Sponsoring Committee: Professor Pedro A. Noguera, Co-Chairperson
Professor Ricki Goldman, Co-Chairperson
Professor James Paul Gee

LEARNING ON A 21ST CENTURY PLATFORM: *GAMESTAR MECHANIC*

AS A MEANS TO GAME DESIGN AND SYSTEMS-THINKING SKILLS

WITHIN A NODAL ECOLOGY

Robert J. Torres

Program in Teaching and Learning
Department of Teaching and Learning

Submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in the
Steinhardt School of Culture, Education, and Human Development
New York University
2009

For Mami,
Tati, Danny, and Millie,
Ieysha, Tommy, and Josh,
Heaven and Mario,
and for Beatriz, who we miss so much.

You give me more than you know.

ACKNOWLEDGEMENTS

Dissertations are strange things. I get credited for what is the work of a community of knowledge. The thinking summarized in these pages has been entirely influenced by scholars, colleagues and friends with whom I practice and learn. I thank them for helping me make meaning.

First and foremost I thank my life partner, Max Estenger, who is my inspiration, my genius and my daily reminder of the beauty of life. Without him this work would not have been possible.

I express profound gratitude to my doctoral committee. Pedro Noguera, my co-chair, has carried me through this process from before day one. His brilliance, mentorship, guidance, extraordinary and generous support, and wisdom has illuminated me in ways for which I will always be appreciative. Thank you for teaching me about everything.

Ricki Goldman, my co-chair, thank you for expecting only the best from learning scientists and for pushing me without relent. You are a powerhouse of intellectual depth and rigor. Thank you for expanding my thinking and holding me accountable to history.

James Gee has opened a path for many of us seeking to chart out dramatic change. Thank you for including me in your vision, for your always precise and surgical wisdom, and for your tremendous generosity and direction. Most of all, thank you for a grand theory.

Not on my committee but just as omnipresent in my work and thinking is Katie Salen, who has sharpened everything I know. Thank you for your leadership, our collaboration, and your masterful wizardry.

Mary Brabeck, many thanks your for your feedback and invaluable guidance and encouragement. It has been a privilege and honor to discuss my work with you.

Courtney Ross, you know something about vision that few do. Thank you for sharing yours with me, for your encouragement, incisive leadership, and knowledge.

Elisabeth Hayes' consistent guidance and supervision made this study possible. Thank you for that and for pointing me to clarity every time I needed it.

Thank you to the children of this study who taught me that learning about game design can help you "use your mind in any possible way." And an extra special thanks to the charter school that granted us permission to be designers.

Arana Shapiro and Charles Vergara were instrumental in making this study a reality. Thank you, you were both invaluable guides and supports. Interns Chloe Varelidi and Albert Dang thank you for just-in-time and much needed assistance.

Madeline Perez and Rebecca Rufo-Tepper are my coaches and team members. I have been so fortunate to have done this with you guys. Our Klein-house boot camp writing retreat has been sealed as one of those remarkable life-long memories. Thank you for making us happen.

Susie Greenebaum, life-long friend and colleague, thank you for your cheers and support, for listening, for your cutting insight, and for the hundreds of late night chats.

Tony de Jesus, thank you for insisting, in your calm and persistent way, that I get a Ph.D. You seem to have known that I should before I did.

Special thanks to Laura Torres, whose love and support lifted me and often led the way during those early years. And to Susan Fairchild for teaching me about research. I look forward to many more years of working and learning together.

Finally, I would like to acknowledge members of a community of great scholars teachers, game designers and leaders whose work has been shown me what is possible: Connie Yowell, Eric Zimmerman, Greg Tefry, Frank Lantz, Jan Plass, Kurt Squire, Constance Steinkhueler, Alice Robison, David Shaffer, Erica Halverson, Rich Halverson, Henry Jenkins, Aaron Schwartz, Michael Thomas, Jim Diamond, JoEllen Fisherkeller, Larry Aber, and Gary Anderson. Thank you all for making the way.

TABLE OF CONTENTS

Continued

Continued

Continued

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

All of human life is mediated by systems. Each day most of us respond to climate changes, negotiate social interactions and use a host of devices to communicate, entertain ourselves or seek out information. We, in essence, spend our days passing through and thus making meaning within and between natural, social or technological systems (Rogoff, 2003). Inherent to each system is an explicit *design*, or a composition of elements, that promote and define the system's behavior. Take the design of any K-12 public school for instance. There are many elements within a school's operating system, but at least three core microstructures (Bronfenbrenner and Morris, 1998) organize those elements—its governance model, its organization of knowledge, and its method for facilitating the ongoing distribution and renewal of knowledge among students, teachers and parents. How the elements within each microstructure effect each other and how the microstructures themselves interact over time produce for that learning environment the reality it calls school. This description is but a rough sketch of a school's (or any organization's) operating system, but considering its major structures and their interacting relationships can lead to a holistic understanding of its overall system, including for example the school's culture and student achievement levels, which the system inevitably emits. We live, travel through, and shape—consciously or not—dynamics systems of all sorts. Indeed, we are entirely immersed in dynamic systems; they are everywhere and everywhere they yield a result (Forrester, 1996).

Learning happens within systems and in every system *something* is learned (Gee, 2003; Goldman-Segall, 1998). Gee (1990, 1996, 2004; 2003), Goldman (2007) Lave (1990), Rogoff (1990, 2003) and others write about the situated nature of learning *within and through* systems of activity (Greeno, 2006; Roth & Lee, 2007). Brown, Collins and Duguid (1989) tell us that learning happens as individuals and communities intersect and act within culture and ideas. Goldman (2007) explains that learning processes are "akin to complex biological systems that can adapt, reconfigure, and interact with events and the experience of those events, over time" (pp. 33-34). These learning scientists share in the belief that learning is a process of contextual interactions that yield meaning as individuals, communities and cultures evolve and change over time.

The notion that learning happens as a result of human-context interactions (Magnusson & Stattin, 1998) is something most people don't tend to think about (Senge, 1990, 2006). In fact, most would say that learning is a result of going to school, listening to teachers, reading, and studying; and then, of course, showing what we have learned by passing a battery of tests. In the past two decades, however, a new field called *the learning sciences* has emerged that counters mainstream beliefs about the nature of learning. Researchers in this field (for an overview see Sawyer, 2006), continuing largely in the tradition of Vygotsky's (1978) socio-cultural theory of the 1920s, have conducted extensive research that points to learning as a process mediated (Gutierrez, 2008) by social experiences and technological tools (see also Sternberg & Preiss, 2005).

Games and learning: an emerging field

Anchored in the learning sciences, a newer field has emerged in more recent years around video games and learning (Gee, 2007). Building on the premise that learning is a socially and technologically engaged process, games and learning researchers (Gee, 2004, 2007a; Gee, 2003; Hawisher & Selfe, 2007; Hayes, 2005; Shaffer, 2006; Shaffer, Squire, Halverson, & Gee, 2005; Squire, 2003, 2005b; Steinkuehler, 2004) have begun to show how the design of video games imbed effective learning principles in highly motivating contexts. Squire (2004), in his work with low-income African-American students engaged in playing *Civilization III*, both in a high school and an after school setting, found that the participants, especially those reported to be among the lowest performing, "developed new vocabularies, better understandings of geography, and more robust concepts of world history." *Civilization III* is a highly complex computer strategy game where players through a recursive process of trial and error build empires by way of managing resources, employing diplomatic and trading skills, and managing the advancement of culture and military power. Squire's participants were identified by their teachers as underachieving in history classes or otherwise disinterested in historical subject matter, yet they were able to engage in a game which asked them to account for a host of interacting variables, including, among others, the implications of working within six types of civilizations (e.g., American, Aztecs, Iroquois, Zulu) 6 government (despotism, anarchy, communism, democracy, etc.) and 13 geographical terrains (jungle, tundra, grasslands, flood plains and so on). Squire reports that engagement in this history-based game simulation motivated some to ask questions like, "Why is it that Europeans colonize the Americas, and why did Africans and Asians not colonize America or Europe?" (Squire, 2006, p. 21)—questions, he asserts, that rarely surface in American history textbooks which tend to narrativize American and European history as the great westward expedition (Wertsch, 1998). Squire's research, like that of others in this new field, points to how the very design attributes of video games support learning (Squire, 2004).

The potential of the new games and learning field has attracted the interest of learning scientists, researchers, not-for-profits, corporations, government agencies and schools of education across the country and abroad. Last year The Harvard College Interactive Media Group devoted their entire first issue of *The Harvard Interactive Media Review* to games and learning. In it game designer and scholar Eric Zimmerman (2007) writes an article of immediate relevance to this study. Entitled "Gaming Literacy," he argues for a type of literacy based on three concepts: systems, play, and design. All three are tied to game design, and each represents the kinds of literacies and skills currently not taught through traditional education. Together these concepts frame a *new paradigm* for what it will mean to be literate in this century. The ability to engage in systems-thinking means seeing the world as a set of interrelated parts and searching for the underlying structures that organize those parts. Games, in fact, are *systems*. Games are organized by a mathematical substratum, that is, "a set of rules that lies under its surface…But with games, there is the clarity of a formal system—the rules of the game. This formal system is the basis of the structures that constitute a game's systems" (p. 31) and, in essence, what situates the game's *play*. Game design, then, requires creating a formal system of rules; that is, it requires careful and systematic thought in the process of creating an engaging and immersive experience of play.

Early games and learning research, along with studies that report on the increasing use by youth of digital media technologies (Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006; Lenhardt & Madden, 2005; Roberts, Foehr, & Rideout, 2005), has led government agencies like the National Science Foundation and private foundations like Spencer and MacArthur to fund further research into the potential of games, digital media and simulations as learning spaces. One such project funded by the MacArthur Foundation supported, in part, the research for this dissertation study. This study considers the potential of *Gamestar Mechanic* to teach middle school students systems-thinking skills. Early games and learning research suggests that video games are well suited to encouraging fluency in specialist language, literacy skills (Gee, 2007a; Gee, 2003), and "meta-level reflection on the skills and processes that designer-players use in building…systems" (Salen, 2007, p. 301). Salen and Zimmerman (2004) define game design as the design of a "system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome. The key elements of this definition are the fact that a game is a *system*, *players* interact with the system, a game is an instance of conflict, the conflict in games is *artificial*, *rules* limit player behavior and define the game, and every game has a *quantifiable outcome* or goal" [emphasis in original] (p. 83). Salen (2007), one of the lead designers for *Gamestar Mechanic*, in writing about this game design project, goes further in her definition of game design as also involving:

> system-based thinking, iterative critical problem solving, art and aesthetics, writing and storytelling, interactive design, game logic and rules, and programming skills. The designer must also be a socio-technical engineer, thinking about how people will interact with the game and how the game will shape both competitive and collaborative social interaction. Designers must use complex technical linguistic and symbolic elements from a variety of domains, at a variety of different levels, and for a variety of different purposes. They must explicate and defend design ideas, describe design issues and player interactions at a meta-level, create and test hypotheses, and reflect on the impact of their games as a distinctive form of media in relation to other media. And each of these involves a melding of technological, social, communicational, and artistic concerns, in the framework of a form of scientific thinking in the broad sense of the term (e.g., hypothesis and theory testing, reflection and revision based on evidence, etc.). Designers are making and thinking about complex interactive systems, a characteristic activity in both the media and in science today (p. 305).

Games as means for developing 21st century skills

As Salen summarizes, systems-thinking skills, problem solving, testing and iterating hypotheses have been identified as skills necessary in the 21st century (Federation of Scientists, 2006). The eminent theoretical physicist Stephen Hawking has termed this century the "century of complexity" making clear that understanding, navigating and accounting for complexity are competencies that will define living in the 21st century. He has also said that complexity is the science of the 21st century and physicist Heniz Pagel claims that those who master the new science of complexity will form the economic, cultural, and political superpowers of this century (Rambihar & Rambihar, 2009).

Researchers, game development executives and education leaders at the 2006 Summit on Educational Games, a national conference convened by the Federation of American Scientists, the Entertainment Software Association and the National Science Foundation, described video games as "able to teach higher-order [21st century] thinking skills such as strategic thinking, interpretative analysis, problem solving, plan formulation and execution, and adaptation to rapid change" (Federation of Scientists, 2006, p. 3). In addition, they point out, interactive games are the medium of attention for youth, who spend on average 50 minutes playing them each day (Roberts, et al., 2005).

The widely circulated list of 21st century skills identified by the Partnership for 21st Century Skills is similar. It includes, among others, critical thinking and problem solving skills, communication skills, collaboration, information and media literacy, creativity and innovation. Some of these skills are regrouped to form a new kind of literacy necessary in the 21st century: "information and communication technology (ICT) literacy." This literacy is defined as "the ability to use technology to develop 21st century content knowledge and skills, in the context of learning core subjects. Students must be able to use technology to learn content and skills — so that they know *how* to learn, think critically, solve problems, use information, communicate, innovate and collaborate" (P21, 2006). This study looked to these skills as the curriculum was designed. While they were not explicitly assessed for this study, connections to them will be drawn in the context of discussing findings in subsequent chapters.

Levy and Murnane (2004), collapse these various skills when they point to two skills that will characterize the 21st century workforce: expert thinking and complex communication. Expert thinking entails rapid pattern recognition and metacognitive skills that enable individuals to step back and consider how a particular problem solving strategy is performing before iterating to a different course of action. Complex communication is the ability to synthesize large amounts of information. Spires (2008), while commenting on the deficiencies of schools today, explains that both these skills are "dominant features" that cut across most games genres.

> For the most part, traditional schools are not set up to provide learning contexts that promote these two skills. Problem-based learning scenarios have been used for years to try to approximate real life problems and have met with some success in education. But typically problem-based learning modules have not approached the cognitive

> complexity and fast-paced processing that game contexts afford. Additionally, there is a gap between what students have a growing demand for, what our global economy requires, and what traditional schools can afford. While game-based learning will not be a singular answer to filling the gap, it can provide movement in the right direction (p. 6)

While wholesale change in schools is imperative if they are ever to teach 21st century skills – a point to which I will return in a moment – hosts of games are imbedding these types of skills in rich multi-media environments that are highly social and interactive. Consider, for example, the games *Political Machine* (2008) in which players manage political campaigns, *NCAA Football 08* where you can build and manage a football franchise, *SimCity* where you can design and build environmentally sensitive communities, or a platform like *SecondLife* where users navigate entire 3D virtual worlds they create. These environments are simulations that invite players to craft experimental worlds in which they select elements (a campaign strategy in *Political Machine*, for example, or a population size in *SimCity*) and through a recursive process of trial and error, marked by immediate feedback, tinker their way through solutions to complex problems requiring systemic reasoning skills. Indeed they are the kinds of problems that may support the development of expert thinking and complex communication (Spires, 2008; Spires, Lee, & Lester, 2008). The kind of strategic problem solving that contemporary games require of players make them make them, in essence, environments that require systems-thinking. In this way, games are embodiments of complex systems that invite players to use systemic reasoning to solve them.

Learning from games to create modern schools

Words like play, games, game design or systems-thinking are not the ones commonly used when referring to the activities that transpire in schools. The Industrial Era model of public education characterized by a socially stratified, one-size-fits-all, "basic skills" approach is what many would recognize as the model still dominating our public school system today. Research into games is beginning to show that games may serve as effective learning tools, but the greater goal of this work is not to advocate for the use of games *per se*, but to learn and extract from them learning principles in the interest of creating modern learning spaces that are more game-like. In his book, *What Video Games Have to Teach Us About Learning and Literacy* (2003), Gee lays out 36 learning principles found in games of various genres that are in essence recommendations for the design and goals of modern learning environments. The principles range from concerns regarding the semiotic design of learning environments to the identity-forming affordances they should provide. Good games (2007), he argues, provide players with what schools should provide learners. That is, an understanding of the internal design of a system – a task players have to solve to effectively complete many of the commercial games available today. Learning in school should give students opportunities to understand the "internal design grammar" of systems, such as the design of a domain of knowledge or discipline. For example, how is the knowledge domain of biology composed? What are the rules of a domain such as biology in terms of the way knowledge is produced and validated? What are its standards and values?

What knowledge is considered credible? What are the central debates? What are the acceptable scientific behaviors of biologists? What are the tools and languages used in biology? What does it mean *to be* a biologist? These types of epistemological questions guided the design of the learning environment created for this study with the goal of bringing to life a knowledge domain; in our case, game design, but part of the goal of this study is to show the potential domain-based learning can have for the reconceptualization and design of school-based learning environments. For the purposes of this study, a learning space was designed to activate:

- the languages (specialist terms) of the domain of game design,
- the particular behaviors and practices of production (play/explore, design, playtest, critique, and iterate) of the domain
- and standards and values (a set of criteria) established by the domain within an online social networking context of novice game designers negotiating what was to be deemed examples of good games.

In this way, participants were not only consumers or decontextualized producers, but designers, not only of games, but of the domain itself.

We can begin to imagine the radical shift education would undergo if students accessed knowledge and developed skills in the context of understanding the epistemology – or the design grammar – in which particular content is housed. What is potentially powerful about this approach – which we could come to call a "game-based pedagogy" – is that learners would come to see that knowledge domains are, like games, designed entities – socially designed entities that are designed and "gamed" by human agents, like themselves. To be sure, the idea that a pedagogy of games and design could play a powerful role in transforming the dismal landscape that is public schooling in the United States, particularly for urban students of color, is certainly radical (Whitney, Grimes, & Kumar, 2007). In spite of endless reform efforts (Tyack and Cuban, 1995), Black and Latino students as a group are still leaving school permanently at a rate of fifty percent (Greene, 2002). Yet these same students are spending increasingly larger amounts of time immersed in games and online new media (Jenkins, et al., 2006; Roberts, et al., 2005). If we are to address the needs and interests of our youth, it is well past the hour for dramatic measures to take form if change is to ever manifest. Indeed, given both the technological advances of today and the rates of which youth are engaging them, we have an opportunity to help education move from the 19th to the 21st century.

The participation gap

Gee (2007) argues that unless a concerted effort is made to address underachieving kids and kids in poorer income brackets, games and the types of complex tech-related skills they can enable could actually contribute to the already existing educational achievement gap (Noguera & Wing, 2006). Video games are a means through which to "develop tech-savvy skills and identities"; that is, the development and sense of comfort with forms of technological and "gaming" literacies. These literacies “will create yet another equity gap as richer children attain productive stances toward design and tech-savvy identities to a greater degree than poorer ones” (Gee 2007, pp. 137-38). This is an important point as youth of all ages increasingly spend more time immersed in media and game platforms. In March 2005, the Kaiser Family Foundation released a report (Roberts, et al., 2005) that found that on average youth of both sexes between the ages of 8 and 18 are exposed to 8 hours and 33 minutes (8:33) of digital and other media (defined as the Internet, music, video games, television and movies) daily, while Blacks were exposed to 10 hours and 10 minutes (10:10) daily and Latinos 8 hours and 52 minutes (8:52), respectively. Of those hours, Black youth spend an average of one hour and 26 minutes (1:26) playing video games daily; Latino youth, an hour and ten minutes (1:10) and Whites an hour and three minutes (1:03). Today 97 percent of teens between the ages of 12 and 17 play computer, web, portable, or consoles games (Lenhart, et al., 2008).

Also in 2005, a study by the Pew Internet and American Life project (Lenhardt & Madden, 2005) reported that 57 percent, or about 12 million, of online teens between the ages of 12 and 17 are content creators of such things as blogs; a personal webpage; a webpage for a school, a friend, or an organization; original artwork, photos, stories, or videos; or the remixing of content found online into a new creation. Interestingly, of these content creators, urban and lower-income youth were more likely than their suburban and rural counterparts to engage in these activities. For example, 36 percent of youth who lived in homes with annual incomes of $30,000 or less created online content compared to the 35 percent of youth who lived in homes earning from $30,000 to $50,000. The percentages of youth as content creators living in homes earning $50,000 or above decreased slightly.

This is not to say, however, that we are close to closing the digital divide, or more aptly, “the participation gap,” as Henry Jenkins (2006) calls it. While significant gains have been made in providing minimal access to a computer and the Internet to most youth in schools and libraries, up-to-date technologies continue to move faster than these institutions have been able to sustain. Lower income communities lag considerably behind in their acquisition of computers and high-speed connectivity. Also, Jenkins explains, accessing technology has become less important than accessing the skills and content necessary to participate in fast evolving technological trends. While accessing books, visiting museums and going to concerts have often drawn the line between the social practices of middle and low-income communities, access to technologies and their related-social online experiences may be playing a similar role in today’s society.

Arguments of video game effects

Video games have also gained the attention of psychologists (Singer & Singer, 2005) who are correct in claiming that some games are rife with violent and misogynist themes. While research on video games as resulting in violent behavior is highly inconclusive (Gee, 2007), Singer and Singer point out that while violentthemed video games may enhance violent ideation, the immersive and context-rich environments video games seem to offer have the potential to serve as useful learning spaces. Yet games can and have been used to propagate particular agendas. Some examples of these include *Under Ash*, *Ethnic Cleansing* and *America's Army*. *Ethnic Cleansing*, which asks players to take on the identity of Klansmen or skinheads as they kill Blacks, Latinos and, Jews, is among the most egregious among these types of games. Game researchers are well aware of these games and indeed take pause as the very claims they make—that games allow players to take on situated identities through which cognitive schemes may develop—hold true for purposes of good and evil (Gentile & Gentile, 2008). This, however, has been true for all massively distributed mediums since the Guttenberg press. The medium of games is no different, if not, perhaps—for good and for bad—more effective.

Since their inception, however, there have been conflicting views as to the effects of video games on youth. The National Institute on Media and the Family has warned that video games can engender social health risks such as aggressive behavior, isolation, and gender bias and psychologists (Anderson, Gentile, & Buckley, 2007) have found that violent video games can normalize violent ideation. Research by Bresnik, Henning, Killen, O'Connor and Collins (2007) have suggested that prolonged engagement with some video games may promote gender stereotypes and aggressive behaviors among males, including impulsivity (Anderson, et al., 2007; Carnagey & Anderson, 2004). Overall, a core concern is that youth are spending an increasing amount of their time alone, leaving less time for the social group interactions that develop civic skills (Lenhart, et al., 2008). On the other hand, scholars including Kutner and Olson (2008) argue that the strength of findings indicating aggression or violent ideation are questionable and are often promoted by those with a particular ideological predilection. Taking a socio-cultural approach to the argument, Gee (2005) contends that "video games are neither good nor bad all by themselves, they neither lead to violence or peace. They can be and do one thing in one family, social, or cultural context, quite another in other such contexts."

