Modeling Games in the K-12 Science Classroom

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ABSTRACT

Digital games can be used as a productive and engaging medium to foster scientific expertise and have shown promise in supporting the co-development of scientific concepts and representational practices. This study focuses on the integration of a disciplinarily-integrated game, SURGE NextG, with complementary model-based activities to support the development of scientific modeling in Newtonian mechanics. Two pedagogical approaches were designed. Students in both approaches modeled the motion of an object inside and outside the game environment. One approach involved the material integration of virtual game play through a physical modeling activity in the classroom. The second approach involved a complementary modeling tool using an agent-based computational programming platform. While both modeling activities demonstrated affordances to support productive student learning, this study highlights the significance of designing multiple complementary representations of the same phenomenon as a core element of game play and related modeling activities.

KEYWORDS

Computational Modeling, Digital Games for Learning, Disciplinarily Integrated Games, Physics Education, Science Education, Scientific Modeling

INTRODUCTION

This study focuses on the design and classroom integration of digital games for K-12 science education with the goal of fostering the development of conceptual and representational practices that are central to understanding Newtonian motion by engaging students in scientific modeling. Specifically, we focus on the integration of disciplinarily-integrated games (DIGs) (Sengupta and Clark, 2016; Clark, Sengupta, Brady, Martinez-Garza, & Killingsworth, 2015) with complementary modeling activities to support science learning. Essentially, all DIGs have the following characteristics: (a) formal representations for controlling the game, (b) formal representations for communicating challenges and opportunities, (c) a phenomenological representation presenting the phenomenon being modeled, (d) intermediate aggregating representations, and (e) game mechanics and goals focused on engaging the player in interpreting, creating, modifying, and translating across these formal and phenomenological representations (Clark, et al., 2015; Sengupta & Clark, 2016).

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At their core, games are multi-representational environments (Virk, Clark & Sengupta, 2016). Research on use of microworlds and simulations in science education shows that the design of multiple and complementary representations of the same phenomenon can create opportunities for model evaluation through comparison of multiple and competing models of the phenomenon (Parnafes, 2007; Sengupta & Farris, 2012; Sengupta, Dickes & Farris, 2018). Similar to simulations and microworlds, DIGs leverage multiple formal representations as both core elements of game play and as tools to control the game environment (Clark, Sengupta, & Virk, 2016; Virk, Clark, & Sengupta, 2015, 2017). However, reasoning across multiple representations and comparing multiple models of a phenomenon can be difficult for students without appropriate scaffolding (Lehrer & Schauble, 2006). This study illustrates two types of modeling activities that could be augmented with disciplinarily-integrated games in order to support teachers and students in developing modeling practices in the classroom: physical modeling and computational programming and modeling. Specifically, we identify some key affordances and challenges of each modeling approach in two middle school classrooms that were taught by the same teacher. Overall, this work shows that creating multiple but complementary representations of the same phenomenon and then translating across these representations as part of core game activities can meaningfully support the integration of DIGs within the curriculum in a science classroom. Furthermore, out-of-game modeling activities involving representational work that is complementary to the game can positively shape student engagement with the game.

BACKGROUND

Modeling and Digital Games

This work is grounded in the "Science as Practice" perspective, which views development of scientific concepts as deeply interwoven with the development of representational practices (e.g. modeling) (Duschl et al., 2007; Lehrer & Schauble, 2006; Pickering, 1995). From this perspective, modeling is a core epistemic and representational practice in the development of scientific expertise and arguably the central activity of science (Giere, 1999; Lehrer & Schauble, 2006; Nersessian, 1999). The practice of modeling involves using a model to make predictions and generating explanations about a phenomenon, testing those ideas against data from the real world, evaluating how well the model fits the data and revising the model if necessary. In this way, models have communicative and explanatory power, and the practice of modeling is one of the key endeavors of scientific work (Lehrer & Schauble, 2006).

Digital games can be a productive and engaging medium to support the development of modeling in the K-12 science classroom (Clark, et al., 2009; Gee, 2008; Hilton & Honey, 2011; National Research Council, 2009). Following Gee (2008), as Sengupta and Clark (2016) pointed out, at its heart, a digital game can be considered as a model, and users make choices that alter the states of the model. When models and modeling are used as key interactive features within the game, students can build their own models by modifying or constructing central game elements to design game solutions. In this view, gameplay is an iterative process of model exploration and modeling, with users making predictions about their game play choices, observing the results and then revising their predictions based on continuing experimentation (Holland, Jenkins, & Squire, 2003). Digital games for learning science can support these modeling components by engaging learners in generating models during game play and then using the models to explain underlying causal relationships within the phenomenon. As levels within the game become more complex, players must build progressively more nuanced models, iteratively refining their representations within the game. This iterative process of creating and refining representations can lead to an increasingly sophisticated understanding of the content being represented as the refinement of external representations co-evolves with the refinement of one's ideas (Lehrer & Pritchard, 2002; Lehrer, Strom, & Confrey, 2002).