actors in the game's simulation space, contrary to the intent of the designers. One student repeatedly talks of 'sending' a force from the timeline into the simulation space in order to do work, even gesturing from force tiles in the timeline to the point in the simulation space in which the force is applied:

Student: Like, where it sends... where you send a 60 Newton force over here to get to this point, and then you'd send another 60 Newton force to stop it *[student gestures from 60 Newton force on timeline to the spot where the force is applied in the simulation space]* ... and then a 20 Newton force... *[repeats gesture]* and then a 20 Newton force to stop it and go up... *[repeats gesture]*

In the student's explanation, he student sends a 20 Newton force "to stop" the ship. In the student's mind, the force tile does not represent a mere command for the ship to apply force and decelerate, but rather the force tile object itself travels into the simulation space to oppose the movement of the ship.

This distinction is important with regard to the student's developing epistemology of force. Within the framework of the force tile merely representing a command of the ship to apply force, the action of the ship carrying out the force tile's command represents a change in velocity to decelerate the ship, Newton's second law of motion. The student's conception of the force tile being 'sent' into the simulation space to 'oppose' the ship, however, gives agency to the force tile to travel into the simulation space and push backward on the ship in order to stop it, an enactment Newton's third law of motion. This unintended consequence is directly related to the design of the force representation.

The student's teacher, perhaps unsurprisingly, also echoes his student's epistemological misconception. Following gameplay, the student's teacher was given an example level from the game and asked to identify each of Newton's laws in the level:

Teacher: Newton's second... of course, when I change from at rest to in motion I've applied a force. So [the ship] starts moving from left to right. When I stopped [the ship] here I had to put an unbalanced force on it to go up to down.

Teacher: Newton's third law... opposites. When I stopped the ship I had to apply an opposite force of the same force amount to make my ship stop.

In these two statements, the teacher's epistemology of force becomes evident: unbalanced forces (Newton's second law) start the motion of the ship and opposing forces (Newton's third law) stop the ship. Parsing the teacher's response, the verb 'to apply' takes center stage. In his second law formulation, the teacher "applied a force" and in his third law formulation, the teacher also "had to apply an opposite force" in order to achieve the outcome he desired in the simulation space. Within the semantic frame of application, force is no longer applied by the ship, but by the teacher. What and where this force is, however, remains elusive. It is conceivable, based on the formulation of Newton's third law to 'stop the ship', that the ability to apply force in the simulation environment is a property of the force tile, which pushes on the ship to cause it to stop. As the teacher seeks to answer the question 'What is force?', the representations of the learning game lead to the conclusion that force is a property of an acting object opposing another acting object, scaffolded by the representation of the force tile opposing the ship.

3 Redesign Suggestions for Scaffolding Learning

As a result of the effects of representations on scaffolding epistemological formation evidenced in the student interview, two considerations for future design of scaffolding in digital learning environments emerge.

3.1 Exploration of Core Concepts

Confusion emerges on the part of the student as to the nature of force. Integrating opportunities within the game to explore the question "what is force?" could potentially clarify for students what the force tiles represent, allow for the representation to better scaffold understanding of force and motion, and further reinforce canonical understanding of Newton's laws. In the absence of such an exploration, students are free to ascribe their own properties to the objects, 'sending' them to do work that they are actually incapable of doing.

3.2 Explicit Modeling of Representations

Beyond exploration, however, teachers and students must have the nature of representations in gaming environments explicitly modeled to ensure properties of the object are correctly ascribed. In the SURGE example, a simple statement that the force tiles are not, in fact, independent objects that travel to the simulation space and push on the ship, but rather are simply commands given to the ship to fire its rockets, could potentially alleviate the confusion as to the tile's agency in the simulation space.

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