Research questions

An intent of *Gamestar Mechanic* is to enable the skills of system-based thinking to develop for its players. Early testing has shown that a set of core design elements define the parameters of a game system created in *Gamestar Mechanic*: Rules, Core mechanics, Space, Components, and Goals. To assemble a game in *Gamestar Mechanic*, players have to think and work systematically to design a system that achieves balance among these elements. Hence, in the context of a game design workshop, this study will be principally driven by the question: Does a learning ecology generated and mediated by the game design software *Gamestar Mechanic* improve participants' ability to engage in systems-thinking? For the purposes of this study, systems-thinking was broken down into four discreet systems-thinking subskills:

1 Understanding of system dynamics: understanding that multiple (i.e., dynamic) relationships exists within a system.

2 Understanding of feedback dynamics (i.e., reinforcing and balancing feedback loops): understanding that reinforcing and balancing feedback loops inform and can continually modify the workings of a system.

3 Understanding of the quality of relationships within a system: understanding when a system is working or not working at optimal levels.

4 Homological understanding: understanding that similar system dynamics can exist in other systems that may appear to be entirely different.

The following sub-questions will guide this study:

a. Are students able to demonstrate the acquisition and use of the sub-skills identified for this study?

b. How did students come to acquire these sub-skills?

Personal entry into study

Three distinct paths led me to this dissertation project: First, I have worked in education since graduating from college 19 years ago. Along this path Maxine Greene, Paolo Freire and Pedro Noguera and have lit the way. My work has and continues to be centered on urban youth. I have worked as a teacher, school principal, school designer and consultant to school superintendents. Second, in the 1994 I began working on a documentary film, *Nuyorican Dream*, about my family's plight with poverty that, after five years of shooting, was accepted to the 2000

Sundance Film Festival and subsequently aired by HBO. Third, ten years ago, inspired by Peter Senge's (1990) work, I began working with a group interested in considering the invisible systems that may undergird and drive organizations. Members of this group live in different parts of the country, and so we meet weekly without fail via phone. This group was instrumental in helping me start a small not-for-profit school-design consulting firm I now run called designbydesign.

My interest in doctoral work has been informed by these paths, but most significantly by an interest in having an impact on the dire state in which educational opportunities for urban youth still remains. I knew I wanted my doctoral studies to be anchored in some form of media work, especially since many youth responded viscerally to my film. At around the same time I started my doctoral work, I began to notice that urban kids of all ages, outside-of-school, were fascinated with video games. In the poor neighborhoods in which I worked, owning a game console (and most owned more than one type) had become as commonplace as having the latest Nikes. Additionally, ad hoc computer centers (where kids paid $2 per hour for a computer station) were cropping up in old factory buildings where these same urban kids, unsupervised by adults, were designing MySpace pages, playing online games, and creating virtual social communities. My nephews, 12 and 13, would take me to the one they frequented in their Sunset Park neighborhood of Brooklyn. That people saw offering kids computers a profitable venture was striking, but more so was that impenetrable buzzing energy produced at my nephews' dilapidated computer center. Some kind of magical engagement was there, I knew; a magic of the kind I had yet to find in schools. Thanks to my nephews, a new fourth path had opened.

It didn't take long for this route to crystallize when toward the end of my first year of doctoral studies I attended the 2005 AERA conference. At one session, the University of Wisconsin Games, Learning and Society (GLS) group, including James Gee, Betty Hayes, Kurt Squire, Constance Steinkeuhler and Alison Robison presented on early research in the games and learning field. In particular, Betty Hayes' (2005) presentation on *Tony Hawk's Underground* showed how virtual game worlds serve as user-modifiable spaces in which players design worlds (in this case complex and intricate skater platforms) and then face the consequences of their designs in play mode. I haven't turned back since and have become convinced that this emerging field has the potential (as has been acknowledged by industries as diverse as healthcare, the military, and the corporate sector) to not only transform education, but change our very understanding of learning as events meditated by highly situated contexts—two areas: the project of American public education and our understanding of learning—that I continue committed to help improve.

We have much to learn as this nascent field takes form. One of the principal goals of my film was to create a tool with which my family and I could reflect on our lives, for while poverty provided a context for our lives, daily decisions were still ours to make. Though systems—whether they be of poverty or corporate dominance—are powerful and potentially improbable paradigms to break, understanding their components allows us, I propose, to better direct one's own sense of agency within them (Coté & Levine, 2002; Taylor, 1985). This was the connection I made when I saw the GLS group present, and it is that informed my work as I submerged into a study of how children through using a video game may come to develop systems-thinking skills and, perhaps, begin to *see themselves* as the designers of systems, including the eventual designs of their own lives. This study, in effect, situates itself in one of a set of larger questions driving this field: What is the potential of games as learning spaces and what kinds of learning might occur as children immerse themselves in these spaces?

A final point

In a closing chapter of *The Cambridge Handbook of the Learning Sciences*, Papert (2006) poses a plain challenge to learning scientists. He urges those of us interested in how learning happens to pursue research in search of a foundational construct—the central *mathetic*, as he calls it—that would serve as a core concept from which further theories and research are built. In a more mature science like physics this construct is the speed of light. Our learning science, he urges, is still in an embryonic stage. This study was encouraged by Papert's challenge. The study considered if a group of middle school students were able to develop systems-thinking skills as a result of interacting with the game, *Gamestar Mechanic*. Taking a sociocultural systems approach to learning, it also considered *how* learning emerged. In the spirit of Papert's challenge, this study also attempts to begin a line of inquiry into a mathetic. Could sociocultural, systems-based studies, for example, about systems-thinking lead to both:

(a) creating effective learning opportunities that provide learners with tools for developing systemic reasoning skills, and

(b) to deeper understandings of how the human mind makes meaning?

Could systems-thinking be a *central mathetic* — a core construct for learning scientists that can lead to further research into the nature of being, acting and learning? The New London Group (1996) whose work I discuss further in the next chapter seemed to point us in that direction.

CHAPTER II

REVIEW OF LITERATURE

This review pulls from three bodies of research and literature: (1) design as a means to systems-thinking; (2) relevant studies intended to develop for children systems-thinking skills; and (3) situated cognition, its theoretical promise and its difference from current theoretical outlooks on learning.

Design as a means to systems-thinking

The term "system" is a very broad concept that relates to a number of general areas including social systems, technological systems, and natural systems. Though the subject has been studied from different angles and points of interest, an all-encompassing definition may include these elements (Assaraf & Orion, 2005): a system is a designed entity—designed by humans or natural evolutionary processes—that maintains its existence and functions as a whole through the dynamic interaction of its parts. The group of interacting or interdependent parts form a unified whole and are driven by a purpose. Systems attempt to maintain their stability through *feedback*. Hence, the interrelationships among variables are connected by a feedback loop, and consequently the status or behavior of one or more variables affects the status of the other variables. Yet, the properties attributable to the system as a whole are not necessarily those of the individual components that make up the system. A leading scholar in systems-thinking, Peter Senge (2006), who alternately refers to systems as structures, argues that we are not trained to recognize the design of systems—social, natural or otherwise—but rather we find ourselves feeling compelled to act within them in certain ways.

Systems-thinking as a field of study arose in the 1950s after the theoretical biologist Ludwig von Bertalanffy and others put forth a general system theory in the late 1930s (Hammond, 2003; Hanson, 1995). Much of the work in systems-thinking, which has significantly informed the behavioral sciences, engineering and management, has come out of the System Dynamics Group at MIT (Forrester, 1996). While systems-thinking has not significantly influenced the field of education, scholars like Schön (1983) and Perkins (1986) have used tenets of systems-thinking in developing theories and approaches to learning and design. Schön, for examples, in his work on learning organizations argues that learning happens within social systems through a mechanism called "feedback loops." This mechanism is a cornerstone in the field of systems-thinking and refers, in Schön's case, to the ability to think and act on problems iteratively and with a sense of criticality—while gaining—at each iteration—deeper levels of understanding regarding the variables governing the problem.

Some researchers (Hmelo, Holton and Kolodner, 2000) have been influenced by Perkins' *Knowledge as Design* (1986) work, using it "to help students view systems as designs: structures adapted to specific purposes" (p. 248). They explain that "viewing a system as a design goes beyond simply defining the parts, and also addresses their functional roles, the mechanisms by which those roles are carried out, and how those functions causally interact with each other" (p. 248).

Hmelo, et al's research has centered significantly on systems-thinking through learning by design. She and her colleagues make several claims as to the affordances of such an approach:

(a) the affordances of iteration: constructing, testing, receiving timely and authentic feedback, and revising of something that works;

(b) purposefulness: makes clearer the utility of learning targeted facts, concepts, and skills;

(c) modeling: can serve as vehicles for promoting model design, model building, model running, and an understanding of modeling as an investigative method.

Mental models as a core construct of systems-thinking

Kolodner also concludes that in a design experiment in which 6th grade children learned about the human respiratory system by designing artificial lungs and building partial working models that "more is needed than simply building and refining working models to get to an understanding of systems…We believe that if the conceptual framework and [specialist language of] systems (structure, function, behavior) had been integrated into the children's discourse, they might have moved more quickly into a systems understanding" (Hmelo, et al., 2000, pp. 290-1). Assaraf and Orion (2004) argue that a system approach is an *attitude of the mind* in facing complexity; it reflects a *search* for the interrelationships of designed matter. Senge (2006) and others claim that systemic thinkers are able to change their own "mental models," control their way of thinking and deal with the problem-solving process. Like Kolodner, however, others report on student's difficulties in developing systems thinking. Sweeny and Sterman (2000) studied the systems-thinking skill abilities of students at the MIT Sloan School of Management who enter with a very solid background in mathematics and science, but no known prior exposure to system thinking concepts. They used a systems-thinking inventory to assess particular concepts of systems-thinking such as feedback, delay, stocks, and flows. The results strongly suggested that those highly able MIT students showed a poor level of understanding of some of the most basic concepts related to systems-thinking.

Senge's (2006) notion of systems-thinking as a means to develop "mental models" appears consistently throughout the literature. Similarly, Shaffer's (2006) work on "epistemic games" calls on the research of sociologist Erving Goffman who described the concept of *frame analysis*. Goffman (1974) argued that any activity is instantiated within the terms of a frame: the organizing rules and premises, which exist partly in the minds of participants and partly in the structure of the activity itself, and which together shape the perceptions of those involved in the activity. Extending this premise, Shaffer adds, "We always have some set of assumptions, understandings, beliefs, expectations, actions, justifications, and sense of self that we use to make sense of what we are doing and what is happening around us. This set of organizing premises is the frame we are using to structure what we are doing at any given moment" (Shaffer, 2006, p.160).

During a talk to teachers, Forrester (1996) comments that he sometimes asks an audience 'how many of you use models to make decisions?' No one responds, he says. Then he asks, 'how do you make decisions?' They quickly understand, he claims, that all decisions are made on the basis of mental models. No one's head contains a family, city, school, country or business. Decisions are based only on assumptions about separate parts of real systems, and trying by intuition to fit those fragments of knowledge into an estimate on how things change and what will be the consequences of a proposed action. Such mental models belong to the same class as the computer models used in system dynamics. In fact a system dynamic model is often built from assumptions in the mental models (Forrester, 1994).

Our mental models, however, can be misleading (Perkins 1987). They are "rich and often sufficiently accurate about the pieces of a system—what information is available, who is connected to whom, what the different people are trying to achieve. But mental models are entirely unreliable in deducing what behavior will result from the known pieces of a complex system" (Forrester 1996, p. 13). Enactments of reality, computer simulations, or games, "on the other hand, can, without doubt, reveal the behavior implicit in the structure from which it is constructed" (Forrester 1996, p. 13). Gee (2000, 2001, 2004, 2006) similarly contends that mental models are basic to thought and learning. "It is odd," he writes, that "children in school do not usually get a lot of time building, manipulating, transforming, thinking with, and discussing models [physical or mental] as a way to understand things like science and society and to produce, and not just consume, knowledge" (Gee, 2007, p. 161). If you lack the understanding of structure, you lack an understanding of the content within it. "If you lack models of it, including mental models, you will not be able to make the sorts of inferences that are a routine part of understanding something" (Perkins, 1987, p. 8).

Games represent epistemological models of learning systems (Shaffer, 2006). Said another way, the types of video games Gee (2003, 2004, 2007) and Shaffer (2006) and others talk about serve as examples of systems whose internal architecture have been deliberately designed to enable players in highly compelling environments to acquire the skills and knowledge necessary to complete the game. The ability to understand the operational characteristics of mental, social, technological models, then, can be said to form a new definition of *critical thinking*—that highly ineffable term perpetually touted in education circles.

Critical thinking and systems-thinking through design

Taking an even stronger position for the urgent need of pedagogical approaches that imbed systems-thinking methods, The New London Group (1986), made up of international literacy scholars, proposed a plan for the future of teaching and learning that called for a pedagogy that was resolute in teaching for "critical understanding," by which they meant "conscious awareness and control over the intra-systematic relations of a system" (New London Group, p. 85). Indeed, for Gee (2003), who was part of The New London Group, the ability to develop a sense and skill of criticality is central to his research on video games. Criticality for him means that learners "must be able consciously to attend to, reflect on, critique, and manipulate…design grammars" — that is, the internal architecture of the system that makes up a game or any other system — "at a metalevel" (Gee, 2003, p. 40). Gee uses the notion of "semiotic domains" to frame this sort of critical meaning-making that learners should be able to make about systems. Approaching meaning-making from a sociolinguistic standpoint of semiotics, Gee contends that such an endeavor is characterized by the dynamic interaction between words, symbols, images, artifacts, human behaviors, affinities and networks. These interactions happen within domains resulting in particular meanings. Domains serve as localities that draw a type of confinement or parameter to a particular space or field and are as varied as a classroom, the sport of soccer, the field of law, the discipline of biology, a massively multiplayer online game like *EverQuest*, or the context of a family. Each domain houses semiotic characteristics that situate a discourse in which meaning is made. Meaning-making, then, is reliant on this interactionism. Hence, critical learners

> must see and appreciate the semiotic domain as a design space, internally as a system of interrelated elements making up the possible content of the domain and externally as ways of thinking,

> acting, interacting, and valuing that constitute identities of those people who are members of the affinity group associated with the domain (Gee, 2003, p. 40).

"It is my contention," Gee suggests further, "that active, critical learning in any domain should lead to learners becoming, in a sense, *designers*" (emphasis in original, Gee, 2003, p. 99).

> Critical thinking, as I am defining it here, involves learning to think of semiotic domains as design spaces that manipulate us in certain ways…and that we can manipulate in certain ways" (Gee, 2003, p. 43).

Critical meaning-making, then, involves understanding design in two senses. 'Design' in the morphological sense of form and function, such as the design that 'is' a building, for instance; and design in the sociological sense of the active willed, human process in which we make and remake conditions of our existence. Understanding design or systems, then, refers to understanding both structure and human agency (Cope & Kalantzis, 2000). This notion gets at the core of the greater goals of this study. While "21st century" and "workforce skills" are important for students to enable for that ability to effectively engage in the modern world of civic participation and work, a much larger concern here is an attempt to experiment with the degrees to which young people may come to access design and reasoning skills of the type that may lead to an appreciation of the dynamic composition of systems. This is a goal not necessarily for the sake of helping urban students enter a "workforce" as a proletariat – though having skills for learning, work and citizenship are increasingly synonymous in the age of a global society – but for the sake of promoting a cognitively emancipatory vision – one where young people can come to develop a disposition of agents capable of decomposing and designing systems, both of the kind they live in, or of their own making.

Thinking like a designer is a new definition of critical thinking and marks a radical departure from schools where the pervasive pedagogical stance is one of "information giving" (Perkins, 1987) to students whose role is largely to consume like good receptors (Freire, 1970) – a topic to which I will return. While various studies have offered valuable insights as to the systems-thinking sub-skills and cognitive processes that may lead to children's development of design or systems-thinking skills, much more work is necessary in this area, especially as it relates to using games and game design as the medium through which these skills may be developed (Hayes & Games, 2007).

Other dispositions as an outcome of systems-thinking and design

Forrester, Gee, Papert and Shaffer have argued that different types of learning lead to different ways of seeing one's self and the world. Forrester (1996) draws a distinction between authoritarian and innovative personalities, claiming that a systems education should engender a personality of innovative tendencies characteristic of one willing to make mistakes while searching for reasons and improvement. One learns that progress is made through exploration and by learning from mistakes. An authoritarian personality fears mistakes and does not try the unknown. An innovative personality knows that mistakes are stepping stones to better understanding (Forrester, 1994). A systems or design education should give students confidence that they can shape their own futures (Forrester, 1994; The New London Group, 1996; Papert, 2006). The very act of designing, of creating an active intervention in the world, transforms the designer.

As it relates to game playing, Gee (2003) and Turkle (1984) have suggested that the act of immersing one's self into a game, gives players an opportunity to try on new identities. He points out, that a game is always about a relationship between two different identities: what he calls the *real identity* of the player and *virtual identity* of the character or role the player has in the game. This relationship is enacted through a third *projective identity*, which is a manifested kind of character the player wants to be in the game world. Indeed, the game gives players a chance to see themselves as—and in fact embody (Damasio & Damasio, 2006; Gee, 2007b)—a different person (Shaffer, 2006). This is an important notion as *Gamestar Mechanic* is not just a platform in which learners create game design artifacts, but rather, it is itself a role playing game in which players, within a social network, take on the identity of a game designer, among others.

Toward a pedagogy of (game) design

Immersing *Gamestar Mechanic* players in a game design context through which they take on the identity of a designer to move through the game is not an accident. Not only do we know that games provide highly immersive and "epistemic" (Shaffer, 2006) contexts for learning and play, but extensive research in the learning sciences suggests that deep learning happens in highly contextualized contexts where students take on behaviors while interacting with the symbols, languages and technologies endemic to particular domains.

Schön (1983) and Kafai (1995) see design as an interacting process that accounts simultaneously for the structures and concepts of a design problem as they are being used. His design approach is both process-driven and reflective, with a critical emphasis on the iterative qualities of design. Kafai explains this bidirectional cognitive relationship between learning and design well when discussing a game design research project she conducted in the early 1990s using Logo where fourth graders designed games to teach younger students about fractions.

> As the students were trying to give meaning to the task of designing a game…they were also involved in understanding what they were learning (i.e., constructing the meaning of fractions and how to make an educational game), while they were implementing their games…Designing and learning contributed to each other in the process. (Kafai, 1995, pp. 288-289)

Citing Schön, Salen (2007) explains that in an optimal design process, this interplay of learning and design is reflective. The designer reflects-in-action on the process of designing the strategies used to enact the design. Unlike traditional learning where problems are posed by others to be solved by learners, designers characteristically pose a problem to solved, and from this problem solutions are learned in the process of design. This approach to learning, Perkins (1986) explains, can be used in disciplines as seemingly incomparable as science and literature. For instance, "when you are writing lines for a poem, you are problem solving; when you sought the basic ideas for the poem, you were problem finding…Behind each problem we usually think of as such, there is the matter of finding the problem in the first place, a widely neglected but pivotal matter" (Perkins, 1987, p. 119). This positioning, however, requires a disposition toward design and systemic problem-solving that is largely absent in schools today.

Kolodner (2000) documented, in a design experiment with middle schoolers attempting to learn science content through design, how students became quite competent at collaboration, communication, design, and science skills. Comparisons between matched groups of Learning by Design (LBD) and non-LBD students demonstrated that LBD students greatly outperformed comparison students in their abilities to design experiments, plan for data gathering, and collaboration. And further, mixed-achievement LBD classes outperformed comparison honors students on these measures. Observations of LBD classes show that LBD students became competent at several design skills, including identifying criteria and constraints, making informed decisions, and justifying decisions. In this same report, however, Kolodner also stresses that while substantive research has been done to investigate how to promote reading and writing skills—no longer the only skills necessary to participate in today's society (New London Group, 1996; Friedman, 2006; Gardner, 2006; Salen, 2007; Shaffer, 2006; Gee, 2007; Hayes & Games, 2007)—very little research has been devoted specifically to promoting the types of skills designers engage in.

Potential systems-thinking skills afforded through a game design approach

From the literature on systems-thinking, I have identified a set of four defining systems-thinking sub-skills. This schematic of sub-skills builds a lens through which to consider students' cognitive development of these skills. Results from this research study show that these sub-skills are affordances of the game *Gamestar Mechanic* and make up the distinct skill-set around which the assessment and research program for this research study was framed. The approach to research and analysis is discussed in Chapter 3. The four systems-thinking sub-skills (also listed as part of the research questions for this study in Chapter 1) include:

1. Understanding of system dynamics: understanding that multiple (i.e., dynamic) relationships exist within a system.
2. Understanding of feedback dynamics (i.e., reinforcing and balancing feedback loops): understanding that reinforcing and balancing feedback loops inform and can continually modify the workings of a system.
3. Understanding of the quality of relationships within a system: understanding when a system is working or not working at optimal levels.
4. Homological understanding: understanding that similar system dynamics can exist in other systems that may appear to be entirely different.

It is worth noting here that this study considered the potential *Gamestar Mechanic* holds in helping participants develop these four systems-thinking skills. It also considered the design of the learning environment in which this study was conducted to understand the issue of how participants came to develop these skills.

While the study did not conduct extensive analyses as to the degrees participants could apply their understanding of systems to situations outside of our immediate game design environment, participants were assessed on their ability to identify homological inter-relational dynamics between systems. Examples of this will be evident in the findings discussed in Chapter 5. Further longitudinal research, however, will be necessary to determine how learners immersed in a continual practice of designing and decomposing systems lead to the development of lasting dispositions such as "innovator," "designer," "expert thinker," "complex communicator" or "dynamic systems-thinker." Still, Chapter 5 will demonstrate the potential game design may hold in developing these skills for a group of middle school-aged children.

