Redefining Constructionist Video Games: Marrying Constructionism and Video Game Design

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Abstract

In this paper we introduce a new class of constructionist learning environments: constructionist video games. These games blend constructionist design principles with video game norms in such a way as to remain faithful to both design traditions. Along with presenting a definition for this type of constructionist environment, we propose two principles for designing constructionist video games that we see as central to creating successful games of this genre.

Keywords

Video Games, Design, Computer-based Constructionist Environments

Introduction

Constructionist learning designs have been successfully used in a variety of content domains, both to motivate learners to deeply explore domain-relevant content and to help learners develop high levels of content understanding. Central to the constructionist design paradigm is the belief that learners should have the opportunity to construct personally meaningful artefacts that can then be publicly shared. Such designs allow learners to set their own agendas and goals thereby becoming architects of their own learning.

Constructionism has a long history of incorporating aspects of video games to achieve desired learning goals. Early LOGO projects utilized game design as an impetus for construction (Papert & Harel, 1991), while other constructionist initiatives used video games to inform the design of the tools learners used when engaging in constructionist activities (Goldstein, Kalas, Noss, & Pratt, 2001; Kahn, 1999).With the increasing popularity of video games in youth culture, some recent constructionist programs have made the building of video games the central task of constructionist learning (Caperton, 2010). Educational researchers have also begun to study the learning that can occur when individuals play video games (Gee, 2003). In the past fifteen years, game studies have explored the possible content children might learn when playing popular commercial video games (Holbert & Wilensky, 2011; Squire & Barab, 2004), the practices gamers develop outside of the game world (Steinkuhler & Duncan, 2008; Stevens, Satwicz, &

McCarthy, 2008), and the ways playing video games might impact common psychology constructs such as visual attention (Green & Bavelier, 2003).

While both lines of work—learning through building games and learning from playing games—have been fruitful, we believe there is an untapped opportunity for uniting the two: designing constructionist video games that make in-game construction the central act of gameplay. This merger is more challenging than it might seem due to a fundamental mismatch between the goal-driven nature of video games and the self-directed exploration advocated by constructionism. Even starting with the best of intentions, it is easy for designers to lose track of constructionist principles in the myriad of design decisions that must be made to create an enjoyable and engaging game. As constructionist designers interested in the educational potential of games, this is a dilemma we must confront: How do we create highly constructionist games that are also consistent with the video game norms players have come to expect? In this paper we propose a definition of constructionist video games and present two key design principles that we believe are central for creating successful constructionist video games: the use of sufficiently expressive construction tools and goal-driven designs that encourage exploration.

Designing Constructionist Games

Juul (2005) defines a game as a "rule-based system with a variable and quantifiable outcome" (p. 36). This widely accepted definition suggests games are constrained by rules and nearly always have a clearly defined notion of success. Furthermore, success in such a game means achieving imposed goals, rather than allowing goals to emerge from play. The definition of constructionist video games that we present here adheres to these aspects of traditional games but also makes the construction of in-game artefacts the central activity of gameplay. Construction activities can take many forms, but it is important that the resulting artefacts are identifiable and useful. By shifting gameplay towards construction (rather than reflex) to achieve in-game goals, the resulting video game has features of both constructionism and traditional video game design.

Few commercial games fit this model of a constructionist video game. Open-ended, exploratory games like *The Sims* have many constructionist aspects, but do not meet the conventional definition of video game due to the lack of 'quantifiable outcomes'. On the other hand, games that have 'authoring modes' like *LittleBigPlanet*, that allow players to construct their own worlds or levels, also do not meet our definition of a constructionist video game as such constructions are not the central gameplay activity. Level creation may in fact be a constructionist activity but it is separate from playing the game itself. In this paper we present two of our own designs, Particles! and RoboBuilder, to serve as examples of constructionist video games as we discuss our two design principles (Figure 1). Particles! (Holbert & Wilensky, 2012) is a platforming video game that encourages players to see physical properties as emerging from atomic-level interactions. In the game, players move through levels by altering the molecular arrangements of blocks, thereby changing their emergent physical properties (bounciness, hardness, etc.), which make up the game world. The second game, RoboBuilder (Weintrop, 2012), is a blocks-based programming game that challenges learners to design and implement strategies to make their on-screen robot defeat a series of progressively more challenging opponents. In both of these games, the construction and revision of player constructed artefacts constitutes the central activity in playing the game. Using these games as "objects-to-think-with" (Papert, 1980), we now move to a discussion of the proposed design principles.

