The Design of Disciplinarily-Integrated Games as Multirepresentational Systems

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ABSTRACT

Disciplinarily-integrated games represent a generalizable genre and template for designing games to support science learning with a focus on bridging across formal and phenomenological representations of core science relationships (Clark, Sengupta, Brady, Martinez-Garza, and Killingsworth, 2015; Clark, Sengupta, & Virk, 2016; Sengupta & Clark, 2016). By definition, disciplinarily-integrated games (DIGs) are therefore multirepresentational systems with the affordances and challenges associated with that medium. The current paper analyzes the DIG structure through the focal parameters framed by the DeFT framework (Ainsworth, 2006) to synthesize effective design considerations for DIGs in terms of the specific design and intended functions of the representations themselves as well as the overarching environment and activity structures. The authors leverage the literatures on embodied cognition, adaptive scaffolding, representations in science education, and learning from dynamic visualizations to address the challenges, tradeoffs, and questions highlighted by the framework. They apply these research-derived design considerations to an existing DIG (SURGE Symbolic) and to hypothetical examples of other DIGs in other domains to explore generalizability of the design considerations and the genre.

KEYWORDS
Ainsworth, Cognitive Flexibility, DeFT, Design Thinking, DIGs, Multiple Representations, Representational Bridges, Science Educational Technologies

INTRODUCTION

Clark et al. (2015) propose an approach for leveraging digital games as a medium to support the development of scientific modeling in K-12 classrooms based on the Science as Practice perspective (Pickering, 1995; Lehrer & Schauble, 2006). Clark et al. (2015) refer to this approach as disciplinary integration. Disciplinarily-integrated games (DIGs) represent a generalizable genre and template for designing games to support science learning in order to bridge across formal and phenomenological representations of core science relationships. Therefore, by definition, DIGs are multirepresentational systems with the affordances and challenges associated with that medium.

Ainsworth (2014) highlights the importance of articulating broader theoretical frameworks to investigate how multiple representations improve learning and under what conditions. She also

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highlights the importance of explicitness in articulating the design and function of representations in multirepresentational systems so that research across the field can move beyond simplistic comparisons to instead drill deeper into how specific design decisions affect learning processes in light of specific intended functions of the multirepresentational system.

More specifically, this paper seeks to analyze the DIG genre and template through the focal parameters framed by the DeFT framework (Ainsworth, 2006) to synthesize effective design considerations for DIGs in terms of the specific design and intended functions of the representations themselves as well as the overarching environment and activity structures. We leverage the literatures on embodied cognition, adaptive scaffolding, representations in science education, and learning from dynamic visualizations to address the challenges, tradeoffs, and questions that the framework highlights. We apply these research-derived design considerations to an existing DIG (SURGE Symbolic) and to hypothetical examples of DIGs in other domains to investigate the generalizability of the design considerations and the genre.

DISCIPLINARY INTEGRATION

As we have asserted in our earlier papers (Clark et al., 2015; Sengupta & Clark, 2016), modeling is generally recognized as the core disciplinary practice in science (Lehrer & Schauble, 2002; Nercessian, 2008; Pickering, 1995). Science and math education research shows that engaging learners in modeling and progressively refining representations can contribute to a deeper understanding of mathematical and scientific knowledge and practices (Gravemeijer, Cobb, Bowers, & Whitenack, 2000; Hall & Stevens, 1995; Lehrer & Schauble, 2009). Clark et al. (2015) and Sengupta and Clark (2016) suggest that DIGs are a generalizable genre and template for supporting players in interpreting, manipulating, and translating across phenomenological and formal representations in support of a Science as Practice perspective.

Disciplinary integration can be conceptualized in terms of Allan Collins’s analyses of “model types” and “modeling strategies” (Collins, 2017), which Collins and colleagues have termed “epistemic forms” and “epistemic games” in earlier work (Collins, 2011; Collins & Ferguson, 1993; Morrison & Collins, 1995). They argue that scientists’ professional work can be understood in terms of model types (epistemic forms) that are the target structures guiding scientific inquiry and modeling strategies (epistemic games) that are the sets of rules and strategies for creating, manipulating, and refining those model types. While Collins and colleagues did not write with the intention of influencing the design of actual digital games (they used the term “game” as a metaphor), DIGs can leverage the ideas of Collins and colleagues by structuring digital game play around modeling strategies (epistemic games) of designing and manipulating formal disciplinary model types (epistemic forms). More specifically, the puzzles and game-play mechanics of disciplinarily-integrated games distill model types and the modeling strategies for navigating and working with those models.

As Clark et al. (2015) discuss, this specific emphasis on modeling as game play around disciplinary model types stands in contrast to engaging in “inquiry” more broadly, as is common in 3D virtual worlds (e.g., Quest Atlantis, River City, or Crystal Island). Essentially, whereas 3D virtual inquiry worlds typically cast players as scientists investigating a phenomenon at the level of overarching inquiry, DIGs do not attempt the depth of immersion, identity-building, and role-playing of virtual inquiry worlds (and do not dispute their importance or value). Instead, DIGs are designed to engage players deeply in the specific modeling and representational practices of developing, interpreting, manipulating and translating across specific model types. This focus allows DIGs to iteratively deepen the puzzle at the heart of the game and, more broadly, all elements of the game to emphasize that puzzle.

Throughout this paper, we will discuss SURGE Symbolic as an example of a DIG (Figure 1, http://www.surgeuniverse.com), but we will also explore generalizability to hypothetical DIGs for other disciplinary topics. We describe the design evolution leading to SURGE Symbolic in Clark, Virk, Sengupta et al. (2016). As described in Clark, Virk, Sengupta, et al. (2016), in addition to the
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