Schools today and the promise of situated cognition—
A systems-based view of learning

Cognitive theory: A theoretical view of school failure

In describing her work on situated learning, Lave (1990) explains that we may begin to understand the character of learning in Western schooling by distinguishing between two distinct and opposing theories of learning: "the culture of acquisition" and "understanding in practice." The first theory, dominant in American schools, assumes that learning is a rationalistic, logical process that can be acquired through abstract activity that stands outside of authentic practice. This theory, she explains, underlies the traditional practice of social scientists who believe that culture can be acquired through the accumulation of factual knowledge. The role of schools is to facilitate this process; they are the "institutional site for decontextualizing knowledge so that, abstracted, it may become general and hence generalizable, and therefore transferable to situations of use in the 'real' world" (p. 18). The school is also a place meant to transmit knowledge "from the top down," taught and efficiently measured by exams. "This implies that culture is a body of knowledge to be transmitted, that there is no learning without teaching, and that what is taught is what will be learned (if it gets learned)" (p. 18).

The theory of the culture of acquisition emerges most clearly from a theoretical tradition anchored in cognitive theory, which in the 1960s proposed that the mind is much like a computer, able to store, register and retrieve information (Phillips, 1976; Putnam & Borko, 2000; Shuell, 1986; Thagard, 1994). Also called information processing, this theory aspired to the positivistic stance that behaviorism introduced to psychology early in the 20th century as it strived to stake its position of scientific significance among the then more respectable hard sciences (Driscoll, 2005). Papert (1991) and Kafai (2006) have used the term "Instructionism" to describe this pervasive trend in pedagogy. Shaffer (2006) calls it an epistemology of the Industrial Revolution and Perkins (1986) has referred to it as the "information attitude." Trying to justify why schools take this stance to pedagogy, Perkins explains:

> Sometimes in more acid moods, I like to put is this way. Education…often amounts to truth mongering. Truths are told to learners as givens to be learned, without context, without critical perspective, without creative application. In gentler moments, I recognize the source of problem: Education for genuine understanding and critical and creative thinking is hard and in some ways a *technical* enterprise, calling for theories and tools of teaching and learning suited to the challenge. Truth mongering is a relatively unsubtle and nontechnical endeavor, so naturally much of teaching and learning drifts into this pattern [emphasis in original]. (p. 73)

Shaffer (2006) adds:

> Not surprisingly, the epistemology of School is the epistemology of the Industrial Revolution—of creating wealth through mass production of standardized goods. School is a game about thinking like a factory worker. It is a game with an epistemology of right and wrong answers in which students are supposed to follow instructions, whether they make sense in the moment or not. Truth is whatever the teacher says is the right answer…School is a game in which what it means to know something is to be able to answer specific kinds of questions on specific kinds of tests. (p. 37)

Arguably, the methods described by Perkins and Shaffer have "worked" for many. That is, traditional modes of teaching and learning have enabled many students, rich and poor, to attain high levels of success in our society. This study, and more significantly, its findings, however, pose a counter argument, one that suggests that learning is a process necessarily mediated by sets of similar experiences over time within a framework that shares a level of constancy. Findings for this study may suggest that effective learning requires a type of a ecological arrangement that supports learning as individuals move across *a set* of microsystems (Bronfenbrenner & Morris, 1998) or "nodes" within an ecological system of nodes. This construct characterizes nodes as relationally connected within an ecology and by a quality of redundancy of content and predictability – a notion I refer to as *ecological constancy*. To get concrete, let's take learning to be a researcher, for example. For me, this has included moving through a series of discreet, but similar "nodes" – similar in their inter-relatedness of content and the types of behaviors I have taken on and practiced over time. A type of node, for example, was the research methods classes I took. Others included apprenticing under experienced researchers; piloting small research experiments; attending conferences where I saw presentations given by people considered master researchers; preparing research papers for conferences or for publication; and presenting and getting feedback on my own work. The notion of learning through a process of movement through an ecology of nodes suggests learning to be a researcher would not have been possible from participating in only one of these nodes, such as attending classes or even from piloting research experiments alone. Learning necessitated redundancy and predictability across a system of nodes.

I explain this in more detail in the section entitled 'a theoretical framework for cognitive development' further below in this chapter, but suffice to say here that the critique I am putting forward is not solely about the instructionist (Kafai, 2006; Papert & Harel, 1991; Sawyer, 2006) methods that pervade in our schools, but about the need to consider learning, and hence the design of learning environments, from an ecological framework. I would argue that the current system hasn't "worked" for many (and surely it hasn't for many students of color). Instead, for those for whom school has worked, school has functioned as one effective node within a system of nodes that supported learning. This point is of relevance when we consider that for many low income students, school is the only place (or node) that can offer them the kinds of knowledge and skills necessary to effectively participate in society (Noguera, 2003; Rubin, Noguera, & Rodriguez, 2006). Might success for the sum of alienated students be facilitated by "nodal designs" of learning ecologies? This study took on such a design and presents findings in this context. In sum, I argue that not only are traditional teaching methods responsible for the levels of alienation students are experiencing in schools, but given what we know about the situated nature of learning within ecological environments, educators are hard pressed to consider how (nodal) learning happens within ecologies. Learning in classes – be they traditional or progressive –would be but one node within a larger carefully designed system.

In a historical account of progressive practices that have attempted to counter traditional instructivist methods, Norris (2004) explains that progressive education has in fact come to dominate education speak in the United States with readily used terms like “hands-on,” “developmentally appropriate,” “differentiated,” and “interdisciplinary.” However, he argues, that a lack of understanding—especially among the education leadership—of progressive Deweyan principles, which were principally interested in creating learning experiences for learners that were driven by a design and ethos that mirrored the participatory ideology of democracy (Dewey, 1916), has led to mis-implementation and, worse, ideological wars between conservatives (Hirsch, 1997; Ravitch & C. E. Finn, 1987) and liberals (Meier, 1995; Sclan, 1990). One principal reason that traditional methods have stuck and pervade today can be attributed to Thorndike’s (1971) behaviorist outlook of learning which has shaped schooling and assessment in the United States since the 1930’s.

If we consider that cognitive theory—which has its roots in behaviorism (Goldman, 2007; Lave & Wenger, 1991; Rogoff, 2003)—remains the most pervasive theoretical framework informing assumptions about teaching and learning, it is not a stretch to see how a “culture of acquisition” has come to dominate teaching, learning and assessment practices in education. This is most apparent in the passing of the *No Child Left Behind Act* (2001), which at its core is an accountability system that assumes that knowledge and knowing can be stored in the mind and appropriately captured through standardized measures. Endless debates have dominated education and media circles as to, among other things, the financial feasibility of NCLB as if relates to its implementation, but outside of academic circles little has been debated as to the theoretical underpinnings of the law. Liberal critics have even praised NCLB for its spirit of equity, but without considering how drastically deleterious – especially dangerous to urban youth – are the pedagogical and assessment practices the law endorses and promulgates, as a nation we continue to support outdated and proven ineffective notions about learning (Rogoff, 2003)

Further proof that learning in the United States is viewed as an act of consuming knowledge lies in research studies that show the one most common teaching strategy in American high schools is Initiation/Response/Evaluation (IRE) (Christoph & Nystrand, 2001), which asks students low-level inferential questions concerned with attaining the right answer. In a comparative TIMSS study of 231 American, Japanese and German eighth grade videotaped mathematics lessons, Geist (2000), found that unlike the Japanese lessons which focused students' attention on understanding and developing underlying concept and mathematical thinking abilities, American lessons focused on teaching students how to complete types of problems, with an emphasis on rote memorization of formulas and procedures for figuring out the correct answer. In discussing how students learn history in the United States, Wineburg (2001) claims that "no amount of correctly remembered facts will prepare students to sift through the historical records of newspaper articles, partisan reports, contemporary documents" when they are faced with having to defend historical interpretations out of what is most often a web of tangled information. This he argues is what learning history should enable a learner to do—to employ the thinking and acting skills of historians (Shaffer, 2006).

As mentioned earlier, considering the effectiveness of the prevailing cognitive learning theories is of dire urgency in light of the abysmal state of achievement levels of all American students, especially those taught in urban settings where half (or about one million (Greene, 2002) leave school permanently each year. In a recent Gates Foundation-funded study (Bridgeland, DiIulio, & Morison, 2006) 467 high school dropouts ranging in ages from 16 through 25 were interviewed in 25 different locations, including large cities, suburbs and small towns. One striking finding stated that 81 percent of those interviewed claimed that "opportunities for real world learning" would have improved their chances of staying in school. Another showed that 69 percent of participants said that they were "not inspired to work hard" and 47 percent stated that "classes were not interesting." Significant to the findings was the fact that *only* 35 percent of those interviewed claimed they left because they were "failing in school." Taken together, these findings speak directly to the levels of alienation from learning that high school dropouts experience as a result of schooling.

Indeed, over a century of constant reform (Tyack & Cuban, 1995) has produced a system of American public schooling able to graduate only 70 percent of its overall population and 51 percent of its Native American, Black and Latino students (Greene, 2002). In many low-income urban areas, the number of graduating high school students is as low as 20 percent (Kozol, 2006). Explanations for this crisis found in the school effectiveness research literature (Brookover, Beady, Flood, Schweitzer, & Weisenbaker, 1979; Reynolds, Creemers, Nesselrodt, & Shaffer, 1994) range from institutional, racial and economic inequity to the more socially conservative views often associated with victim-blaming (McWhorter, 2000; Thernstrom & Thernstrom, 2003). At the school level, several common and interrelated factors are often cited as contributing to student underachievement, such as unqualified teachers, insufficient resources, dysfunctional school climate, unstable or ineffective leadership, and the like. Low student expectations or inadequate curricular programs are also usual indicators of poor student achievement (Noguera, 2003; Rubin, et al., 2006). These indicators often correlate well with the results of standardized exams, which may offer added evidence of a school's overall performance. However, in spite of the significant research conducted to understand the effects of schools on student achievement, education as a science still remains at an embryonic stage, when compared to the mature sciences of physics and astronomy, and in relation to understanding the fundamental construct that leads to learning (Papert, 2006). This critically suggests that better understanding of learning itself would contribute to understanding the causes of school failure.

Situated cognition, bioecological systems theory and building a nodal network

The fact that notions about learning lead to how learning experiences are shaped by schools and educators is in part the reason why understanding the contributions of past and emerging learning theories is of vital importance. Cognitive learning theory, also known as symbolic processing or cognitive processing theory, claims that thinking or symbolic computation happens for humans in the process of engaging in perceiving and acting (Anderson, Reder, & Simon, 1996; Gagné, Wager, Golas, & Keller, 2005). This is a mental process that relies on environmental forces, but occurs in the minds of sole individuals. It is in the autonomous minds of each person where meaning is made and stored (Anderson, et al., 1996; Driscoll, 2005; Kirshner & Whitson, 1997). Symbolic processing theory organizes learning around the belief that individual minds acquire and transfer information and that well-defined learning objectives, skill practice and standardized summative assessments should establish the conditions through which to organize pedagogy and evaluate learning results.

Conversely, situated cognition learning theory focuses on interactive systems of activity of which the individual is only one part. In this model, cognition cannot be computed in the head, but rather it is realized as a result of the interactivity of a dynamic system. These systems construct paradigms in which meaning is produced as a result of the social nature of humans and their relationships with the material world of symbols, culture and historical elements.

The structures, then, that define situated inquiry and settings are concerned with the interactivity of these elements, not with elemental components in the individual mind, such as stages of memory, storage and retrieval of information, pattern recognition, encoding and the like (Driscoll 2005).

This research study examined the learning system of *Gamestar Mechanic* through the lens of situated cognition. Situated cognition as an approach to research and cognitive assessment takes as crucial the integral nature of learning systems; that is, the relations between persons, symbols, tools, spaces and the systems of meaning these interconnected relations instantiate (Derry & Steinkuehler, 2003; Kirshner & Whitson, 1997; Lave & Wenger, 1991; Rogoff, 1990b, 2003; Vygotsky, 1978; Walkerdine, 1997; Wertsch, 1998). This approach to examining learning is not only appropriate when trying to understand the nature of meaning-making in context, but also critical in an age where young people increasingly use a wide variety of social and technological platforms to mediate and make meaning of everything they do—from communicating, constructing on and offline communities, experimenting with identities (Turkle, 1984), creating and uploading online content, and participating in an open-source culture (Jenkins, et al., 2006).

Situated cognition sits in a new family of theories that make up the learning sciences (Derry & Steinkuehler, 2003), and include, among others, varied and diverse research and theories ranging from situated cognition (Agre, 1997; Gee, 2004; Gee, 2003; Kirshner & Whitson, 1997; Lave, 1990; Lave & Wenger, 1991), activity theory (Engestrom, Miettinen, & Punamaki, 1999), discourse theory (Gee, 2004), ecological psychology (Gibson, 1986) to sociocultural theory (Driscoll, 2005; Vygotsky, 1978). Another useful theory, not often cited among those in the family of the learning sciences, is Bronfenbrenner's (Bronfenbrenner & Morris, 1998) bioecological systems theory, which I discuss further below. His, along with the others listed here, are theories unified in the belief that learning is achieved as the result of the interactions that occur within complex systems. This research study positioned situated cognition as its principal theoretical framework and considers it in light of the limitations of cognitive theory. Core to the framing of this study were also considerations regarding notions of cognitive development as a result of dynamic interactionism

For a variety of reasons, some of which include a response to the current state of educational failure (Gee, 2004; Gee, 2003; Kirshner & Whitson, 1997; Papert, 1998), situated cognition learning theorists have begun to consider the degrees to which epistemic elements of learning such as people acting in context, discourse structures and non-symbolic processes may play a role in the nature of human learning (Daiute, 2004; Derry & Steinkuehler, 2003; Gee, 2004; Gee, 2003; Lave & Wenger, 1991; Rogoff, 1990b).

The field of situated cognition over the past 25 years has made significant contributions to research in the fields of linguistics, math and literacy education. Lave and Walkerdine, for example, have offered compelling analyses of mathematics not as an abstract cognitive task, but as something deeply bound in socially organized activities and systems of meanings. Though each has been decidedly at odds with the nature of how meaning is made in situated contexts, a synthesis of their contributions lends a sharp lens through which to continue investigations in this emerging field. Lave (1990) challenges the ideology of the computational metaphor of abstract processes happening in the mind of individuals and instead positions her analysis of situated cognition in the dialectical exchange between environment and human activity. In a study she conducted of adult tailors in Monrovia, Liberia, she explains that unlike the disassociated style in which schools characterize learning, the apprenticeship environment created by the 250-male tailors' context established a space in which learning-in-practice was facilitated by the "integral nature of relations between persons acting (including thinking and learning) and the social world, and between the form and content" (Lave, 1990, p. 20) of the task at hand. Learning to tailor for these men (none who ever took an exam nor who were asked to leave to due to lack of learning), took place through observation and practice. They learned through making garments, in an order of increasing difficulty, at their own pace. When Lave asked the apprentice tailors what they need to learn in order to become a master tailor, who made up 120 of the 250 tailors, the response each time was an inventory of garments: "hats, children's underwear, short trousers, long trousers, Vai shirts, sport shirts, Muslim prayer gowns," etc. Through her ethnographic study of these men, she came to see that learning to make each garment held a set of encoded social and material practices between the apprentices and between the apprentices and the master tailors. In sum, she explains: "[t]he curriculum of tailoring, is more a set of landmarks for learners than procedures to be taught to learners. It shapes opportunities for tailoring activities and hence the processes of learning to tailor" [emphasis in original] (Lave, 1990, p. 23).

Walkerdine (1997) studied children in elementary schools. Unlike Lave's dialectical approach (Agre, 1997), she takes a Foucauldian approach, using concepts of discourses and the production of symbols and signs within them. She argues that subjects are produced in discursive practice and asks us to consider the relationship between the subject and the situated subjectivity within contexts. Which comes first, the child classified as requiring special education or the classification "special education"? In contexts, which "truth" overrides the other, that of the subject or of our own subjectivity? For Walkerdine the "truth," or the potential classification about the subject's position is "normalized" within discursive practice.

Though at odds with each other's work (Agre, 1997; Walkerdine, 1997), Lave and Walkerdine offer differing but useful models for understanding learning in context that are of particular relevance to this study. Lave offers a critique of the ideology of cognitivist psychology and posits that an understanding of human social activity more accurately accounts for human learning, while Walkerdine looks to discourses to define and understand the constructs that motivate human activity. Taken together, they offer a set of lenses through which to begin to shape an integrated unit of analysis that accounts for the dialectical practices of human activity in context. This research used notions from each model to frame the study, employing both a design-based research approach (described in the Research Design chapter) and tenets of discourse analysis (Gee, 1999) to theorize about learning.

<u>Situating tools in situated cognition</u>

Wertsch (1998), who is the principal English-language interpreter of Vygotsky (Hirschfeld, 2000), is deeply influenced by the work of the Soviet psychologist. Lev Vygotsky's socio-cultural theory serves as foundational to the work of situated cognitivists and learning sciences researchers as a whole. At the core of Vygotsky's theory is the notion that cognitive agreements are first made *intra*individually, that is, socially or between individuals, before it is made in an individual's mind. Wertsch expands on Vygotsky and suggests that meaning is made in the irreducible tension between agents and cultural tools. He calls this tension "mediated action," attempting to combine the individual and her context into one integrated unit of analysis, a separation of which—as is the nature of the typical standardized exam—he argues, would offer inconclusive or misleading accounts as to the nature of human functioning and meaning-making. A cultural tool for Wertsch is a broad term that includes historic, social, and material rituals and artifacts used by humans. A multiplication procedure, a book, a game, a meeting structure, a classroom, a family, an institution can each be considered a type of cultural tool. As an example, he asks us to consider the multiplication problem: 343 x 822. If asked to solve the problem we would likely employ the long multiplication procedure and would likely show the calculations of how we multiply digits separately:

```
     343
x    822
     686
    686
  2744
  281946 (p. 28)
```

> Wertsch then asks us to consider who solved this problem.
>
> Was it really (the isolated agent) who solved the problem? (After all [we would say] "*I* multiplied…") To see the force of this question, consider what we would do if asked to make one small change in the procedure. Namely consider what you would do in response to the request to multiply 343 by 822, but without placing the numbers in the vertical array used above. Most of us would be stumped at this point, and even if we could solve this problem, others involving larger numbers would probably be impossible if we could not relay on the procedure of placing one number above the other as in the illustration. The first issue these questions raise, then, is whether it is really the agent alone who solved the problem. If this were the case, why do we have such difficulty in solving the "same" problem when asked to do so in the second condition?… The answer to such questions clearly lies in the fact that a specific mediational means is involved… that make[s] solving the problem possible for us. (p. 29).

Here Wertsch is illustrating the point that an abstract task was mediated by a cultural tool that is the mathematical procedure we use to solve, if ignorantly, a complex problem. He continues:

> From the perspective of mediated action, this means that the spatial organization, or syntax, of the numbers in this case is an essential part of a cultural tool without which we cannot solve this problem. In an important sense, then, this syntax is doing some of the thinking involved. We might be unaware of how or why this syntax should work, and we might have no idea about how it emerged in the history of mathematical thought. In this sense, we are unreflective,

> if not ignorant, consumers of a cultural tool. The extent to which our performance relies on it, however, quickly becomes clear when it is not available. This leads me to suggest that when asked who carried out the problem, the more appropriate answer might be, “I and the cultural tool I employed did.” (p. 29)

Like Lave, Wertsch problematizes and in fact attempts to rectify the cognitive psychological overemphasis on individuals acting in isolation of historical and socially constructed cultural tools. Furthermore, he attempts to extend Vygotsky’s notion of the social context as the unit of analysis. In this way, he argues that neither individual mental functioning nor sociocultural settings alone can account for an understanding of cognition, but rather, that only an analysis that accounts for the dynamic interplay between both can begin to yield such information.

In closing this section, it seems apt to look to Gee’s (2003) notion of “semiotic domain” as a way of synthesizing the various contributions of situated cognitivists. Approaching meaning making from the socio-linguistic standpoint of semiotics, Gee contends that such an endeavor is characterized by the dynamic interaction between words, symbols, images, and artifacts and human behaviors, affinities and networks. These interactions happen within domains to create particular meanings. A domain serves as a locality that draws a type of confinement to a particular space or field and is as varied as a classroom, the sport of tennis, the field of law, or the immersive context of a good game. Each houses semiotic characteristics that situate a discourse or a domain in which meaning is made. Meaning-making, then, is reliant on this interactionism.

In a critique of traditional schooling, Gee (2003, 2004) makes clear that the design and delivery of instructional practices falls far short from not only understanding, but from building learning spaces conducive to learning. True learning for Gee requires that learners are given the context necessary to build and understand what he calls the "design grammar" of semiotic domains, which he uses to define critical learning. A critical learner understands the *internal* and *external* design grammar of a domain. By internal design grammar he means the internal workings of a domain such as its principles, procedures and acceptable content within a domain. By external he means the principles and patterns of the acceptable social practices attributable to the domain.

For example, he explains that to have an actual understanding of the domain of modern architecture, one needs to know why or why not some buildings count as typical or untypical modernist architecture. If all one knows is a list of modernist buildings, then one doesn't know the internal grammar which holds *the systemic, underlying patterns* of what the field and it's corresponding buildings are and are not, and, perhaps more importantly, one is not equipped to make judgments about buildings one has never seen or ones that have never been built. Furthermore, to understand the external grammar of modernist architecture, one needs to have an understanding of the "thinking, acting, interacting, and valuing" of "someone who is 'into' modernist architecture." If one is able to recognize the sorts of identities people take on in the domain of modern architecture and social practices of the members of the affinity group associated with the domain, then one knows consciously or unconsciously the external design grammar of the domain. The ability to distinguish, then, the pattern, principles, symbols and behaviors of those associated within a domain enables one to make critical inferences, to participate and to make meaning about (and perhaps within) the domain. These practices for Gee not only necessitate and engender critical learning, but also contribute to how a learner comes to see herself, that is, to how she *identifies* herself within a particular domain. Critical "learning is a change not just in practice, but in identity" (Gee, 2003, p. 190).