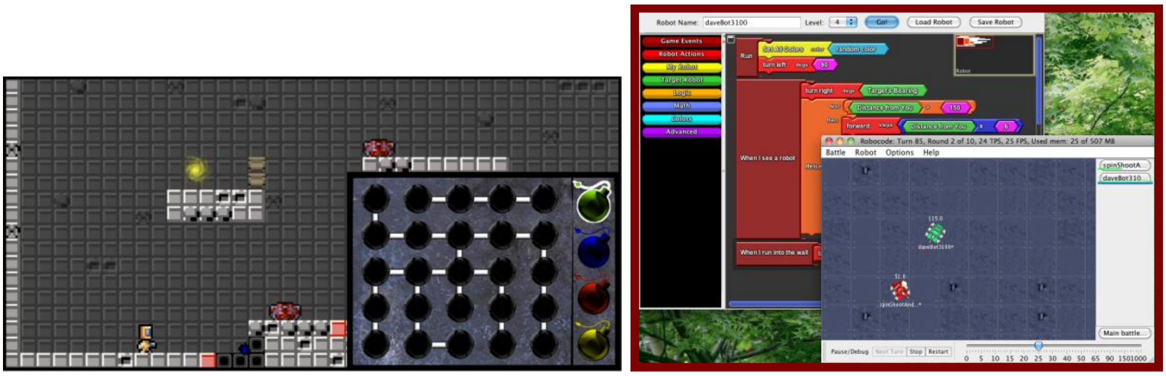

Figure 1. In Particles! (left pane) players rearrange molecules in blocks throughout the game to change the emergent physical properties of objects in the game world. In RoboBuilder (right pane) players construct a robot strategy in a block-based language then watch their robot enact it in competition.

Construction Tools must be sufficiently expressive

Principle 1: Constructionist video games must include sufficiently expressive construction tools so that players can interact with the game in personally meaningful ways.

Papert has written that constructionism was first inspired by frequent walks past an art classroom where students were making soap-sculptures (Papert & Harel, 1991). The "soap-sculpture" approach to mathematics allowed children to take their time to explore ideas of mathematics while building things they actually cared about – things they wanted to show to their parents, their teachers, and to keep for themselves. The soap-sculptures were treasured, not because they were built "correctly," but because they represented the builder's intention. In a constructionist environment, the thing being built must have personal meaning for the builder; the choices made in the construction must be authentic and consequential, and the result should be something one can be proud of. Transferring this important feature of constructionism to video game design is no easy task as video games have predefined goals that are imposed on the player. However, we contend that by providing materials and tools that can be arranged in a wide variety of ways to produce valid constructions, the learner is free to proceed in a way that leads to personally meaningful constructions.

Sufficiently expressive construction tools allow the player freedom to express ideas and strategies that are meaningful in the context of the game while still allowing the player to accomplish in-game tasks. As a game designer, we can adjust the expressiveness of the in-game representations through the breadth of control options provided as well as the granularity of the *building blocks* offered to players. If building blocks are too large, then the game may become too easy, or too restrictive in terms of expressiveness. At the same time, blocks that are too "small" might make the activity tedious or too difficult (Wilensky, 1999). While it is difficult to make a sweeping recommendation as to the size of the components, we believe game designers should err on the side of creativity – construction pieces must be small enough that each construction made by the player is decidedly unique and personal.

RoboBuilder's representational system takes the form of a custom block-based programming language that provides a mix of movement blocks (ex: Forward, Turn Gun Right), event blocks (ex: When I see a Robot, When I Hit a Wall), state blocks (ex: My heading, My Energy), and conventional programming blocks (ex: Repeat, If/Else). Care was taken in the development of RoboBuilder's language to ensure the grain-size of the language primitives were small enough that almost any in-game strategy could be supported while not being so small that complex robot strategies seemed out of reach. Additionally, the number of blocks, the complexity of the task, and the near-infinite number of combinations that could result in a successful robot strategy help give the in-game representational system the expressive power to engage players in the game's central constructionist objective. In RoboBuilder, the choices made by players as they design and build their robot strategies are authentic and consequential as the resulting constructions are the sole mechanism through which the game is played. These decisions are authentic and consequential as they directly impact gameplay and determine the success of the player's robot as it competes. This principle advocates for games to have a highly flexible construction system that allows the builder to create something personally meaningful to accomplish the in-game task.

In-game Goals Should Encourage Exploration

Principle 2: In-game goals and construction tools should encourage exploration and discovery during game play.

