Computational Thinking in Constructionist Video Games

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ABSTRACT

Video games offer an exciting opportunity for learners to engage in computational thinking in informal contexts. This paper describes a genre of learning environments called constructionist video games that are especially well suited for developing learners’ computational thinking skills. These games blend features of conventional video games with learning and design theory from the constructionist tradition, making the construction of in-game artifacts the core activity of gameplay. Along with defining the constructionist video game, the authors present three design principles central to their conception of the genre: the construction of personally meaningful computational artifacts, the centrality of powerful ideas, and the opportunity for learner-directed exploration. Using studies conducted with two constructionist video games, the authors show how players used in-game construction tools to design complex artifacts as part of game play, and highlight the computational thinking strategies they engaged in to overcome game challenges.

KEYWORDS

Computational Thinking, Constructionism, Design, Learner-Directed Exploration, Video Games

As our world continues to become progressively digital, the way in which we interact with and shape our environment is increasingly dependent on the ability to translate problems and ideas into forms that computers can interpret and execute. Recent calls by education researchers and computer scientists advocate for bringing this “computational thinking” into formal education spaces. “To reading, writing, and arithmetic, we should add computational thinking to every child’s analytical ability” (Wing, 2006, p. 33). This enthusiasm has resulted in new curricula and tools that provide opportunities for students to engage with computational thinking in classrooms. While we applaud this effort to bring computational thinking into formal educational spaces, we think there is untapped potential in the many computational contexts of the everyday. Tools and environments such as video games, mobile applications, and online social communities are ubiquitous in youth culture and already provide compelling computational thinking experiences.

While the emphasis on the importance of computational thinking has received much recent attention (National Research Council, 2010, 2011), the ideas that underpin this movement have long been championed in constructionist theory and research circles, which advocate for engaging learners in meaningful design and has produced a long tradition of educational environments, tools,
and interventions that foster computational thinking in young learners (Harel & Papert, 1991; Papert 1980, 1996). By incorporating constructionist design into video games and the digital world in which young learners live outside of the classroom, we can not only develop computational experiences that leverage the affordances of the medium and its position in youth culture, but also reimagine the forms that computational thinking can take and how, when, and where learners engage with it.

This paper describes a genre of learning environments called constructionist video games that are especially well suited for developing learners’ computational thinking skills. We argue that by blending features of conventional video games with learning and design theory from the constructionist tradition, we can create compelling, motivating learning experiences that align with the skills and practices advocated by the computational thinking community. Using two constructionist video games of our own design, we demonstrate how constructionist design principles can be used to embed computational thinking in the activity of playing video games and provide evidence for the effectiveness of this approach.

This paper begins with a discussion of relevant constructs and design traditions. We then formally define constructionist video games and discuss the three central design principles of the genre. Our two constructionist games are then introduced, highlighting the design principles in use and reporting on a study conducted with each, providing evidence of the development and use of computational thinking skills by learners during game play. The paper concludes with a discussion of the potential of this design genre and a challenge to the educational video game design community to push on narrow views of computational thinking and further explore and experiment with the video game medium as a context for situating these critical skills.

RELEVANT CONSTRUCTS AND THEORY

Computational Thinking

The driving theme behind the computational thinking movement is the idea that knowledge and skills derived from the field of computer science have far reaching applications that can be beneficial to all learners. Central to this skillset is the ability to encode ideas into a form that can be interpreted and executed by a computational device. Though this idea, or close variants, have been proposed frequently under a variety of names over the last half century (diSessa, 2000; Guzdial & Soloway, 2003; Guzdial, 2008; Papert, 1980; Wilensky, 2001), Wing’s (2006) recent call to make computational thinking a subject everyone should learn has brought renewed interest and excitement to the cause of bringing these skills into the mainstream.

Despite a long history of research to draw on, no clear consensus of where the boundaries of computational thinking lie has emerged (Grover & Pea, 2013). Wing defines computational thinking as: “the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent” (Wing, 2011). The Computer Science Teachers Association succinctly captures both the central goals of computational thinking and the importance of the skills stating: “the study of computational thinking enables all students to better conceptualize, analyze, and solve complex problems by selecting and applying appropriate strategies and tools, both virtually and in the real world” (2011). A National Research Council report on the scope and nature of computational thinking detailed a lengthy list of skills including: heuristic reasoning, reformulation of difficult problems by reduction and transformation, parallel processing, testing, debugging, simulation, and search strategies. (NRC, 2010, p. 3). Replacing a constrained set of skills tightly coupled to programming with this broader set of concepts opens the door to a much wider set of possible designs that learners can engage with as part of developing computational thinking skills. This more inclusive view has motivated us to look beyond conventional computer science contexts to find opportunities to design novel, engaging computational thinking learning environments that build on existing digital practices of young learners.
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