It is this situated and complex understanding of learning that situated cognitivists are advancing as a model through which to both conduct research about learning and to create sites that facilitate it. *Gamestar Mechanic* is such a site.

Theoretical framework for cognitive development

Situated cognition is the organizing global theory through which the study's design is operationalized. However, to make claims about the causes of cognitive change I used notions of Bronfenbrenner's bioecological systems theory and White's social network theory. Bronfenbrenner holds an interactionist view of human development and proposes that development is best measured and understood when units of analysis carefully account for the interactive process between person and context over time. He also argues that assessment of cognitive development that does not account for context is of little value. Contexts for Bronfenbrenner's are defined as a set of nested and overlapping structures that he called micro-, meso-, exo- and macro-systems, which range in order of complexity from microsystems (such as a classroom) to macro, accounting for greater social systems, such as an urban setting. Cognitive development is accounted for as the result of *proximal processes* (Vygotsky, 1978) which are short-term developmental processes by which skills are developed in locally specific contexts. Skill development is a result of activity within and between microsytems. The character and predictability between these various microsystems largely drive cognitive development. For example, studies of middle class families (see Barron, 2006) have shown that dinner conversations at home (a type of microsystem) and learning activities in middle class school classrooms (another type of microsystem) mirror each other and draw a level of parallel redundancy necessary for cognitive development, in this case of school-related skills. This study was conceptualized as having a system of six distinct microsystems, five designed by me and one other, the "out-of-school" microsystem, was accounted for as part of the design. Building on Bronfenbrenner's bioecological metaphor of dynamically and interdependent interacting structural systems, the six microsystems together composed the study's learning ecology.

Microsystems are reconceptualized in this study as 'nodes' to more appropriately indicate not only promixal convergence, but deliberate and homological redundancy across nodes. The six interacting nodes (explained in more detail in Chapter 4) included, among others, *Gamestar Mechanic*, the workshop, visits with game designers, and an end of workshop exposition. Each node was designed to house a set of common and cross-cutting elements: social activity, mostly framed by constant and continual informal and formal feedback; tools such as game review protocols, story boarding structures, *Gamestar* itself; specialist language (core mechanics, reinforcing feedback loops); distinct physical spaces; norms defined early on by participants; ways of being (e.g., taking on varied identities: game designer, critic, competitor, game player); specified time allocations for each node; and perhaps most importantly, material production. That is, it was clear that the purpose of all activity within nodes was to produce games that adhered to a set of criteria defined by the community. These nodes composed the study's learning ecology though which participants traveled to make meaning.

Bronfenbrenner is not the only social scientist (see also Barron, 2006) to make claims about meaning making in this way. White's (2008) notion of "net-doms" ("dom" from domain and net from network relations," p. 7) as is Gee's (2005) notion of "portals" within affinity (semiotic learning) spaces are similar to Bronfennbrenner's postulate that meaning-making and cognitive development results from activity through microsystems (nodes). Implicit in this study is a parallel between cognitive development and identity formation. White's work on identity formation as a process of seeking control as the individual travels *between* netdoms (in my case, nodes) served as a useful lens through which to operationalize both the design of a learning ecology and claims herein about participants' cognitive developments. Of use too was White's notion that meaning making does not in fact occur within netdoms, but in “switchings” between netdoms. That is, in the process of the individual seeking a kind of equilibrium out of the chaotic transitions between netdoms. Hence, an individual’s cognitive structure is determined by (and located within) the physical movement *between* netdoms (also reconceptualized for this study as nodes). Determining whether learning happens exclusively *between* or in fact *within and between* nodes is not a focus of this study. Of organizing focus, however, is the notion that learning happens (and should be assessed) within the context of learning ecologies composed of a kind of constellation (Goldman, 1998) of nodes. The idea of cognitive development resulting from social, physical and mental activity through the passage of nodes offers a striking departure from the design of learning environments in schools today where the only learning node available for most urban youth is often the single 45 minute Carnegie period. If learning necessarily requires travel though a system of nodes, or rather, if redundant activity and predictability across nodes determine cognitive development, then, how are we to expect cognitive change from students whose social and cultural capital may relegate their learning opportunities to one node (the classroom), as is the case for the vast majority of students in schools today? This central concern (of cognitive development as a process of travel through microsystems, netdoms or portals) informed the design of this study’s nodal learning ecology. Further, the study sought to investigate the potential learning ecologies hold in facilitating learning. The emerging games and learning field has not yet defined the need to redesign classroom learning spaces in this way per se, but it has advocated for the design of learning spaces that are more "game-like." Most modern electronic games are in fact systems defined by an ecology of nodes through which players travel (most often via a recursive process of completing quests and ascending levels) to solve complex problems. Games also, as is the case for *Gamestar Mechanic*, sometimes serve as central nodes, or "generators," as Gee (2005) calls them, activating the creation of entire ecologies of nodes, from online forums, chat rooms, and informational web sites created by users. For this study, *Gamestar* served as a generator connecting the other five nodes I designed for the study, and allowing for the emergence of other nodes beyond those designed by me. Emergence and other findings will be discussed in Chapter 4. Chapter 5 will consider results from assessments of cognitive development within the overall context of the ecology.

The approach to learning presented in the study posits that the process of acquiring knowledge is mediated by highly social, situated settings in which various discourses and technologies are used (Stone & Gutierrez, 2007). Thus, tenets of Gee's approach to discourse analysis served as an additional theoretical lens through which to consider the overall learning enterprise this study presents. Gee argues that

> the basic premise of the whole enterprise of discourse analysis is this: *How* people say (or write) things (i.e, form) helps constitute what they are doing (i.e., function). In turn, *what* they are saying (or writing) helps constitute *who* they are being at a given time and place within a given set of practices (i.e., their socially situated identities). Finally, *who* they are being at a given time and place within a given set of social practices produces and reproduces,

moment by moment, our social, political, cultural institutional worlds.

In this light, the discussion in Chapter 4 regarding *how* learning occurred as a result of the learning ecology the study instantiated has also taken into account the types of identities – that is, the *kinds* of people – participants came to represent as they negotiated and articulated situated meanings.

Studies relevant to this project

Of relevance to this project are various past studies conducted to (a) examine the potential of design as a viable instructional method; (b) develop systems-thinking skills for K-12 students; and (c) teach game design skills. Some have been discussed to some extent in the first segment of this literature review above. Specifically two studies are considered here, reviewing in particular their research methods and outcomes. The research design and methods sections in Chapter 3 will make connections and draw from some of the methodological strategies discussed here.

Study I: Students and teachers conception of natural and social systems

Sweeney and Sterman (2007) conducted a study whose methods have been particularly salient to this study. They studied how middle school teachers and students, prior to any formal training on these topics, think about aspects of systems such as feedback, stock and flows, time delays and nonlinearities. 30 students (ranging in ages 10-12) and 11 teachers participated. Students and teachers came from two different schools, one where students had participated in an experiential ecology curriculum. Students from the other school had participated in one semester of a standard natural science curriculum. Sweeney and Sterman operationalized their research around the definition of systems-thinking below that also served to frame this study's assessment program:

> Systems intelligence combines *conceptual knowledge* (knowledge of systems properties, structures and reoccurring patters of behavior) and *reasoning skills* (the ability to locate situations in wider contexts, see multiple levels of perspective within a system, trace complex interrelationships, look for endogenous or "within system" influences, be aware of changing behavior over time, and recognize "homologies"—recurring patterns that exist within a wide variety of systems.

To determine students' and teachers' notions of systemic operations, the researchers developed a tool, the Systems-Based Inquiry (S-B I) protocol. It consists of 17 probes and four major sections that ask participants questions relating to, among areas, reinforcing and balancing feedback loops and homological reasoning. Summarized here are findings relevant to this dissertation's study: those related to understanding of feedback dynamics and homological reasoning. In preliminary analyses, they found that overall means scores for students were higher at the school where they had participated in an experiential ecology curriculum, though the differences between students from each respective school were small and not statistically significant. The S-B I protocol included five different scenarios (3 of which were used for this study; see Appendix A, pre and post testing protocol designed for this study) designed to assess conceptions of cause-and-effect relationships and behaviors that can "feed back" to form reinforcing and balancing dynamics. Gains in these scenarios could reflect a "demand effect": students and teachers learned what they were supposed to say by the third prompt and become better at responding to the researchers' prompts. However, overall, performance did not improve consistently. Overall, findings indicated that students and teachers tended to focus on one-way causal relationships, and their overall ability to describe reinforcing and balancing feedback behavior was poor. Finally, teachers outperformed students in their ability to recognize homologies, with 33% of students and 77% of teachers responding correctly.

Sweeney and Sterman report that overall results for their study show weak understanding of systems-thinking concepts on the part of both teachers and students. Their conclusions raise questions about schools' approaches to teaching for the development of systemic reasoning skills. They pose that the standard way of teaching about feedback loops may lead to misinterpretations. For example, the water cycle is often taught using the notion of a "cycle," which can create a misguided notion of "feedback." Cyclic behavior in school texts often refer to a closed loop of energy flow, as in the hydrological or carbon cycle, which obscures the notion of a dynamic feedback loop process. Appropriately, Sweeney and Sterman raise concerns "about the degree to which ordinary discourse, educational materials, and common teaching methods may encourage and support sloppy and incomplete thinking about complex systems" (p. 307).

Study II: Development of systems-thinking in earth science

Assaraf and Orion (2005) conducted a study to investigate (a) the extent to which middle school students are able to develop systems-thinking skills; (b) the factors that influence the development of systems-thinking; and (c) the kinds of relationships that exist within the cognitive components of systems-thinking? The study was conducted in the context of a curricular unit called the "Blue Planet" that was to teach students an earth systems-based curriculum that focused on the water cycle. The sample population included 70 urban Israeli eighth-grade students (from three different classes in two different schools) from different socioeconomic backgrounds. According to the teachers' portrayal of their classes, about 25 percent of students in each class expressed cognitive or *behavioral* difficulties, which, according to the researchers, contributed to teachers' difficulties in encouraging students to collaborate in the learning process. To prepare teachers to teach the curricular unit, they attended an in-service training prior to the research study. The study combined qualitative and quantitative methods and involved various research tools, which were implemented in order to collect the data concerning the students' knowledge and understanding before, during, and following the study.

Data collection was based on a series of ten distinct quantitative and qualitative research tools. These included (1) three Likert-type questionnaires (2) drawing analyses, (3) word associations (4) concepts maps, (5) two interviews, including the "Factory Inventory" and the "Hidden Dimension Inventory", (6) the Repertory Grid, and (7) Observations. Since most of the research tools were designed specifically for the study, the researchers piloted their validity and reliability a year before with 20 eighth-grade students from one of the two schools from which the sample was generated. Below I discuss four of their ten tools. These four were adapted for this *Gamestar Mechanic* project, most significantly for the pre and post testing protocol. Please see Appendix A for a description of the pre and post testing protocol used for this dissertation study.

Assaraf and Orion's pre-assessment findings indicate that most of the sampled students expressed difficulties in all the aspects of systems-thinking even in regard to the very basic aspects of identifying the system components. They entered the eighth grade with a naïve understanding of the water cycle, lacking a dynamic and cyclic understanding of the system or the ability to identify relationships within the system components. Almost all of the students were unable to link the various components of the water cycle together into a coherent network. Research and post-assessment data showed that in spite of the minimal initial systems-thinking abilities of the students most of them made some meaningful progress in their systems-thinking skills, and a third of them reached the highest level of systems-thinking.

Considering the initial knowledge and cognitive abilities of the students, the post-assessment findings suggest that most of the students shifted from a fragmented perception of the water cycle toward a more holistic view of it. About 70 percent of the students, who initially depicted only the atmospheric component of the water cycle, significantly increased their acquaintance with the components and processes of the cycle. About half of the students demonstrated an improvement in their ability to identify relationships among components within the system. Analyses of concept maps revealed that the number of concepts and their interconnections, and the number of concepts that were related to more than two concepts significantly increased. By and large, most of the students improved a dynamic understanding of the system, with one third reaching the higher level of cyclic perception. Hence, in relation to the first research question (‘‘Could junior high students deal with complex systems?’’), the answer is positive. In relation to the second questions ("What influenced the students' ability to deal with system perception?"), the Assaraf and Orion point to two principal factors that might account for the differential progress of the students: (a) students' individual cognitive abilities, and (b) students' levels of involvement in both the indoor and outdoor learning activities.

Both the Sweeney and Sterman and Assraf and Orion studies point to the limitations and promises of engaging middle school students in systems-thinking work. Their methods and conclusions have significantly framed this study.

CHAPTER III

RESEARCH DESIGN AND METHODS

A designed-based research approach

This study employed a largely naturalistic, inductive design-based research program with quantitative elements to allow for tabulations of participant pre and post mean scores. Design-based research attempts to investigate an intervention through a particular theoretical lens with an intent to make further claims about theory (Barab, 2006; Barab & Squire, 2004). The theory of situated cognition has served as this core theoretical lens, while a starting hypothesis posed that computer game design may be well suited to improving students' systems-thinking skills.

A design-based research approach customarily calls for an iterative research process, allowing for flexibility to adapt or redesign research procedures, with (in the case of this study) participants and/or game designers influencing the design of the research. Pioneered (Collins, Joseph, & Bielaczyc, 2004) by Brown (1992) and Collins (1992), design-based research treats as fundamental the problem of context (Hoadley, 2004) and entails both "engineering" (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) particular forms of learning and, in a systematic and iterative fashion, studying those forms of learning within the very context defined as the means for supporting them. In this way, design-based research ideally results in a greater understanding of a learning ecology and constitutes a means of addressing the complexity that is especially characteristic of educational settings.

Similar to the notions of learning as situated described in the literature review, design-based researchers view the interacting elements of a learning ecology as mediating learning events. This view departs from notions of understanding teaching and learning through a set of reductionist, discreet factors, such as student test scores, whether or not a teacher writes a lesson's objective on the blackboard, or a student completes her homework. Cobb, et al. (2003) offer five crosscutting features as characteristic of design-based research. They are summarized here with small modifications made to align them more fully to my study:

1. The purpose of design-based research is to develop a class of theories about both the process of learning and the means that are designed to support that learning.
2. Design-based research is driven by the highly interventionist nature of the methodology. In this way, research projects of this nature are typically test-beds for innovation. The intent is to investigate the possibilities for educational improvement.
3. The third crosscutting feature builds on the first two: design-based research projects create the conditions for developing theories yet must place these theories in harm's way. Thus, design experiments always have two faces:

prospective and reflective. These two faces are familiar to all empirical scientists, but the forms they take in design-based research are somewhat specialized. On the prospective side, designs are implemented with a hypothesized learning process and the means of supporting it in order to expose the details of that process to scrutiny. In the case of *Gamestar Mechanic*, a workshop model designed as a nodal ecology was used as the pedagogical framework and continually examined as the program unfolded. On the reflective side, design-based research projects are conjecture-driven tests, often at several levels of analysis. My initial ecological approach to the design of the learning environment, for example, was a conjecture about a means of supporting the development of game design and systems-thinking skills; however, during the process of the study more specialized conjectures were framed and coded for. These conjectures, as described in Chapter 4, include analyses of the affordances nodes provided, such as participants "taking on" productive identities, or noteworthy relationships between nodes.

4. Together, the prospective and reflective aspects of design experiments result in a fourth characteristic: iterative design. As conjectures are generated and perhaps refuted, new conjectures are developed and subjected to testing. The result is an iterative design process featuring cycles of invention and revision. This iterative revision process for me entailed discussions with co-instructors and members of the *Gamestar Mechanic*

research and development team. Indeed, one of the distinctive characteristics of the design-based research methodology is that the research team deepens its understanding of the phenomenon under investigation while the research program is in progress.

5. The fifth feature of design experimentation reflects its pragmatic roots: theories developed during the process of experiment are humble not merely in the sense that they are concerned with domain-specific learning processes, but also because they are accountable to the activity of design. (altered from Cobb et al., pp. 10-11)

A brief comparison of methods

In order to place design-based experiments in the landscape of different methods, Collins, Joseph & Biclaczyc (2004) compare them to three general types of educational research approaches. First, *Laboratory and training studies* attempt to control variables in order to determine how particular independent variables affect a few dependent variables such as the learning of content and skills. These studies are effective for identifying effects of particular variables, but they often neglect variables critical to the success of any intervention. Second, *ethnographic* research is also set in the contexts of actual learning environments, but it has some of the same characteristics of the analytic sciences in that it does not attempt to study interventive programs. In general terms, ethnographic research attempts to characterize relationships and events that occur in different educational settings, but there is no explicit attempt to change educational practice. To be sure, however, ethnographic research produces rich descriptions that make it possible to understand what is happening and why. Third, *large-scale studies* of educational interventions use a variety of measures to determine the effects of a program or intervention. The methods usually emphasize standardized measures and surveys of critical participants not necessarily tied to any particular design. These studies are often used to identify critical variables and to evaluate program effectiveness in terms of test scores and institutional culture, but they often do not provide the kind of detailed picture needed to guide the refinement of an educational intervention. They are crucial however for conducting summative research; hence, design-based research often borrows from this methodology in efforts to reach summative conclusions.

Research site selection and participant recruitment

Research was conducted at a charter school in the New York City area. Site selection was based on close proximity to Gamelab, the game development company responsible for designing *Gamestar Mechanic*; access to middle school-aged students (10 to 12 year olds), access to a student population representative of the overall demographics of New York City public schools; and interest on the part of the school in engaging their students in a game design research project. After the school expressed interest I presented to the school's board of directors who reviewed the research plan and later released an official letter of consent. Additionally, approval was attained from both the New York City Department of Education and New York University's human subject committees.

The workshop was designed to meet from February to June 2008 for 32 sessions, three times a week. Per participants' requests, four more optional sessions were offered, totaling 36 in all. Sessions lasted 75 minutes and met in the afternoon during the school's "enrichment" period. This was a time when students in the school participated in a variety of homework help or tutorial experiences intended to support students academically. Per IRB regulations, participants in the *Gamestar* workshop attended on a volunteer basis and understood they could terminate their participation at any time. 16 (fifteen sixth grade and one seventh grade) students participated throughout the 17 weeks of the study.

The charter school serves predominately Black and Latino students, 68% of whom received free or reduced lunch at the time of the study. Middle school teachers were very supportive of this research study, and from time to time dropped in to workshop sessions. They also provided performance-level academic and test score data for the students who participated in the study.

Participation was open to all students in the middle schools grades. To recruit participants, I visited classrooms and lunch periods and explained to students of the option of participate in a game design research project. Interested participants were required to return IRB-approved consent forms signed by a parent or legal guardian.

I served as the lead instructor for the study, directly interacting with participants and leading instruction from day to day. Two technology teachers from the school participated in the study as teaching assistants. Their primary interest in participating was for professional development purposes. However, they quickly became an integral part the research project; as a team of three, for example, we debriefed each Friday for 90 minutes on the progress of the study. The goals and theories associated with the study were explained to the teachers. Debriefs allowed for the kind of iterative nature of design-based research programs. During this time, I also conducted semi-structured interviews (Holstein & Gubrium, 1997) to formally record (with audio recording equipment) observations and suggestions made by the teachers.

<u>Participants</u>

16 middle school students (15 sixth graders and one seventh grader) participated in this study. Eight participants attended the workshop from beginning to end. 13 students chose to attend at the outset of the workshop. Six of the eight were chosen as participants of focus based of a desire to maintain a heterogeneous balance in gender; ethnicity; race; prior academic achievement levels as reported by teachers, participant report cards, and standardized test scores; level of English language proficiency; and consistent attendance on the part of participants. The two participants not selected to be participants of focus were males who had either inconsistent attendance or were already represented in the sample in terms of

ethnicity or level of academic performance. According to the school, all of these 16 participants in the study qualified for free or reduced lunch.

Data Collection

Five qualitative data collection methods were used in order to determine gains in systemic reasoning skills made by participants. All of the methods employed have been used in studies that have sought to capture levels of systemic reasoning skills among middle school students but have been combined for this study in a novel way.

Pre and post test protocol

A pre and post test protocol was administered to all participants who attended the workshop from beginning to end. The protocol had approximately 20 probes within a five-part structure and lasted approximately one hour. The protocol was based on a combination of assessment items used in two recent studies (Assaraf and Orion, 2005; Sweeney and Sterman, 2007) that investigated middle school student's systemic reasoning abilities. Similarly, the protocol designed for this study assessed participants' ability to show development of four systems-thinking skills. Please see a copy of the protocol created for this study in Appendix A. Additionally, all pre and post testing sessions were video recorded.

Think-aloud protocol

A think-aloud protocol was be used to hear and record participants' (a) thoughts and rationales when making particular design decisions, and (b) facility with systems-thinking. Think-alouds are a form of documentation of what participants say when asked to solve a problem, and have been cited as a promising technique for gauging the extent to which students possess systems-thinking skills (Doyle, 1997). They have also been theorized to be among the most effective ways to gauge participants' cognitive development because they are produced in "real time" and thus, not subject to the type of processing that may weaken the validity of retrospective reports (Ericsson & Simon, 1984, 1993; Reich, 2007). Participant think-alouds were video recorded using *ScreenFlow*, a software application that enables the simultaneous video capturing of on screen activity of each participant in "real time" as they responded to questions posed by me.

Writing samples

Participants completed various writing samples during the study. One sample, referred to as a "film treatment," was used for the purposes of data analysis. Film treatments asked participants to "pitch" one of their games to a film company executive in the form of a film narrative. Treatments were not assessed for content, style, or grammatical conventions, but rather for how well participants could use design elements to represent dynamics in their narratives. While this study did not set out to track literacy improvement among participants, we were interested in seeing how game design could support literacy development. To complete this assignment, participants moved back and forth between their games and treatments, making adjustments to both in a reflection-in-action (Schön, 1983), iterative fashion.