In Papert's discussion of microworlds, he stresses the open-ended, exploratory nature of these learning environments. "Although there are constraints on the materials, there are no constraints on the exploration of combinations…the power of the environment is that it is 'discovery rich'" (Papert, 1980, p. 162, quotes in original). The idea of self-directed learning and opportunity to explore through constructed artefacts may seem at odds with the "defined rules and quantifiable outcomes" that we have adopted as a central, defining characteristics of video games. If the game requires specific outcomes how then can we also reward exploration and self-directed discovery?

We believe there are a few ways we can encourage exploration of constructions in a goal-constrained video game. First, by not limiting the player to a single or a small set of winning strategies, the game can reward players for a wide variety of discovered or invented ideas. In this way, the existence of multiple winning strategies supports an epistemological pluralism (Turkle & Papert, 1990); not rewarding one particular solution but instead rewarding any approach that accomplishes the task. This variety of solutions also introduces a qualitative aspect to constructions; players can decide if they prefer one construction over another. Additionally, by creating a low-stakes environment, there is little risk associated with experimentation.

Particles! is designed to explicitly encourage players to explore "molecule" configurations to move successfully through game levels. While the player is given tips throughout the game to introduce him to new types of molecule arrangements (long chains, cross-linking, etc.), the player constructs his own molecular arrangements (instantiated in-game as "bombs") to make the blocks that populate each level. To overcome obstacles the player explores many different molecule configurations until he finds one compatible with his particular play style and accomplishes the challenge at hand. In this way players are encouraged to explore the construction space as they navigate their way through the game. To further support this construction refinement, Particles! allows the player to save each bomb for future use, while limiting the total number of bombs one can carry – in other words, it pays to find a molecular arrangement that can work for many different obstacles.

Conclusion

Both constructionist learning environment and video games have a long history of successfully achieving their design goals through the creation of innovative computational environments. Where constructionist environments have succeeded with respect to achieving desired learning goals by allowing for open-ended exploration and construction, video games have succeed in creating challenging and motivating activities that have permeated kid culture. As designers of constructionist learning environments, we believe there is a potential synergy between these two design traditions. The challenge is integrating the successful aspects of video game design into our learning environments without compromising on the core constructionist principles that help us achieve our desired learning goals. To that end, we have outlined what we view as defining characteristics of constructionist video games and proposed two design principles that we believe will help guide future designers in building successful, compelling constructionist games. As video games continue to grow in popularity in youth culture, we see a great opportunity for constructionist designers to reach larger audiences by introducing Mario to the Turtle.

References

Caperton, I. H. (2010). Toward a theory of game-media literacy: Playing and building as reading and writing. *International Journal of Gaming and Computer-Mediated Simulations, 2*(1).

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Goldstein, R., Kalas, I., Noss, R., & Pratt, D. (2001). Building rules. *Cognitive Technology: Instruments of Mind*, 267-281.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*, 534-537.

Holbert, N. & Wilensky, U. (2011). *FormulaT racing: Designing a game for kinematic exploration and computational thinking*. Proceedings of 7th Annual GLS Conference, Madison, WI.

Holbert, N. & Wilensky, U. (2012). Particles! Evanston, IL: Center for Connected Learning and Computer-Based Modeling.

Juul, J. (2005). *Half-real*.Cambridge: The MIT Press.

Kahn, K. (1999). *From prolog to zelda to toontalk*. Proceedings of International Conference on Logic Programming.

Papert, S. (1980). *Mindstorms*. New York: Basic Books.

Papert, S., & Harel, I. (1991). Situating constructionism. In S. Papert & I. Harel (Eds.), *Constructionism*. New York: Ablex Publishing.

Squire, K., & Barab, S. (2004). *Replaying history: Engaging urban underserved students in learning world history through computer simulation games*. Proceedings of the 6th International Conference on the Learning Sciences.

Steinkuhler, C., & Duncan, S. (2008). Scientific habits of mind in virtual worlds. *Journal of Science Education and Technology, 17*(6), 530-543.

Stevens, R., Satwicz, T., & McCarthy, L. (2008). In-game, in-room, in-world: Reconnecting video game play to the rest of kids' lives. In K. Salen (Ed.), *The ecology of games: Connecting youth, games, and learning* (pp. 41-66). Cambridge, MA: The MIT Press.

Turkle, S., & Papert, S. (1990). Epistemological pluralism: Styles and voices within the computer culture. *Signs, 16*(1), 128-157.

Weintrop, D. (2012). Robobuilder. Evanston, IL: The Center for Connected Learning and Computer-Based Modeling.

Wilensky, U. (1999). Gaslab: An extensible modeling toolkit for exploring micro-and-macro views of gases. In W. Feurzeig & N. Roberts (Eds.), *Modeling and simulations in science and mathematics education* (pp. 151-178). New York: Springer-Verlag.