Concept maps

Participants were asked to complete a concept map of one of their games toward the end of the study. Assaraf and Orion (2005) explain that concept maps are a schematic device that allow examination of the way learners structure their knowledge. Concept maps focus on the structure and the links that the participant perceives as they link relational dynamics between concepts. Participants worked independently to create concept maps using a software application called *OminGraffle Professional*. Participants were trained on how to use the software for about 15 minutes, then asked to work independently. Each of the six participants of focus was asked to design a concept map of one of their games depicting balancing and reinforcing feedback loops. Before beginning their concept map designs, various visual models appearing in engineering or research journals depicting reinforcing and balancing feedback loops were shown and discussed with participants. Time did not permit for iterations of concept maps. Hence, think-alouds for concept maps are based on one-time renditions.

Field observations

Field notes were generated for each workshop session. Field notes served principally to document both (1) the implementation of the study's learning ecology as designed and (2) its emergent qualities. The nature of design-based research programs is such that the very contexts in which studies are conducted are subjected to analysis. Hence, the next chapter offers an extensive description and analysis of the study's learning ecology. Field notes were complemented by video recordings of most sessions. In total, 40 hours of video footage were collected for this study. Recordings consisted of pre and post test sessions, workshop sessions, and interactions between participants and professional game designers. While this study did not use video ethnography as a primary methodological means through which to collect and analyze data, researchers in Learning Sciences (for an overview see *Video Research in the Learning Sciences*, Goldman, Pea, Barron & Derry, 2007) have significantly adopted the use of video as it can serve to effectively advance studies primarily concerned with the issue of learning contexts. The use of video primarily documented the learning ecology of the study.

Analysis

The Systems-Based Inquiry (SB-I) protocol designed by Sweeney and Sterman (2007) largely framed both the pre and post test protocol created for this study and the analysis of results. Sweeny and Sterman report that various analyses were conducted to ensure instrument validity, including item analysis, corrected item-total correlation, Cronbach alpha, factor analysis and Rasch analysis. Results of these analyses indicated that the instrument possesses good psychometric properties. The rubric developed for the S-BI was adapted and used to assess and score of participants' systemic reasoning skills, ranging five levels from 0 (no response) to 4 (integrated use of systemic reasoning). Probes and participant responses (all of which exist within a video clip) were grouped by *type* of systems-thinking skills, then coded using a rubric I created based on the S-BI protocol. Four systems-thinking skills – identifying (1) dynamics, (2) reinforcing and balancing feedback dynamics, (3) quality of a system and (4) homologies – were assessed in this study. Coding was facilitated by the use of the video analysis software known as *Transana*. In all, 135 distinct video clips averaging two minutes in duration were transcribed and coded within *Transana*.

Coding within *Transana*

Transana is widely used qualitative video analysis software that that allows for the management and analysis of video-based data. For this study, approximately 40 hours of video footage were collected. All footage was transcribed. Within *Transana*, I stored, transcribed and coded 135 discreet video clips of participants' pre and post test responses using a system of keywords. Think-alouds, and clips from workshop activities, such as students presenting their work and giving each other feedback, were also stored and coded. A coding scheme based on the SB-I was created (see rubric in Table 1). For example, codes (keywords) included “identification of dynamics Level 1,” “identification of dynamics Level 2,” and so on; “identification of reinforcing and balancing feedback loops Level 1,” “identification of reinforcing and balancing feedback loops Level 2,” and so on. Coding within *Transana* facilitated the creation of reports such as a “*Transana* collection report,” which allowed me to synthesize individual participant responses across skills. As well, reports allowed for comparisons of pre and post testing responses.

<u>The Systems-Based Inquiry protocol adapted for this study</u>

The intent behind creating the adapted rubric was to create specific and uniform assessment criteria to minimize subjective opinions as to what determined a particular score (Newell, 2002). Walvood and colleagues (1998) have written about the need to articulate measurable and demonstrable traits and competencies when designing rubrics attempting to assess learning outcomes. Newell (2002) and Young, et al (2001) have also stressed the importance of this to ensure inter-rater reliability. The comparison chart on the next two pages shows how a rubric was adapted for this study using the Systems-Based Inquiry rubric. The competency traits for the SB-I are listed in the first (left) column. Competency traits developed for this study based on the SB-I are listed by skill type in columns two to five.

Systems-Based Inquiry by Sweeney and Sterman (2007)	Systems-based Inquiry adapted for this study to assess systems-thinking skill: identification of dynamics	Systems-based Inquiry adapted for this study to assess systems-thinking skill: identification of reinforcing and balancing loops	Systems-based Inquiry adapted for this study to assess systems-thinking skill: identification of quality	Systems-based Inquiry adapted for this study to assess systems-thinking skill: identification of homologies
Systemic Reasoning Level 0: *Incorrect or non-applicable response*	There is no response, response of "I don't know", or non-applicable response.	There is no response, response of "I don't know", or non-applicable response.	There is no response, response of "I don't know", or non-applicable response.	There is no response, response of "I don't know", or non-applicable response.
Systemic Reasoning Level 1: *Describes simple interconnections:* A response is scored as Level 1 if it involves simple interconnections and inter relationships, linear chains of causality and static (vs. dynamic) descriptions of change.	A Level 1 response includes identification of a system and <u>some</u> identification of discreet elements within a system, interconnections and inter-relationships, linear chains and static (vs. dynamic) descriptions of change.	A Level 1 response includes interconnections and inter-relationships, linear chains and static (vs. dynamic) descriptions of change.	A Level 1 response identifies a potential design problem within a system.	A Level 1 response involves an attempt to indicate a homologous structure.
Systemic Reasoning Level 2: *Describes aspects of system structures and behaviors:* A response is scored as Level 2 if participants show some understanding of the behaviors and characteristics of systems, including multiple interconnections and feedback, as illustrated by this student description	A Level 2 response shows <u>some</u> identification of discreet elements within a system, understanding of the behaviors and characteristics of elements within a system, including a dynamic or an interconnection.	A Level 2 response shows <u>some</u> understanding of the behaviors and characteristics of reinforcing <u>and/or</u> balancing feedback loops, including multiple interconnections and feedback.	A Level 2 response identifies a potential design problem within a system and asks about or offers a potential solution.	A Level 2 response shows <u>some</u> understanding of the behaviors and characteristics of natural, technological or social systems and includes <u>some</u> observations and descriptions of homologous structures.

Table 1. Systemic Reasoning Rubric based on the Systems-Based Protocol by Sweeney and Sterman (2007)

Systemic Reasoning Level 3: *Demonstrates understanding of principles guiding system behaviors:* A level 3 response demonstrates sound understanding of the behaviors and characteristics of natural and social systems and includes observations of cycles, causality, feedback and dynamics.	A Level 3 response demonstrates sound understanding of discreet elements within a system, understanding of the behaviors and characteristics of elements within a system, including a dynamic or an interconnection affecting an outcome.	A Level 3 response demonstrates sound understanding of the behaviors and characteristics of reinforcing and/or balancing feedback loops and includes observations, such as time delays, patterns, cycles, causality, feedback and dynamics.	A Level 3 response takes into aspects of the design of a system, identifies potential design problems and asks about or offers potential solutions.	A Level 3 response demonstrates sound understanding of the behaviors and characteristics of natural, technological or social systems and includes clear observations and descriptions of homologous structures.
Systemic Reasoning Level 4: *Fuller utilization of systems intelligence:* A level 4 responses includes a fuller manifestation of systemic reasoning including description of a system at multiple levels, multiple feedback loops, understanding of stock/flow structures and recognition of homologous structures.	A Level 4 response includes fuller manifestation of understanding of discreet elements within a system, understanding of the behaviors and characteristics of elements within a system, including multiple dynamic interconnections at multiples levels affecting an outcome.	A Level 4 response includes fuller manifestation of systemic reasoning including description of a reinforcing and balancing feedback loops and includes observations, such as time delays, patterns, cycles, causality, feedback and dynamics.	A Level 4 response accounts for most or the entire design of a system, identifies it's elements, identifies potential design problems and asks about or offers potential solutions.	A Level 4 response includes fuller manifestation of the behaviors and characteristics of natural, technological or social systems and includes clear, in-depth and novel observations and descriptions of homologous structures.

Table 1 (continued). Systemic Reasoning Rubric based on the Systems-Based Protocol by Sweeney and Sterman (2007)

Inter-rater reliability

Two professionals familiar with the systems-thinking field were employed to serve as inter-raters. One is a faculty member at Baruch College currently teaching a school leadership course using a systems-based thinking framework for organizational change. The other is a school principal of a school in New York City (scheduled to open in 2009) designed to use games as a means to learn design and systems-thinking. Inter-raters were trained for half a day using samples of participants responses previously coded within *Transana*. Samples used during training did not include sample responses from the six participants of focus. The training included an overview of the study, samples from each type of response inter-raters were expected to rate, and opportunities to rate each sample. During this time, raters discussed their ratings and sought clarity as the appropriateness of ratings using the rubric. To establish independent ratings, after the training raters were asked to terminate discussion regarding participant ratings. A reliability formula suggested by Miles and Huberman (1994) was used:

$$\text{Reliability} = \frac{\text{\# of agreements}}{\text{total \# of agreements and disagreements}}$$

Inter-rater reliability was sought for all participant responses on the pre and post tests, and for all responses to the think-alouds and writing sample assignments. Inter-raters scored 68 items for which they established agreement 96% of the time. Score-ability and overall scores were based only on score-able items; that is, items presented to the inter-raters during the inter-rating session. Therefore, if a participant had only 10 items that could be scored, the participants' overall mean score was based on the scores of these items. Score-able items were selected by the researcher based on available pre and post test items. Items were only excluded if sound or any other technical concerns made the item incomprehensible. On average each participant had 11.4 items scored of 20 possible score-able items. Overall gains for each participant were tabulated by drawing a difference in mean scores from Time 1 to Time 2.

CHAPTER IV

DESIGNING FOR ECOLOGICAL CONSTANCY

> The mind is at every stage a theatre of simultaneous possibility. Consciousness consists in the comparisons of these with each other, the selection of some, and the suppression of the rest.
>
> William James (1890)

This study investigated (a) the potential a video game could have in helping middle school students develop of systems-thinking skills, and (b) the role context played in the learning process. Context was defined for this study as a "learning ecology" to signify, in a sense, a system of interconnected and interacting *learning nodes* populated by people and tools. A node here is a kind of microsystem (Bronfenbrenner & Morris, 1998) or a semiotic conglomeration that is, actually, a part of a family of like nodes, each filled with people acting and interacting in similar ways, using a similar language and using similar kinds of tools. This study took special care in *designing a learning ecology.* Indeed, if learning happens as individuals and groups move within and across systems – here conceived of as a learning ecology – it is important to account for how the study's learning system was designed. In this way, the chapter responds to the study's second (research) sub-question; that is, the question of *how*: *How* was a learning landscape constructed and, more importantly, *how* did participants come to acquire the systems-thinking skill identified for this study?

The conceptualization of this landscape as a *learning ecology* was guided by research and theories (Bronfenbrenner & Morris, 1998; Goldman-Segall, 1998; Lave & Wenger, 1991; White, 2008) pointing to meaning making, cognitive development and identity formation as a process whereby individuals travel through various learning spaces. The ecology here is framed around a set of seven interacting, interdependent "nodes." Of significance to the study is the emergence of a new node (which I call the 'Rise' node) that surfaced sometime after the first month of the study and was entirely driven by participants. Field notes documenting the affordances (Gibson, 1986) of each individual node were kept and largely inform the descriptions of the learning ecology below. Magnusson and Stattin's (1998) notion of *dynamic interactionism* contributed to an analysis of reciprocal and non-linear relationships between participants and nodes. Dynamic interactionism considers processes going on within environmental contexts, the mental and biological processes going on internally for individuals, and the relations between the two. Relatedly, Magnusson and Stattin present a strong critique of the vast traditional research in the social sciences that by and large fails to consider holistic interactionism in favor of concepts like independent and dependent variables, which assume unidirectional causality. In this light, this study is conceptualized as a departure from traditional research and presents a holistic descriptive analysis (Gibson, 1986) of the interactional aspects between nodes within a learning ecology. This approach to the design and analysis of a learning environment is salient especially in light of the changes in cognitive development presented in the following chapter. That is to say that this chapter presents the argument for how it is that participants came to show the gains in systemic reasoning summarized in the next chapter.

The learning ecology is framed as a network of nodes. Each node was defined as containing a set of cross-cutting, architectural elements: social activity, mostly framed by constant and continual informal and formal feedback; tools such as game review protocols, story boarding structures, *Gamestar Mechanic* itself; a specialist language that included terms like core mechanics, reinforcing feedback loops; distinct physical spaces (classrooms, the studio offices of Gamelab, the game development company); norms defined early on by participants; ways of being (e.g., taking on varied identities, such as game designer, critic, competitor, game player); specified time allocations for each node; and perhaps most importantly, the material production of various artifacts, especially games. Indeed, the purpose of all activity within nodes was to produce games that adhered to a set of criteria defined by the community.

Taken together, the seven nodes described here made up what I refer to as a condition of *ecological constancy*: an ecological condition in which perceived objects have a tendency to give rise to very similar perceptual experiences in spite of variations in the condition of observations. Said another way, each node in the ecology in spite of its difference in feel and appearance attempted to instantiate similar perceptual experiences for participants across nodes, intending to create perceptual redundancy and predictability. This notion takes guidance from Bronfenbrenner's bioecological systems theory, but also attempts to extend his and White's (2008) notion of meaning-making or learning as occurring in the "switchings" between "netdoms." Learning as a result of ecological constancy necessitates a network of connected nodes that each houses similar perceptual experiences. Take for instance the way in which a high school basketball player might become a masterful player. If she is to become masterful, only playing basketball with her high school team will likely not grant her mastery. She will need to *be a basketball player* in other nodes as well, such as (a) with friends on a local court on the weekends, (b) on the phone at night with friends critiquing her game and those of others, (c) with her coach during one-on-one lessons, (d) when reading magazines about basketball, (e) when watching a professional team play on television, (f) when attending a summer basketball camp, (g) or when competing against other teams in her region. In schools most urban students are given opportunities to learn in one node (and in most instances they are learning *about* something). This study has been an investigation into a departure from this type of teaching and learning program. Overall implications of the design and findings of the study are discussed further in Chapter 6. The description of nodes that follows, however, is intended to account for a kind of ecological constancy not evident in schools, urban or non, and its impact on participant learning.

Descriptive analysis of nodes

Each node described below is followed by an analysis that takes into account four distinct areas. The analysis of nodes does not make claims about which node or group of nodes best facilitated learning. However, field notes were coded using these four areas of focus (listed below) to establish commonalities and relationships between nodes, and conjectures are made in relation to the limitations of each node as it relates to its potential to facilitate design and systems-thinking skills. Specific results accounting for participant learning are presented in Chapter 5. Because of the nature of this study as an educational intervention (Brown, 1992), understanding the specific design under which this research program was conducted is of relevance to the overall study. Field notes were kept and coded to account for the design of the following four areas:

a. the types of systems-thinking skills afforded by each node;
b. identities afforded by each node;
c. proximity and interdependency between nodes; and
d. cognitive limitations of each node if used in isolation.

Systems-thinking skills

Before describing the learning ecology, listed below are the four systems-thinking skills that framed this research study. More specifically, this study investigated the potential of *Gamestar Mechanic* to help facilitate for learners the acquisition of these four skills:

1. Understanding of system *dynamics*: the ability to identify when multiple (i.e., dynamic) relationships exists within a system (Forrester).
2. Understanding of feedback dynamics (i.e., *reinforcing and balancing feedback loops*): the ability to identify reinforcing and balancing feedback loops, and to show how they can inform and can continually modify the workings of a system (Senge, 1990, 2006).
3. Understanding the *quality* of relationships within a system: the ability to identify when the relationships within a system are or are not working at optimal levels.
4. *Homological* understanding: the ability to determine that system dynamics can exist in other systems that may appear to be entirely different.

The concern for context and the study's theoretical framework of learning as situated, led to a design that carefully accounted for the variety of experiences students were to have within a learning ecology. At the outset, six different types of nodal learning experiences included (1) pre and post tests; (2) the online video game *Gamestar Mechanic*; (3) a workshop, including a workshop curriculum; (4) *Gamestar*

Mechanic outside-of-school, (5) interactions with Gamelab[1] game designers; and (6) an end of workshop games exposition. Each is described below separately, as designed. Except for use of *Gamestar Mechanic* outside-of-school, various aspects of all other nodes of the learning ecology were documented using a combination of participant assessment instruments, video recordings, photography and field notes. Finally, a seventh and unexpected node emerged during the study. After a month and half (in April) the majority of participants felt they wanted to spend more time designing games. Hence, on their own, they recruited one of the assisting teachers and asked him if he would supervise the game designers during their lunch period (the knew they would need an adult to secure approval from the school principal). Hence, starting in mid-April and lasting through June, the game design participants met five days each week for 50 additional minutes. I describe this node in more detail below. To denote its emergent quality within an ecological system of nodes, this seventh node is called Rise.

Node One: *Gamestar Mechanic*

Created as part of a research and design collaboration between The Games and Learning Group at the University of Wisconsin-Madison and Gamelab, a New York City-based game development company, *Gamestar Mechanic* is an educational tool that, as a core part of its development, was guided by current research and

[1] Gamelab is the name of the game development company responsible for creating *Gamestar Mechanic*. In the fall of 2008, the company changed its name to Gamestar Mechanic.

theory on situated learning. Theoretical facets that appear to have been of particular interest were those positioning learning as an act of "taking on" the identities and behaviors particular to a knowledge domain; and those of producing knowledge in ways that are valued within that knowledge domain. The knowledge domain of interest here is game design, particularly as conceived by game designers Salen and Zimmerman in their influential book, *Rules of Play* (2003). Various features of *Gamestar Mechanic* that can be attributed to situated learning theory, for example, is *in situ* design (e.g., players produce games *within* the *Gamestar Mechanic's* system) as opposed to designing games more abstractly and disconnected from an internal system – a point to which I will return in the discussion section. Yet another core feature in this respect is the game's community component, which enables players to "take on" public identities of "game designer," "community member," "critic," "helper," and "writer" (of game reviews).

In a micro sense, *Gamestar Mechanic* [2] is a video game – a Flash-based software program – designed to give middle to high school-aged players a set of experiences through which they may come to develop basic game design skills. These skills include (a) designing two-dimensional games using a set of "sprites"—creatures players select to define a play space; (b) iterating from a prototype to a more complete design through a recursive process of trial and error, and feedback from other players; (c) designing play, that is, the skill of engineering socio-technical (Salen, 2007) play worlds that account for hosts of complex variables from

[2] At the time of this study, the closed Beta version build of the game was used.

narratives, balance of difficulty, win and lose conditions, and replayability. Iteration is built into the software as a key feature by incorporating an edit/play switch that allows players (whom I will call "game designers" from here on) to continuously test their designs by toggling back and forth between play and edit mode. Game designers level-up through the game by completing a set of play and design "arcades" intended to give the developing game designer a sense of the game's capabilities and overall plasticity. In an incrementally challenging fashion, 17 arcades serve as a training ground, rewarding game designers with "experience points" and additional new sprites as they "level-up" by completing each arcade.

Set in a fictional narrative, the game designers assume the role of "game mechanics" whose mission is to bring an old dilapidated game factory back to life. Factionalism between "game schools" eventually led to mass breakdowns in the land of Ludonia, a place dependent on games as the core source of culture. Now Samson, an elder master mechanic, is calling on game designers to try their skill in bringing life back in the only way possible: by making games.

As game designers level up, they amass a variety of sprites in their arsenal. The game organizes sprites into five types: avatars, enemies, blocks, items, and system components. *Avatars* (one allowed per game) represent the intended "player," that is, the player imagined by the game designer. *Enemies* and blocks, among other things (such as the particular design of a space, like the use of gravity or boundedness), represent types of obstacles. *Items* and *system components* enable players to assign games a variety of game elements, including speed (by choosing to include a timer), a system of points (by choosing to include a point or frag (enemy) counter, or a system of health and allowable lives. In edit mode, the behavioral parameters of each type of sprite (avatars, enemies, blocks) can be modified. Unlike all other sprites, avatars (controlled by the player) and enemies (which can move at varying patterns, can suddenly reproduce or disappear, or can have varied strengths or abilities as determined by the game designer) are animated creatures composing the visible system of dynamic activity on the screen. That every single type of sprite can be modified is of special significance as game designers have to account for large numbers of dynamic variability as making one change in their game system can lead to a series of other consequential design choices to consider. One sprite called the Chronox Sniper, for example, has nine different settings to choose from (e.g., units of health, speed, movement style, spawn rate) with each having between three to six choices to make within each setting (e.g., 1 to 5 units of health, or movement styles of random, straight or patrol), totaling 42 different behavioral adjustments a designer can make to that sprite alone.

In a more complex, macro sense, *Gamestar Mechanic* is an online social network that facilitates a game design community space for multiple player-designers. In essence, *Gamestar Mechanic* is a small world, through which participants travel. To participate, designers secure a single-user account. Accessed through an online browser, games created by *Gamestar Mechanic* users become instantly available to the community of designers. At the time of this study the site reported about 600 single user accounts with whom the 16 participants in this study were able to interact. As designers' main activity is to produce games, the site's games are the central currency of this social network, as, for example, new research would the central currency of a professional research conference, or displaying new fashions would be at a fall fashion show in Milan. In addition, the site's various features facilitate status-building within the community. Through a rating and comment system, designers can select to play, rate and review games created by others. A "game alley" page posts the top ten rated games, the newest games designed, and top rated mechanics. Yet a another page called "workshop" allows you to create a watch list of your favorite designers. The design intent here is to instantiate a unique world – a semiotic learning system – propelled by a set values, or as Gee (2007) has a called it, an "appreciative system" of values – a specific kind of system which in fact exists for all knowledge domains, from research to fashion. A principal value in our case is that of design (specifically *game design*) as a means to community membership and participation. Game design (or at least game design as conceived by the designers of *Gamestar*) establishes the language platform on which users will communicate and negotiate meaning. *Immediate feedback* (facilitated by the game's edit/play feature is another value as is iteration based on *community feedback*. *Iterating* in a quest for continual improvement based on recursive "tinkering" and trial and error is yet another value imbedded in *Gamestar*. Finally, *expertise* is a value of *Gamestar* because a designer may achieve "top 10 designer" status based on how highly other designers rate your games. In this way, the community of designers itself – not an outside entity – determines what may be deemed as meriting "top quality."

Designed around *Gamestar Mechanic*, the game served as a generative platform for the overall workshop. Indeed, *Gamestar* served as the generator (Gee, 2007) node among the six nodes designed at the start of the workshop.

Types of systems-thinking skills this node afforded

Gamestar Mechanic served as the generator node without which activating all of the other nodes would not have been possible. More specifically, *Gamestar* served as a modeling platform (Lehrer & Schauble, 2005) wherein participants could build and test game systems. It allowed them to identify and purposely apply (1) dynamics, (2) reinforcing and balancing feedback loops and to (3) assess the quality of their game systems – three of the four systems-thinking skills this study sought to assess. The fourth skill – identifying homologies – was also facilitated by *Gamestar*. For example, for one assignment participants were asked to identify a "real life" system in which reinforcing and balancing feedback dynamics were apparent. Using *Gamestar*, participants were asked to build the system, showing how the same elements of that system, including its reinforcing and balancing dynamics, could be represented within *Gamestar*.

Productive Identities

Gamestar Mechanic made it possible for participants to "*learn to be*" game designer versus "*learn about*" game design as is the traditional mode of learning in schools. For instance, in most schools students are taught *about* history, biology or algebra. Instead, by stepping into a variety of *productive identities*, participants "learned to be" (Brown 2006; Gee, 2007) – within a public, national space made possible by the *Gamestar's* community feature – game designers, game reviewers and critics, competitors, experts, and members of a game design community that actively negotiated what was to be deemed "best" and "worst." Each identity was driven by a *productive stance* that facilitated the material productions participants created—which for the most part were critically driven by the same concern*: ideas for creating and improving games*. Games that stood out for a particular kind of ingenuity were noticed by the community and given high marks, thereby assigning them and their designers special status within the community. As is the case for how new ideas shape and propel all fields of knowledge –- from, say, determining the most accurate genomic DNA sequencing method to arguing for the most credible historical artifact – game ideas became the driving currency of the community.

Proximity and interdependency to other nodes

Bidirectional, non-linear relationships between nodes was an intent of the workshop's design. Reciprocal interdependency became evident during the workshop as participants traveled from one to the next, with each containing intentional redundancy especially in terms materially productive identities. For example, in one instance participants were first asked (in the workshop node) to create paper and pencil storyboards depicting reinforcing and balancing feedback dynamics, then asked to build game models (in the *Gamestar* node) showing the same dynamics. In general, all other nodes supported – and were supported by – the *Gamestar* node. Figure 1 shows the bidirectionality of relationships between nodes, with the *Gamestar Mechanic* node depicted as generator.

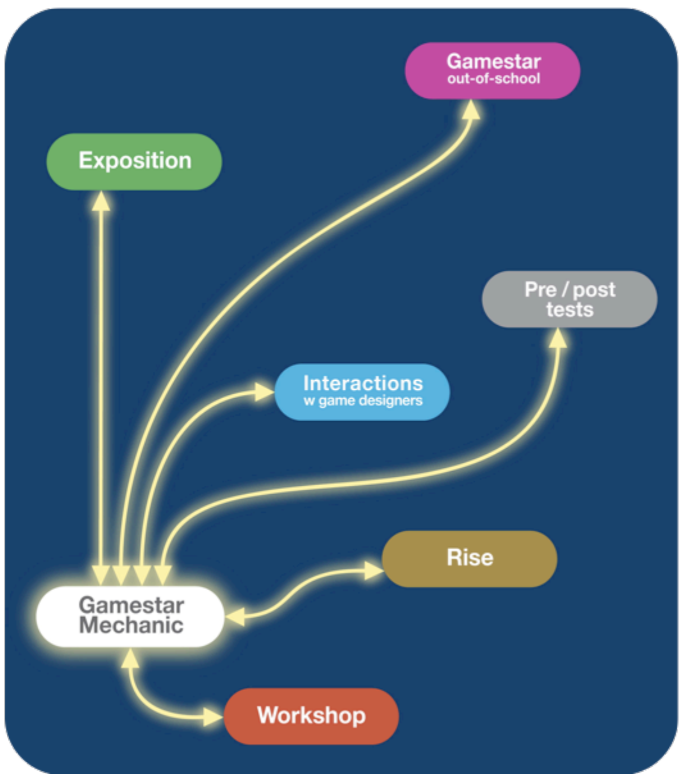


Figure 1. Bidirectional interactivity of the Gamestar Mechanic node

Bidirectionality in the context of this study meant that neither one node 'worked' without the other. Activity in each node was reliant on the human activity, knowledge, tools, symbols and values – the semiotic substance – of the other. Together they allowed for predictable redundancy (Bronfenbrenner & Morris, 1998; Magnusson & Stattin, 1998) intended to support cognitive development.

Cognitive limitations of this node if used in isolation

If considered in isolation, it is clear that *Gamestar Mechanic* enables users to participate in a community of novice game designers who design, share, comment and rate each other's games. Interactivity was somewhat static (vs. fluid or constant), however, due to limitations of the beta build we used, which didn't yet have a search feature, making it arduous to search for games made by other players. While the build did include a "training" program that took gamers through a robust series of game and play challenges, it did not attempt to guide designers through an explicit design curriculum that would support the acquisition of specialist terms or game design concepts. The greatest limitation perhaps was the absence of a space for participants to reflect on their designs, a practice facilitated outside of this node, such as in the workshop and interactions with professional game designers. The explicit development of systems-thinking skills (and related specialist terms) may also have not been possible without a workshop curriculum with this as an explicit focus.

Node Two: The workshop

The workshop met from February to June, 2008 for 32 sessions, three times each week. Per participants' requests, four more optional sessions were offered, totaling 36 in all. Sessions lasted 75 minutes and met in the afternoon during the school's "enrichment" period. This was a time when students in the school participated in a variety of homework help or tutorial experiences intended to support students academically. Participants in the *Gamestar* workshop attended on a volunteer basis and understood they could terminate their participation at any time. 16 (fifteen sixth grade and one seventh grade) students participated throughout the 17 weeks of the study. Eight defining, interdependent elements organized the workshop's discourse (Gee, 1990, 1996). An 'element' is defined here as a dominant core activity, a framework, or a core instructional strategy.

Workshop Element 1: A game design and systems-thinking curriculum

Prior to the workshop, I designed a 32-session curriculum. It was based on iterations of two pilot studies I conducted from March to July 2007 in collaboration with members of the *Gamestar Mechanic* research team. The first pilot was conducted with middle schoolers in the spring of 2007 in New York City using a prototype build of *Gamestar* (once a week) over a 12-week period. Among the foci of that pilot was to test how well the software could facilitate the understanding of specialist terms like "core mechanics." Core mechanics are the behaviors players have to engage in to successfully complete a game, like collecting points, jumping, floating, or shooting enemies. The second pilot study, conducted over one week in New Berlin, Wisconsin, used an alpha build of *Gamestar* and focused on developing assessment tools, such as developing a pre and post test that asked participants to design paper based games and show an understanding of a set of five core design conceptual elements (or specialist terms): core mechanics, space, components, goals and rules. The curriculum for the present study also guided participants through the acquisition of these conceptual terms. However, systems-thinking skills were layered onto the curriculum, requiring participants to see that the dynamics of interacting elements (core mechanics, space, rules) were systemic in nature; or rather, could be designed to emit a particular dynamic.   Design and systems-thinking skills, then, were conceptualized for this study as essentially dialogic (Bakhtin, 1986).

Three "big ideas" framed the overall workshop and learning ecology. Appendix B offers a detailed overview of the curriculum. Below, however, are the three big ideas that informed the overall design of the learning ecology:

Three big ideas:

1. Games are dynamic, designed systems.
2. Games are made up of components that interact with one another within a system to create a particular kind of experience for a player.

3. Goals, rules, space and core mechanics, and components (e.g., creatures, blocks, etc.) are the core design elements of a game designed in *Gamestar Mechanic*.

The curriculum was divided in four distinct time periods. The first period lasted approximately four weeks and introduced students to the workshop's five core conceptual specialist terms: space, rules, core mechanics, components and goals. These five also served as the core game design elements of focus for this study. Past design and systems-thinking studies (Hmelo, et al., 2000) have found that introducing participants to core terms early on may aid the development of systems-thinking concepts. Participants considered the interactions of elements and eventually were asked to decompose existing games within *Gamestar* using the five elements as a framework. Participants were also asked to account for the quality of a game's overall system as it related to the interactional and relational effectiveness between these five elements. Participants mostly worked in pairs during this time to facilitate conversational practice and application of the terms. They were also asked to write journal entries and to present whole-class critiques of existing games in *Gamestar* using the specialist terms.

The next three time periods were framed as "quests." Quests posed a particular challenge for participants and were marked by the arrival of a letter from Samson, the elder *Gamestar* master mechanic. The first quest asked participants to design a game for "competition." This game needed to be designed, iterated based on written feedback from other participants, and submitted for final ratings from two other participants (using a set of criteria set by the participants as a group during the first weeks of the workshop). From this process, a “top game” emerged as the winning game. This quest sought to: (1) provide an opportunity for participants to apply their understanding of specialist terms, and (2) introduce iteration as a core game design practice.

The second quest officially introduced participants into systems-thinking concepts. Participants had never heard of “reinforcing and balancing feedback,” – at least not in the context of the workshop – yet Samson (see sample letters in Appendix D) asked them to

> For Quest Two, design a game that has sections of both balancing and reinforcing feedback! As usual, your fellow designers will review and rate your games. But there’s a catch! You have to base your game on a real life situation... Robert will explain more... Good luck!

The intent was to create, in a sense, *a need to know.* That is, in order to complete the next challenge participants would need to know what Samson meant by reinforcing and balancing feedback loops. Indeed, this is a learning strategy imbedded in many of the most successful commercial video games on the market now. The final quest asked participants to prepare a final game for exhibition at a school wide exposition to be held at the end of the workshop. Each quest lasted three to five weeks.

Workshop Element 2: Designing games in *Gamestar Mechanic*

Apple MacBook computers available at the school were assigned to each participant at the start of each session. Participants spent a greater part of each workshop designing games in *Gamestar*. This time was characterized by a social tenor during which participants completed design and play arcades, designed and playtested games, discussed games in small groups, asked a peer to play their game, and gave informal feedback to someone's game.

Workshop Element 3: Game standards (criteria) and reviews

During the first four weeks of the workshops, participants developed a set of criteria against which to evaluate games. These criteria were then formatted into a game review protocol which they used to evaluate each other's games. Criteria included such things as effective use of core mechanics, originality, clear goal, etc. Additionally, I developed a rubric to assist participants in rating each criteria on a scale of one to five. See Appendices E and F.

Workshop Element 4: Critiques

Two to four times each week, participants volunteered to show their work on a video projector for the purposes of eliciting "critiques" from their peers. This was also a time when participants were asked to practice using the design concepts and specialist terms to explain their designs. Attention was paid to ensuring that all participants had equal numbers of opportunities to present their work.

Workshop Element 5: "Lecturettes," daily agendas and debriefs

Lecturettes are short talks I gave from time to time to introduce new concepts, such as games as systems of interacting elements, reinforcing and balancing feedback loops, homologies, etc. Lecturettes were often followed by "debriefs" throughout the course of one to three weeks and took the form of short (10 to 15 minute) round table conversations about the concepts pertinent to a particular task or quest. Session agendas were posted on a white board that articulated the relevant concepts and goals for each session.

Workshop Element 6: Video presentations

Video presentations were shown to complement the explanation of a particular concept. For example, when discussing homologies (i.e., similarities) between systems, students were shown YouTube videos of examples of natural systems, such as the dynamic system of migrating flying penguins (which may also be considered a social system); or of social systems, such as the dynamics within the Bart Simpson family. Participants then broke down these systems by identifying within them the same five core game design elements we had been using in the workshop. A "goal" of flying penguins' migratory system is to ensure survival, for example, while core mechanics include flying and following.

Workshop Element 7: Tools

Things considered tools in the workshop included *Gamestar Mechanic*, the generator node already discussed above, but repeated here again as the design of the workshop included the careful consideration of how tools as a group were employed as mediational means for learning. Tools as defined here are sources of information or instruments that helped facilitate acquisition of knowledge or skills. Video presentations and the game review protocol were tools as was a 30" x 40" poster I designed depicting the workshop's major concepts (see Appendix C), and which the participants referred to throughout the workshop. Others included letters from Samson, a story boarding structure, a rubric, and one-on-one conferencing sessions between myself and participants.

Workshop Element 8: Writing notebook

Participants kept notebooks in which they wrote reflections, responded to writing prompts or completed writing assignments. Writing in notebooks did not occur each session as participants mostly wrote for the purposes of reviewing games using the game review protocol (see Appendix E) or wrote comments to each other directly on the *Gamestar Mechanic* site. Notebooks served primarily as a synthesizing space at the end of the workshop when participants were asked to complete "film treatments" (discussed further in the results section below) based on one of their games.

Workshop Element 9: Instructors

One lead instructor (myself) and two teaching assistants facilitated the workshop. Additionally, at midway through the research program two interns who attended once each week also supported the study. I was the only adult to address participants in a whole group fashion when introducing new concepts or giving directions. Most of us spent our time conferencing one-on-one with participants.

Types of systems-thinking skills this node afforded

The workshop node afforded all systems-thinking skills that were of focus to this study. *Gamestar Mechanic* served as the generator node and primarily facilitated all design activity. The workshop node on the other hand, facilitated access to *design and systems-thinking skills and knowledge*. As such, it served as the epicenter of the study's *domain knowledge*. Indeed, a goal of the study was to instantiate a kind of knowledge system that aligned to the greater knowledge domain of game design, with the kinds of semiotic or epistemic make-up – values, behaviors, ways of legitimizing knowledge, specialized kinds of tools and languages – that are particular to any domain.

Productive identities

Productive identities of most prominence to this node included "game designer," "community member," "expert," "critic," "writer," "evaluator," and "competitor." The "taking on" of each of these identities within the workshop was mediated by the inter-change of dialogue between participants. That is, the act of publicly presenting their work to each other for review legitimized their "ideological becomings" in a collective struggle in the process of "searching for truth" (Bakhtin, 1986, p. 210). Truth in this instance meant not only acting out a role (as a designer or critic) convincingly, but in so doing, striving to create *for their peers* the most compellingly playable, gratifyingly challenging, dynamically balanced game – a feat from which the novice socio-technical engineers seemed never to tire.

Proximity and interdependency to other nodes

A layer depicting the bidirectional activity between the workshop node and other nodes has been added in Figure 2. The intent here is to show added interacting complexity between nodes. The yellow arrows indicate the added layer. The bidirectional orange arrow indicates a reactivation of the relationship between the *Gamestar Mechanic* node and the workshop node. Overall, the figure shows relationships between *Gamestar Mechanic* and other nodes and between the workshop and other nodes. No longer is *Gamestar Mechanic* singly interacting with nodes, but the workshop node is adding another layer of predictable redundancy (Bronfenbrenner & Morris, 1998; Magnusson & Stattin, 1998) intended to support cognitive development. Of note is that the workshop node was, as was *Gamestar*, designed to interact with all other nodes. Bidirectional interactivity here is meant to indicate the homological redundancy and predictability between nodes.

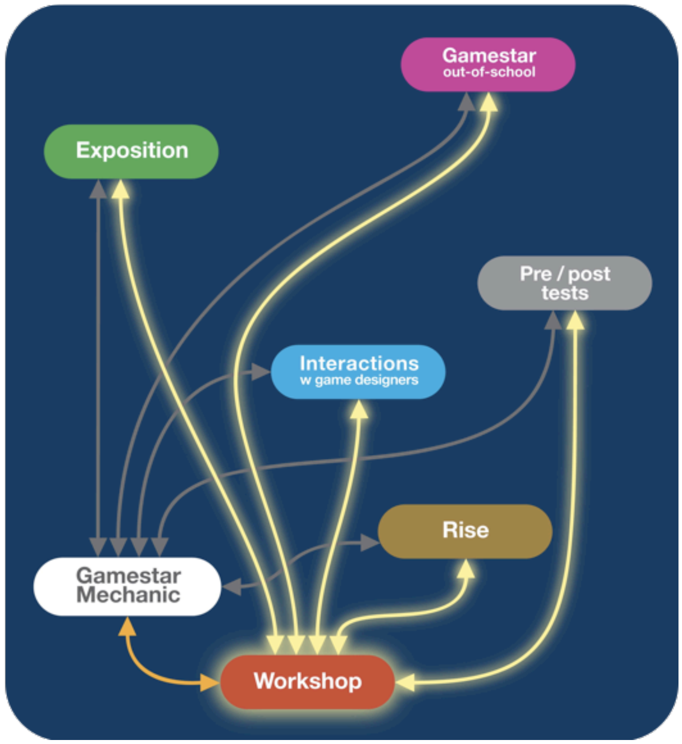


Figure 2. Bidirectional interactivity of workshop node

Cognitive limitations of this node if used in isolation

In many respects, the workshop node acted closest to what might be seen in traditional classrooms. A curriculum was designed and a set of tools such as rubrics and protocols were used. Arguably, it would be possible that participants could have developed design and systems-thinking skills in this way in a process of, say, developing paper-based games. In fact, a textbook, though one does not exist for students at the middle grade levels, could have served as a generator node (Gee, 2007a). Using such an approach, however, could have tended toward the method of teaching *about* game design, which this educational intervention was keen on moving away from. Perhaps the greatest limitation to this approach is that of immediate feedback, which would not have been available. Instead, it would have been offered in a more abstracted fashion by the instructors or by other participants in the process of playtesting games. Many introductory game design graduate level courses are taught in this way. Though it is not possible to offer a precise assessment as to the limitations of having used only the workshop, evident during the study was the degree to which participants could instantaneously tinker and iterate on their designs using the edit/play mode in *Gamestar*. Of certainty too is that the game design skills and knowledge introduced in the workshop could not have been taught at the speed in which we did if participants not had immediate access to experiment (within *Gamestar*) with building models of their designs.

<u>Node Three: Pre and post tests</u>

Pre and post tests are included among the core six nodes of the learning ecology as they represented a time and space through which participants traveled. They were "sequestered" (Schwartz, Sears, & Chang, 2007) asynchronous spaces that by and large were decontextulized from the overall experiences participants had throughout the course of the study. This is worth noting as these particular experiences were not dissimilar to the types of assessment experiences students experience in schools, though not necessarily in a pre-and-post assessment fashion.

Types of systems-thinking skills this node afforded

The pre and post test node did not intend to support the development of systems-thinking skills. However, participants were given sets of feedback and time-delay scenarios (see pre and post test protocol in Appendix A), which may have aided in developing of systems-thinking skills. Scenarios, however, were abstract dilemmas not situated within the discourse of the overall workshop. Hence this node was not designed to support cognitive development. Of potential significance is that the two participants (Maleke and Noel) identified by teachers as “low academic achievers,” demonstrated high levels of difficulty staying focused during the post test period, which was not the case during pre testing, when the participants and I met formally for the first time. Both participants asked repeatedly if they may use *Gamestar Mechanic* to respond to the various items on the post test. This was not possible in the interest of maintaining consistency in pre and post test conditions across participants. Their difficulties staying focused may indicate the asynchronous nature – potentially more significantly impacting participants with lower academic skills – of the post test when compared to the types of learning experiences participants had become accustomed to during the study. Neither participant demonstrated difficulty of this sort during any other time of the study. (Note that participants are discussed in greater detail in the next chapter, Chapter 5).

Productive identities

Participants were predominately given opportunities to respond to testing prompts during pre and post testing. The only identity allowable and "taken on" by participants was that of "student" or "test-taker."

Proximity and interdependency to other nodes

As shown in Figure 3, pre and post tests did not add complexity between itself and another node beyond those shown in Figures 1 and 2, hence the absence of yellow arrows. There was, however, a level of relevant reactivated redundancy of experience between the *Gamestar*, workshop and pre and post test nodes, depicted by the orange arrows.

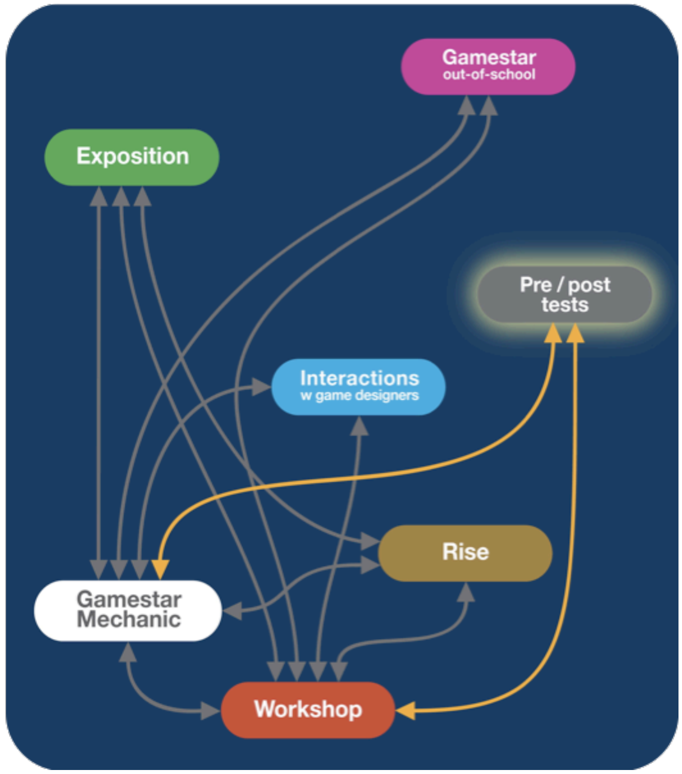


Figure 3. Bidirectional interactivity of the pre and post test node

Cognitive limitations of this node if used in isolation

Used in isolation, that is, without the use of any other nodes, it is expected that participants would not have made any gains in the development of systems-thinking skills.

Node Four: Interactions with game designers

Participants interacted with designers of *Gamestar Mechanic* at three different times during the workshop. The first time the game designers visited they witnessed participants, in a whole class presentation format using an overhead video projector, decomposing the effectiveness of existing games as systems in *Gamestar* using the workshop's five core design elements. The *Gamestar* project manager commented, "this is *Rules of Play* in action," referring to the widely used game design text by Salen and Zimmerman (2004). The designers engaged each participant who presented in a question and answer period. Then a whole class discussion followed during which the designers explained their respective jobs on the project (lead designer, writer, artist, programmer, etc.), and took questions from participants.

The second interaction took place at the offices of Gamelab, during which participants received a tour of the facility and later sat with the professional game designers for an hour to engage in a conversation regarding a host of issues, including technical irregularities with the *Gamestar* software or suggestions to the designers as to improvements they may consider in subsequent builds of the game. As the lead instructor for the study, I was concerned that participants would not be able to sustain an hour-long conversation of a technical nature with a group of eight game designers, many of whom had little prior experience interacting with middle school children. In the end, the concern was unwarranted and the conversation in fact had to be cut short. The final interaction occurred during the final exposition when designers attended, played participants' games and asked them questions as to their final design decisions.

Types of systems-thinking skills this node afforded

Participants' demonstrations to game designers revolved principally around (1) game dynamics (the ability to identify when multiple relationships exists within a system); and (2) quality (the ability to identify when the relationships within a system are or are not working at optimal levels).

Productive identities

Conversations between participants and game designers at the Gamelab headquarters revolved around meta issues regarding the overall effectiveness of *Gamestar Mechanic* itself as a game system. Game designers explained their respective roles and gave an overview of the design process for making Gamestar. Participants then offered their experiences with the game, stressing that they were enjoying designing as much as playing games. They also asked questions regarding various design decisions and offered suggestions. These interactions extended the learning ecology beyond the research site (or "school") and allowed participants to see themselves as critics and contributors to *Gamestar*, which they understood was still under design. If we consider, in Bahktin's terms, the particular discourse of game design held between participants and game designers as a kind of ideology – and there are indeed varied and conflicting beliefs in the field about what is good game design – both groups here engaged in a kind of *ideological becoming*, indeed a becoming of *game designers*—an "act" for which the professional game designers themselves is an ongoing process, mediated by their own sets of networks and learning ecologies. If learning happens for humans via the social interactions within and between microsystems (Bronfenbrenner & Morris, 1998), then the shared experiences between the game designers and the participants were developmental for both. This is of significance as it is rare, if ever likely, that urban public school students have an opportunity to sit around with professionals in a given domain and inquire or make suggestions as to the ongoing development of a professional project. It is possible that such an activity could develop agentive behaviors – if only for the affordance of influenceability (Taylor, 1985) – as participants co-produced a discourse of design ideas.

In the instance shown here, Maleke, an African-American participant classified as special education, asked about conducting searches within *Gamestar*. Designers had already said that conducting searches was a feature they hoped to add to the game soon. Maleke had been having difficulty finding games by other designers and had given some thought to the different ways searches could be conducted. Conversation samples are shown here to show the level of sophistication of exchanges between participants and the professional game designers.

Greg: Maleke, do you want to say something?

Maleke: About the usernames, if you type in the username, are you going--if ya'll accomplish what you're working on about typing the username, will that person's account show all their games? If you just type in one game—

Polly: What is it you—

Maleke: If you type in someone's username, it shows all the games they made. But if you type in that one game--

Polly: The title?

Maleke: Yeah.

Polly: Right. Are you asking whether it'll just show that--are you asking how exact you have to be? Like if you type in the title, what do you expect to see? The game?

Maleke: Just the person's factory, and then there's just a list of games.

Katherine: What you're doing is you're thinking, and you're actually thinking about a lot of issues that Bob was talking about and what Polly was talking about. If you type in the name of the game, there could be five different games for that name, right? Made by different users or even made by the same user. If you type in a username, there's only ever one person--those are unique identifiers. But then they might have hundreds and hundreds of games, so how would you find it? So we might do a two-tier search for you. You might search for a type of game and the username.

Maleke was interested in having the professional games designers consider the complexity of searches, given the enormity of the site. He wanted to see if there was a way to narrow down searches. From a discourse analysis perspective, Maleke had become part of the domain of game design and, more importantly, had cast himself as a member whose voice may have enough saliency to impact the overall project in question. This is significant as Maleke's output in school has largely been met with a high degree of failure. His biographical sketch in Chapter 5 will explain this further, but this is of note here as the sense of belonging Maleke expressed in this instance and throughout the workshop was likely mediated by the character of immersiveness afforded by the study's nodal ecology.

Another example below shows a different participant, Nola, asking about deleting games. Maleke chimes in to help her figure it out. Nola concludes her question with a suggestion, after prompted by Ben, a game designer. The issue in question here – that of deleting games – was pressing for participants as the iterative nature of game design made it so that participants inadvertently accrued many unfinished samples of "tinkerings," or rather, of experiments that they used on their way toward building a game. Keeping a clean palate after completing a game was of interest to the participants. Here Nola offers a solution.

Nola: How come we can't delete games?

Greg: How can you delete a game? Oh, that's a good one. How do you delete it?

Maleke: When you're in the toolbox, if you're working on a game and you saved it, you could go to the game and it's mostly like load or delete. Just hit delete.

Ben: That's the only way you can delete a game. So you're getting that as an error? Yeah. That's a bug. It shouldn't do that. There's something weird in there--some of the game information gets messed up. You can't delete it. I have one of those, too. I can't get rid of it and I hate it. Would you want us to be able to delete the game from somewhere else? Does that seem like the right place to delete it? Or does it seem like you want to delete it from your workshop page?

Nola: From the game section. There should be like a games you've played section, and games you deleted section, because then all of them aren't mixed.

Finally, increasingly comfortable in her role as co-designer of *Gamestar*, Nola, offers a novel solution that the professional designers had not yet considered.

Nola: I have a question. When you are making games like the whole scrolling game, it's so long. Can you just minimize it and do it if it's that screen? You just put it where you want it. It would just be mini. While you are making the game, can you minimize it so that it's a scrolling game, so it's just small.

Polly: For while you are editing it and working on it?

Greg: To zoom out? That would be cool.

Polly: Like a video editor.

Robert: That would be nice.

Greg: It's technically possible. I think it would be a good idea.

Both Nola and Maleke participated as co-producers of knowledge within the domain of game design. Implications of these kinds of activities are discussed further in Chapter 6, but it is worth noting here that such learning experiences are in fact radical when considering the vast levels of alienation from school students across the country are reporting; levels to the scale of 50% in terms of drop-out rates in our largest metropolitan areas.

Proximity and interdependency to other nodes

The Interactions with game designers node was most contiguous to the *Gamestar Mechanic* and workshop nodes. However, because of the relationships participants developed during the course of the study with the *Gamestar* game designers, participants were especially concerned to show their "best" games to the designers during the workshop's final exposition, making that node relationally connected as well. The professional game designers were a special audience to whom participants projected their own expertise as designers. As a result a significant connectivity developed (indicated in Figure 4) in which there existed bidirectional relationships of redundancy between four nodes: *Gamestar*, the workshop, the interactions with game designers and the final expo. Note that a yellow arrow indicates a new apparent relationship between nodes in the ecology, orange arrows indicate newly reactivated relationships, while black ones indicate prior existing relationships.

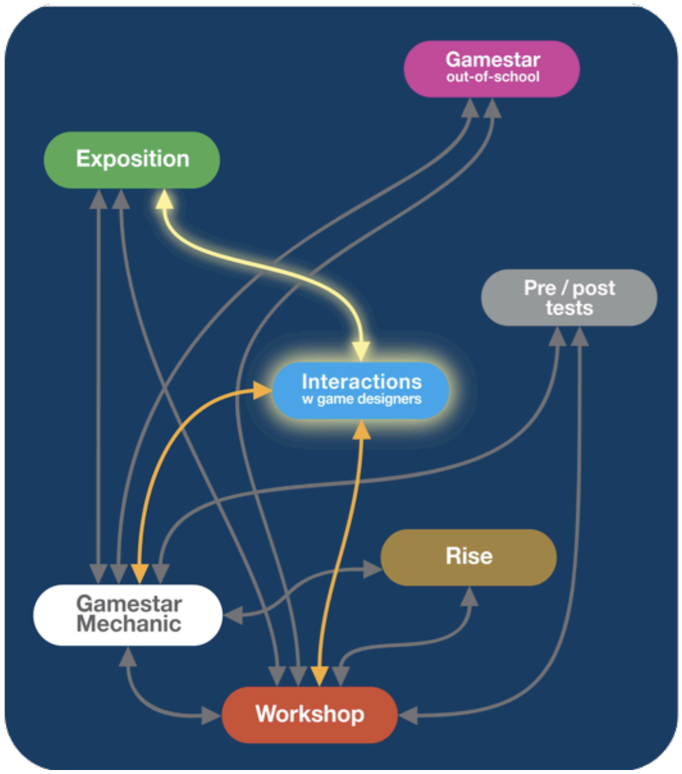


Figure 4. Bidirectional interactivity of the interactions with game designers node

Cognitive limitations of this node if used in isolation

It is expected that this node alone would not have produced significant gains in game design and systems-thinking skills and knowledge.

Node Five: *Gamestar* outside-of-school

As an online computer game, participants had access to *Gamestar Mechanic* outside of school. Though no structured requests were made of participants to access the game outside of school, they were encouraged to practice designing and to share their designs with friends and family. All 16 participants reported accessing the *Gamestar* site outside of school, though at varying levels of frequency. About a third of participants reported having Internet access at home, which made it difficult for some participants to access the game's site on a regular basis.

While collecting data that tracked participant use of *Gamestar* outside-of-school was beyond the scope of this study, participants reported that they shared their games with friends and family at home, and some requested accounts for siblings and other relatives, which were granted. Because this node stood outside of all others at the outset of the study, I did not account for the type of affordances it may give participants in developing systems-thinking skills. Noguera (2008) has commented on the unintended inequitable dynamics of homework, arguing that students with greater resources attributable to social and cultural capital are at a significant advantage when completing homework than those without. Given this, and the fact that so few participants had Internet access at home, homework was not assigned. That said, it is possible, though unknown, that *Gamestar* use at home supported skill development for some participants.

Types of systems-thinking skills this node afforded

Unknown.

Productive identities

Two principal identities were apparent when participants spoke of sharing their work outside of school: game designer and expert. Several participants spoke of experiencing initial reactions of incredulity from friends and family members that they had indeed designed a computer game that others could play. They also explained of wanting to “teach” friends and family “how to do it.” Outside of all other nodes, then, the online “live” (i.e., always and ubiquitously available) aspect of *Gamestar* enabled participants to re-instantiate game designer and expert identities on their own terms. More significantly, perhaps, they were able to have a level of influenceability (Taylor, 1985) (via showing and/or teaching a kind of expertise) to people outside of our learning ecology. Gee and The New London Group (1996) have argued that design work could lead to agentive (Ahern, 2001) behaviors as learners begin to develop a sense that they can imagine and design their own lived systems. Taylor has noted that influenceability – the ability shape or cause change to a given set of conditions – is a core feature of developing a sense of agency. Participants’ desire to share and teach friends and family outside the research site may suggest that as a result of taking on the identities of game designers and emerging experts within the knowledge domain of game design, participants may have developed greater degrees of confidence (Duckworth, Peterson, Matthews, & Kelly, 2006) as it relates to game design and systems-thinking. This, then, may have in turn facilitated their persistent participation and ongoing learning within the workshop. While this is not an explicit study of agentic development, it is worth noting that recent research (Duckworth, et al., 2006) of high-success individuals points not to IQ as a predictor, but to persistence and continued development of confidence within a domain.

Proximity and interdependency to other nodes

While the *Gamestar* out-of-school node was always reciprocally connected to the *Gamestar Mechanic* and workshop nodes (see Figure 5), the out-of-school node began to influence the Rise node and exposition nodes. Both those nodes are discussed below, but worth noting here is that a relationship between those three nodes became apparent as participants indicated that friends and family would be attending the exposition. That the Rise node arose is of significance as participants used it as they did the out-of-school node: to offer game design lessons to their friends, which I discuss in more detail in the context of the Rise node below.

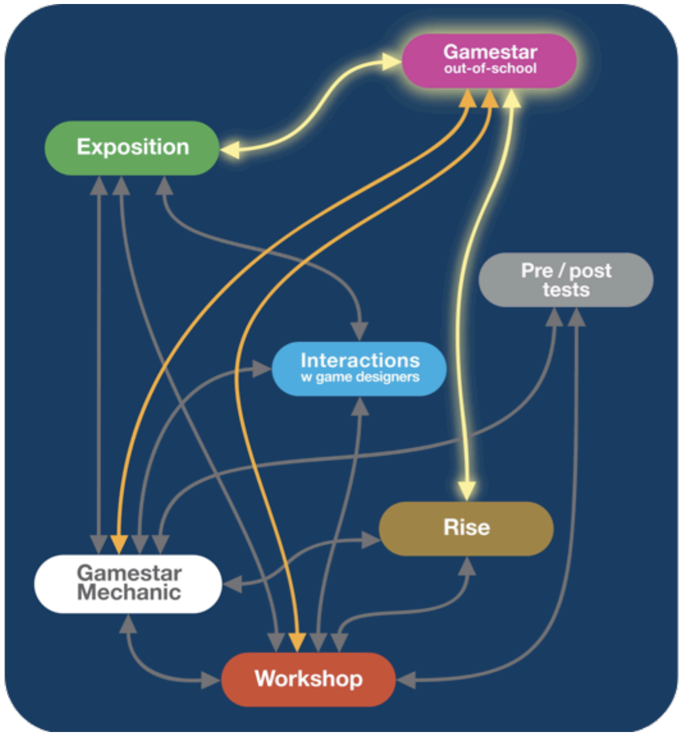


Figure 5. Bidirectional interactivity of the Gamestar *out-of-school node*

Cognitive limitations of this node if used in isolation

As far as consciously developing the four systems-thinking skills which framed this study, it is difficult to conjecture as to the viability of this when considering this node in isolation.

<u>Node Six: Rise</u>

A significant unintended outcome of the design of the learning ecology was the emergence of the Rise node. Sometime in mid-April, a series of teacher professional development days at the research site had been scheduled that coincided with scheduled *Gamestar* workshop days. This meant students were to stay home on those days, resulting in cancellations of some workshop days. The *Gamestar* workshop had been in session for a month and a half now. Most participants had moved through most of the game's design and play arcades and were beginning to design more of their own games, many of them in response to the quest challenges Samson, the elder fictional mechanic, had posed via a series of letters (see Appendix D). By now, participants had also begun to share their game designs with non-participant peers at the school. The energy levels of participants, which was always high with enthusiasm for *Gamestar* during workshop sessions, had also risen to even greater levels. Though never problematic to the point of unruliness, this meant having to remind participants to quiet down so as to not distract other designers. These reminders were not always ceded as participants in many ways had come to make the space theirs; indeed the workshop had become more of an atelier than a classroom, with participants moving about with laptops in hand or congregating in small groups, vying for an opportunity to have someone else playtest their games. This description is given to accentuate the level of disappointment participants expressed when told that workshop sessions would need to be cancelled during the teacher professional development days. This is how the Rise node emerged. Participants asked if they could meet during their lunch period, which lasted 55 minutes. The request was granted as one of the two technology teachers employed by the school and serving as an assistant to the study volunteered to supervise the participants during this time. The Rise node also served as a recruitment space for participants and within a week they had brought in eight friends to the Rise node. Some of these new "informal" participants already had accounts which had been created earlier at the request of workshop participants. A few days later, the technology teacher, recounting on how the lunch session was going, said that participants and their friends were managing to eat lunch within five minutes so as to maximize their time at the lunch session. "What have you done to these kids?," he commented, somewhat incredulous at how impassioned participants had become about their design work. The Rise node remained a constant workspace for participants and their guests for the remainder of the study, meeting daily, five times each week, for approximately 50 minutes each day. All participants attended daily, except for two of the female participants (Tania and Sandra) who attended when their schedules did not conflict with prior commitments.

Types of systems-thinking skills this node afforded

The Rise node quickly became an extension of the workshop sessions during which participants debated and continually playtested to ascertain the quality of their designs. It was also a space to complete Samson's challenges, such as designing games with clear reinforcing and balancing dynamics. Designing for dynamic interactivity, as an overall task, also became central to this node. I should note that I did not participate during this time as an active instructor, notes here are based on field observations I conducted from time to time and from semi-structured interviews with the technology teacher who supervised the Rise sessions. I should stress that how participants chose to spend their time in this node was completely driven by participants, with adults playing no role other than providing staffing or observing the space in which participants met.

Productive identities

The same identities taken on in the workshop node were evident here: game designer, community member, expert, critic, writer, evaluator, and competitor, with competitor often leading. Indeed, this became a time when participants seemed especially interested in demonstrating their individual game designer talent and prowess – a topic to which I return when discussing participant biographical sketches in the next chapter.

Proximity and interdependency to other nodes

Interactional redundancy was evident between the Rise node and the *Gamestar*, workshop, *Gamestar* out-of-school and the exposition nodes. Figure 6, however, shows an added level of interactionism between the Rise and exposition nodes within the learning ecology. This distinct relational interaction – as is the case between the Rise node and all other interacting nodes – would not have been possible without the emergence of the Rise node.

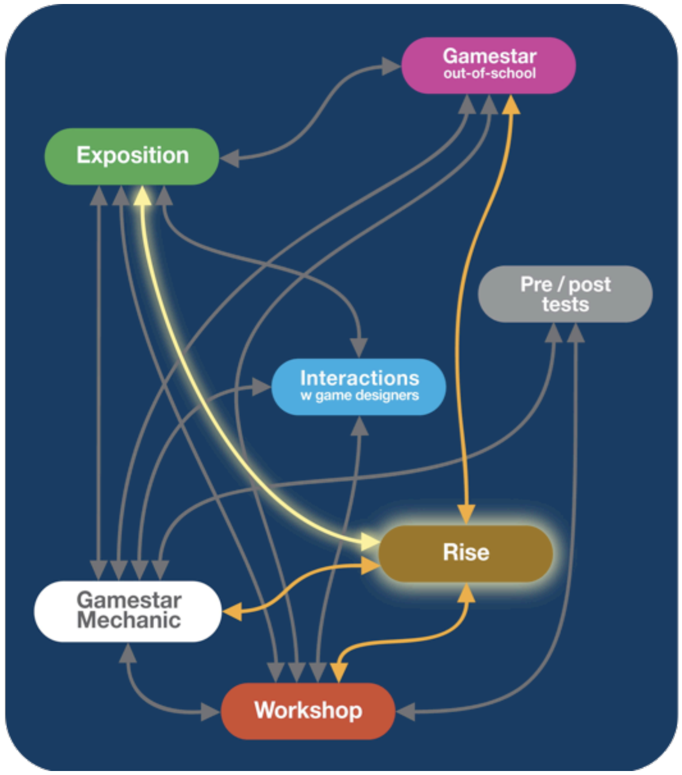


Figure 6. Bidirectional interactivity of the Rise node

Cognitive limitations of this node if used in isolation

This node surfaced as an emergent entity not conceived of before the start of the study. It is expected that if existed alone in the manner thats it did – without the intentional scaffolding provided in the workshop node – participants would not have developed systems-thinking skills.

Node Seven: The exposition

The final exposition had a two tiered design: (1) each participant formally presented their Quest Three designs to fellow participants; and (2) two additional days were added to the workshop to facilitate an opportunity for participants to exhibit their games to their middle school peers within a "final exposition" format. An "exhibit hall" was set up in the cafeteria and scheduling arrangements were made with each middle school teacher to escort their classes through the exhibit hall. Each participant set up three laptop computers in "play stations" that allowed guests to sit and play their games. Of note here is that adult voices were kept to a minimum during formal final presentations, allowing participants to "take the stage" themselves and negotiate how they would present. This also meant that if anyone other than a participant had a comment or question, they (the presenting game designer) would manage the discussion period. Overall, this was a time to allow participants to orchestrate the manner in which they chose to present themselves as game designers.

Types of systems-thinking skills this node afforded

This node was particularly marked by its anticipation. Participants knew from the start of the study that our work together would culminate publicly in this format, and frequently expressed concern about ensuring they had "quality" games to present. This meant that the stakes were driven by their ability to create "good" games as defined by the criteria set by the group early on, and creating games that demonstrated reinforcing and balancing dynamics. In a sense, the "appreciative [cultural] system" (Gee, 2007) of values that enabled participants to assess their own games and those of others throughout the workshop, drove interactivity between participants and guests in this culminating node.

This node also became an opportunity for participants to challenge each other beyond the workshop, asking questions of each other like, "What is the hidden dimension of your game." There had been a fifth systems-thinking skill (identifying hidden dimension) that had been part of this study at the outset, but which we ultimately withdrew due to insufficient time available to support its development for participants. Various materials, however, included the term "hidden dimension," such as the poster designed for the workshop (see Appendix C). Towards the last few weeks of the workshop some participants began to inquire as to its meaning, which I informally explained as: "stuff" in your design *that cannot be seen by players*, such as adjustment choices made by the game designer of sprite behaviors (e.g., special behavioral patterns) that a player cannot see; adjustments, too, that when made can trigger a causal reaction of other unintended changes. Creating a hidden dimension, was, in essence, programming behavior for sprites – a task all participants engaged in. Yet, because time did not allow for the implementation of scaffolds and tools to support cognitive development of this skill, we chose to forego assessing it. To our surprise, however, final presentations became a space where participants wanted to find out about each other's hidden dimension. "The hidden dimension," thus, became the theme of final presentations, and each listening participant took turns "taking on" the role of the hidden dimension investigator. It was not clear, in fact, that participants asking others about the hidden dimension understood what they were asking, but what became clear was that they had chosen to solve for the hidden dimension, if prematurely, on their own.

Below are two instances of this. In the first one Nola explains her hidden dimension (prompted by Sandra's question) as having programmed enemies (*by selecting their rate of speed*) to get to the goal block before the avatar. Note that Nola asks for clarity at first. Nola had been the fourth participant to present that day and the meaning of hidden dimension had by then been co-constructed by participants, enabling her to respond without much difficulty to Sandra's prompt. In her response, Nola explains that her hidden dimension can be seen in the way she programmed enemies to "get the goal block before Yuu," the game's avatar.

Instance 1

Sandra: What is your hidden dimension?

Nola: What is the hidden dimension again?

Sandra: It can be pattern or what you program the thingy behind these [the games] to do.

Nola: In this level, in Ready-Set-Go, the enemies who run down and <u>they usually get to the goal block before you</u>. Then they get there and Yuu only had two lives and sometimes Yuu will die or he'll get paralyzed and you won't win the race.

In the second instance, George (who was one of the newer participants) asks Xano to *locate* his hidden dimension, suggesting that in the course of the hour and a half block of final presentations, participants had moved from asking "what" was a hidden dimension to "where" it was. That participants took on the role, in a sense, of going beyond the workshop is noteworthy, but more significantly, this is suggestive that the ecological conditions were such that the participants themselves could emerge collectively as discussants of a topic more theirs now than of the study. In the instance below Xano explains that his hidden dimension can be seen in various ways: in the different levels of speed in which two different groups are able to shoot; and the design of the movement pattern he designed for his tanks. He also indicates that the section in which one group has a lesser ability produces a reinforcing feedback dynamic.

Instance 2

George: Where's your hidden dimension?

Xano: The hidden dimension here is that these people and these people are not friends. <u>They shoot really fast and they do not.</u> They have a lot of power, but I made this part, I think this part is the reinforcing feedback loop because this part is out of whack. But when you come over here, you can't just stay here. The tanks, <u>their pattern is go here, down, up, and then come back</u>. It goes up like that.

Productive identities

Participants demonstrated "stepping into" three identities in this node: game designer, expert and evaluator. Opportunities for game designers to exhibit two of these – game designer and expert – were planned as part of the study's design. Indeed, it was clear to all participants from the start that this would be the space in which they would present their fruits as designers and their ability to guide others through their design decisions. Relatively unexpected, however, was that as participants took turns presenting their final designs to each other during final presentations, there was an eagerness on the part of listening participants to ask questions of the presenters. This suggests that participants – in their roles as evaluators – had become comfortable holding each other accountable for design decisions they made which at times were not clear to others.

Proximity and interdependency to other nodes

Although participants knew of this node as a final presentation space at the end of the workshop and as such could only interact within it in the abstract, it instantiated the other nodes, making it serve as a formal assessment space, such as a professional conference for professionals may serve for researchers, architects or, indeed, for dynamic systems designers. The preponderance of bidirectional orange arrows in Figure 7 represent the reactivation of the *Gamestar*, workshop, Rise, interactions with game designers and *Gamestar* out-of-school nodes.

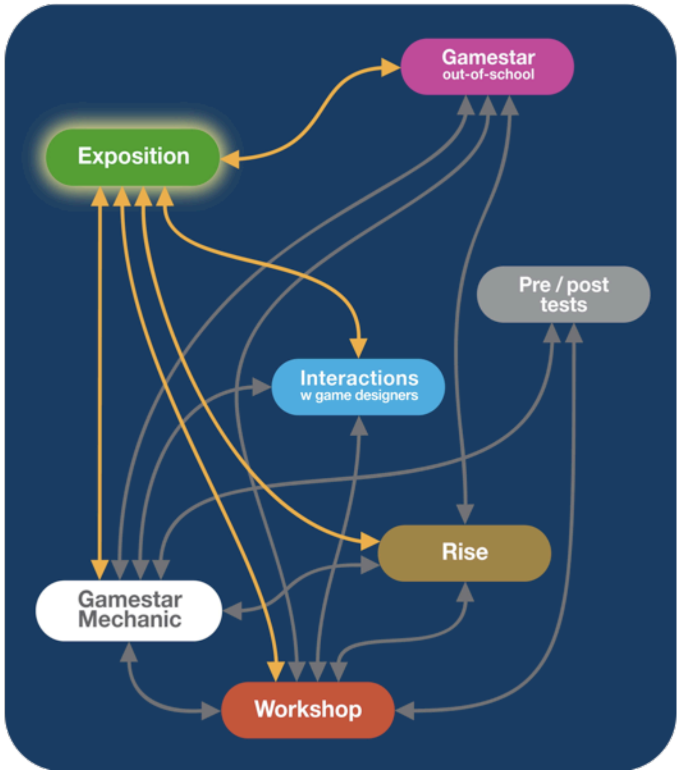


Figure 7. Bidirectional interactivity of the exposition node

Cognitive limitations of this node if used in isolation

It is expected that participating in this node alone would not have enabled participants to make cognitive gains in systemic reasoning.

This chapter responded in large part to the question of how participants came to show gains in systemic reasoning, for which I make specific claims in the next chapter. Special care was taken in this study to design an educational intervention that accounted for a specially designed *learning ecology.* Guidance was taken from Bronfennbrenner and White's notions of learning as a result of moving between "microsystems" or "netdoms." A goal here, however, was to extend these notions and offer the possibility that learning is in fact achieved as a result of taking on productive identities (Gee, 2003, 2004, 2007a; Gee, 2005; Turkle, 1984) within an ecology that maintains *ecological constancy* as a necessary condition. This was the intent of the design of this learning intervention and it is the context in which the results of this study are presented in the next chapter.

CHAPTER V

FINDINGS

This chapter presents a summary of participants' gains in systems-thinking as indicated by pre and post tests. While gains in systems-thinking are evident, these findings are presented in the context of the overall nodal design of the workshop. That is, that while *Gamestar Mechanic* served as the anchoring tool for this study, gains here suggest that the overall designed ecology and not any one tool facilitated learning. The small sample size of the study allowed for exploratory conclusions as to the viability of creating a learning environment in which *Gamestar Mechanic* mediated the development of systems-thinking. More incisive conclusions, however, were possible with regards to the mediating viability of using *Gamestar* to assess the development systems-thinking. Overall, findings are meant to indicate that *Gamestar Mechanic* used in the context of a greater ecological learning framework may be useful in helping middle school-aged students the development of systems-thinking.

Participant work samples are presented to show examples indicating use of systems-thinking skills, or overall systemic understanding. All examples shown were scored by independent inter-raters using a rubric based on the Systems-Based Inquiry (SB-I) protocol developed by Sweeney and Sterman (2007). Before summarizing gains in participant learning, brief biographical sketches are offered for each participant.

Participant biographical sketches

16 middle school students (15 sixth graders and one seventh grader) participated in this study. Eight participants attended the workshop from beginning to end. Six of these were chosen as participants of focus based on a desire to maintain a heterogeneous balance in gender; ethnicity; race; prior academic achievement levels as reported by teachers, participant report cards, and standardized test scores; level of English language proficiency; and consistent attendance on the part of participants. The two participants not selected to be participants of focus were males who had either inconsistent attendance or were already represented in the sample in terms of ethnicity or level of academic performance. According to the school, all of these six participants qualified for free or reduced lunch. Prior to the start of the workshop, I had a meeting with the middle school teachers at the school to discuss each participant's academic record. At the conclusion of the workshop in June I collected year-end report cards and scores on literacy and math standardized exams. Biographical sketches are based on meetings with teachers, report cards and standardized test results, and on a participant questionnaire I administered on the first day of the workshop.

Questionnaires asked participants to report on the types of computer-related activity they have engaged in the past, favorite subjects in school, experiences with games, and uses of technology, such as emailing, texting, and social networking. Biographical sketches also include special recognition awards were presented to participants in the form of "a special achievement award" in a particular aspect of game design. Awards were determined based on syntheses of peer-based game reviews participants wrote for each other. As a group, the practices reported by all 16 participants correlate well with research findings reporting that today's youth are engaged with media and technology across multiple and converging platforms (Jenkins, 2006). What follows are biographical sketches for the six participant of focus. Pseudonyms of have been provided for each.

Maleke

Maleke, 12, was the only seventh grader who participated in the workshop. All other participants were in the sixth grade. He is an African-American boy classified as special education for "learning disabilities," a general classification assigned to students who show difficulties in learning. His teachers reported during a pre-workshop meeting that he maintains a "low" achievement level in school. This correlates with his year-end report card which showed his performance levels at 1 and 2s[3] throughout the year in literacy and 1s in math. Maleke's math and literacy

[3] This scoring rubric outlines how student performance was rated by teachers at the research site:

scores on standardized exams were 1 and 2, respectively for the 2007-08 school year. In his questionnaire, Maleke reported that his favorite subjects in school are art, music and theatre; indeed, these are areas in which Maleke attained performance scores of 3s and 4s. He reported that his computer skills are "below average." He also reported that most of his game play is on game consoles, such as the X-Box. He spends "more than three hours" playing games each week with his mother, brother or by himself. Maleke did not have Internet access at home, did not participate in any online community, and said in the questionnaire that he has been playing games for 12 years.

Maleke was awarded best achievement in space design. Maleke's games depicted expansive geometric arrangements, some abstract, others more figurative, of urban landscapes. Built as mutli-leveled, the space design of his games had a clear and artistically aesthetic point of view. As well, he incorporated a sound track in all of his games, an option given by the *Gamestar Mechanic* site, but not used by most participants. See Appendix G for screenshots of Maleke's games.

Level 4: Meeting Learning Standards with Distinction: Student performance demonstrates a thorough understanding of the knowledge and skills expected at this time.
Level 3: Meeting Learning Standards: Student performance demonstrates an understanding of the knowledge and skills expected at this time.
Level 2: Partially Meeting Learning Standards: Student performance demonstrates a partial understanding of the knowledge and skills expected at this time.
Level 1: Not Meeting Learning Standards: Student performance does not demonstrate an understanding of the knowledge and skills expected at this time.

Nola

Nola, 12, in the sixth grade, of Caucasian descent, recently immigrated from Russian with her parents. She lived over an hour away from school in a neighborhood in Brooklyn with her mother, with whom she communicated in Russian. Her English was fluent, though she was classified as an "English Language learner." Her favorite subjects in school, as she reported in the questionnaire, were art, music and theatre, for which she received 3s and 4s in her report card. She reported her computer skills as "average," and said she mostly played web-based fighting and adventure games on the her mother's computer at home, though during her pre-test and throughout the workshop, she reported that her mother allowed her to access the computer on a limited basis to complete school assignments. When she does play games online, she does so with friends or with people she does not know for an hour or less each week. She has been playing computer games for about four years. She also said she was a member of the online social network called *Gaia*. During our pre-workshop meeting, Nola's teachers considered her a "medium to high" achiever at school. Her literacy report card grades reflect this with scores of 2s and 3s; her math grades are 3s and 4s. On standardized tests, Nola scored a 3 in literacy and a 4 in math. She received a special achievement award for narrative ability in the workshop. Her games were among the most developed in terms of clear stories that guided players through the play space. See Appendix H for screenshots of Nola's games.

Noel

Noel, 11, is a Puerto Rican boy. He reported his favorite subject to be physical education and considered his computer skills "average." Noel has Internet access at home where he reports playing mostly computer games online, with massively multiplayer online games listed among his favorites. A member of the social network site, *Gaia*, Noel reported he played two to three hours of video games daily, mostly with his brother. He uses email to communicate with friends and family. His teachers reported him to be a "low to medium" achiever at school and his literacy and grades on his report card reflect this with scores of 2s and 3s. On standardized exams, Noel scored a 3 in both literacy and math. Noel received a special achievement award for originality for designing an AIDS related game in which the play activity took place inside the body of an infected person from Africa. See Appendix I for screenshots of Noel's games.

Tania

Tania, 11, is an African American girl who reported on her questionnaire that her favorite subjects were reading, math, art, music and theatre, science, technology, and wellness. She also reported her computer skills as "above average." She likes to play a variety of games including board games, word and card games and sports, though she prefers to play computer games on weekends for 3 hours or more with friends and family. She has been playing games for about four and half years. She has Internet access at home, which she uses to communicate with friends by email. Tania's teachers reported that she was a "low to medium" achiever, and her report card grades indicate scores of 2s and 3s in literacy and math. Tania received a special achievement award for innovation. Early in the workshop, Tania asserted that she was interested in creating "games that made you relax," as opposed to games that made you anxious. Therefore, she created games where players traveled, explored, and collected coins, instead of shooting games that involved conflict. In this way, Tania offered the workshop participants – and myself as the lead instructor – some pause and reframing as to what a game could be as our early critiques were driven by an inquiry into where "challenge" and "conflict" rested within games. Later in the workshop, however, as will be evident in a discussion of her work below, Tania did fuse aspects of conflict into one game—but conflict encountered by her players in search of a "relaxation center." See Appendix J for screen shots of Tania's games.

Xano

Xano, 11, immigrated with his mom from China about a year and half ago. He is classified as an "English language learner" and has noticeable difficulties when speaking and writing in English. Xanos' favorite subject in school is physical education and is considered by his teachers to be a "high" achiever. He considers his computer skills to be "average" and though he does not have a computer or Internet access at home, his preferred games are online, which may explain why he reports that he plays one hour or less daily. "O to 1 hours" was the lowest number of hours selectable in the questionnaire when choosing how many hours he plays computer games on a typical day, suggesting that Xano does not access computer games on a regular basis. Xano reports that he does not participate in online social networks, nor does he use email to communicate. He did report accessing the Internet at his local library, which he frequented. He has played games for the past three years, which he does, when possible, by himself or with his father. Xano's literacy grades on his report card indicate scores of 2s and math scores of 4s; and he scored a 3 and 4, respectively, in literacy and math. Xano received a special achievement award for clearly demonstrating reinforcing and balancing feedback dynamics in his game. See Appendix K for screen shots of Xano's games.

Sandra

Sandra, 11, is Puerto Rican and Caucasian and was the only participant in this study to have participated in a prior pilot. Sandra reported reading, math, art, music and theatre, social studies and physical education as her favorite subjects. She considers her computer skills "average" and has Internet access at home. She enjoys playing a variety of games, including board games, word and card games, role-playing games, and games on the Wii, though her favorites are played online. She reports enjoying playing alone, with her friends or with her brother and father. On a typical day, she plays an hour or less. Sandra uses email to communicate with friends and family. Teachers reported that her achievement level ranges from medium to high, and her report card grades and standardized test score correlate this with scores of 3s in literacy and 4s in math. Sandra received a special achievement award for best use of pattern programming (referred to in the workshop as the ability to design a "hidden dimension") in her games; that is, for the keen ability to create special and observable patterns by adjusting the behavioral parameters of sprites to perform specific pattern-making behaviors. See Appendix L for screen shots of Sandra's games.

Results

Game scholars (Gee, 2007; Salen, 2007) and science and engineering organizations have made claims in recent years that video game play and game design are useful means through which to develop systems-thinking skills. Design and systems-thinking skills, in this study conceptualized as dialogic in nature, are considered here as having the potential to guide learners to understanding the dynamic complexity of systems of various types. The study focused on testing the viability of *Gamestar Mechanic* and the ecology it instantiated to improve participants' systems-thinking skills. The principal research question that guided the study was: Does a learning ecology generated and mediated by the game design software *Gamestar Mechanic* improve participants' ability to engage in systems-thinking?

The following sub-questions guided this study:

a. Are participants able to demonstrate the acquisition and use of the systems-thinking skills identified for this study?
b. How did participants come to acquire these skills?

Results from a variety of assessments are summarized here for six participants of focus. Four core assessment tools were used to measure growth in participant learning: a pre and post test protocol; think-alouds; a writing sample; and video documentation of student presentations during whole-class critiques. Two independent inter-raters were employed to score participants' (1) pre and post test responses; and (2) two think-alouds and one writing sample. Think-alouds and the writing sample comprised assessment artifacts collected from participants during the final weeks of the workshop. Two different think-alouds were scored by the raters: one describing a game in which they incorporated systems-thinking concepts, most notably understanding of reinforcing and balancing feedback loops, and a second one describing the system dynamics of a game they designed. The writing sample participants completed during the workshop was of a "film treatment" they composed which asked them to "pitch" one of their games to a film company executive in the form of a film narrative. Inter-raters used a rubric I developed based on the Systems-Based Inquiry (S-B I) method and a protocol created by systems-thinking scholars Sweeney and Sterman (2007), included in Chapter 5. Possible rubric scores ranged from 0 to 4, with four indicating the highest level of sophistication in a particular systems-thinking skill a participant could get.

Time 1 (T1) and Time 2 (T2) scores in Table 1 are based on pre and post test mean scores. Change (C) in levels from 0 to 4 were characterized by the difference in mean scores from T1 to T2. As shown in Table 1, pre and post test results show that five of the six (83%) participants made some level of gain in systems-thinking skills, with four (66%) showing a change in levels of systemic reasoning of .5 points or more within the 0 to 4 scale. Two participants (33%) demonstrated a change of 1 or more points on the scale. One participant, Maleke, a special education student, showed no change from Time 1 to Time 2. Though consistent with findings from other systems-thinking studies (Assaraf & Orion, 2005) that also found that special education students appear to experience greater difficulty developing systems-thinking competencies, Maleke, did score at higher levels in his think-alouds. Work samples below will offer an example of Maleke's work.

Table 2

Participant	Time 1	Time 2	C=T2-T1
Maleke	0.66	0.66	0
Nola	2.57	3.14	0.57
Noel	3	3.4	0.4
Tania	3	4	1
Xano	2.22	3.1	0.88
Sandra	1	3	2
Averages	2.075	2.88	0.60

Table 2. Time 1 and Time 2 mean scores

Besides Maleke, the other participant making the least amount of gains was Noel, with a C mean score of 0.4. For this sample of focus, Noel was considered among the lowest academic performers by his teachers. It is interesting to note, however, that Noel, as did Tania, both received mean scores of 3 at T1, making them the two highest pre test scorers. While accounting for this is beyond the scope of this study, it is notable that Noel and Tania had by far the most extensive experiences with different types of games, including computer games, which they preferred. They both reported playing games for three hours or more each week with friends or family. This may suggest, as do the overall results of this study, that video games and computer games in particular have the potential for helping develop systems-thinking skills. Sandra made the greatest overall gains of 2 points. She was the only participant who had participated in a pilot study of *Gamestar Mechanic* using a prototype build of the software, therefore she had some prior experience with the game. This may suggest that longer use of the software and game design concepts may lead to increasingly greater gains in systemic reasoning skills. In general, however, none of these suggested inferences are of significant consequence without conducting a more expansive comparative study. What is of notable significance is the observable change in systemic reasoning skills that participants exhibited as a result of engaging in a design and systems-thinking educational intervention.

Inter-raters also scored think-alouds and a writing sample for each participant. Mean scores for think-alouds and writing samples are shown in Table 2 for each participant under the category called “Workshop” or “W.” Inter-raters rated 83% of participants as scoring at 3.8 points or higher, and 66% as scoring the highest possible score of 4. Various work samples scored by raters are discussed below. Work samples represent think-alouds participants completed during the final weeks of the study. All samples were video recorded and are available for viewing upon request. Time did not permit for iterations of concept maps. Hence, think-alouds for concept maps are based on one-time renditions. This is of significance as most participants scored at level 4 for their concept map think-alouds.

Table 3

	Time 1	Time 2	C=T2-T1	Workshop
Maleke	0.66	0.66	0	2.2
Nola	2.57	3.14	0.57	4
Noel	3	3.4	0.4	4
Tania	2.25	4	1.75	3.83
Xano	2.22	3.1	0.88	4
Sandra	1	3	2	4

Table 3. Time 1 and Time 2 mean scores and Workshop mean scores

<u>Instances of systems-thinking</u>

Examples of work below represent artifacts scored by the independent inter-raters using the SB-I-based rubric. The discussion of findings below presents a mix of two types of examples: workshop-created artifacts by participants and pre and post test artifacts, the latter of which show change from one level of systemic competency to another.

<u>Systems-thinking skill: indentifying dynamics</u>

The understanding of system dynamics was defined for this study as the ability to identify when multiple (i.e., dynamic) relationships exists within a system (Forrester, 1994). Two core strategies that cut across the various nodes in the learning ecology were used to facilitate this skill. Five core game design concepts (core mechanics, space, rules, goals and game components—also referred to in this study as "specialist terms" or "game design elements") were introduced in the first days of the workshop. Without necessarily waiting for participants to show an understanding of these concepts I was interested in creating socially situated circumstances – or, rather – a social practice spaces where participants "practiced" using these terms with each correctly or incorrectly in various situations, such as describing their games to each other in pairs or in more public moments for all participants to see. The goal was to provide opportunities for participants to develop conceptual understandings *intra*mentally (within the individual mind) *after* practicing them *inter*mentally (between individuals), so as to legitimize the specialist terms within the discourse of the learning ecology.   To achieve this, specialist terms (or design elements) were paired (core mechanics and space, for example); then, participants – working in small groups, though each with their own computer – were asked to design a game that showed how these two elements *interacted* and *interrelated* to make the game work. At the end of each workshop session, participants volunteered to share and elicit feedback on their work – with given feedback needing to incorporate specialist terms. In essence we were learning a new language of design *in situ*, while also beginning to test for and learn about dynamic interactions between elements.

As a second strategy, participants were asked to "teach" the five core design elements as foundational to any game's design to a cohort of participants (six total) who began attending the workshop during its final month in mid May. Participants taught in various ways. They presented "lecturettes" and paired with the new participants to show them via design processes how these elements existed in games.

Scored data show that participants were able to demonstrate competency in describing dynamics in the systems-thinking skill associated with system dynamics. Three of the six participants of focus (Tania, Xano and Sandra) demonstrated gains of 2 (Xano) and 3 (Tania and Sandra) points for this skill. Work Sample 1 shows Tania's film treatment. Before describing it further, I will note here that various "narratives" ran through aspects of the learning ecology. One of these included the narrative of "we live in systems and most systems are homologous," meaning that systems have *elemental* characteristics (core mechanics, rules, space) that appear across all systems: natural, social, technological. Hence, we discussed and revisited this notion repeatedly. For instance, the workshop itself was considered a "system." There were various *spaces* through which we moved (various classrooms), we performed various *core mechanics* (we designed games, shared games for feedback, iterated), and adhered to a set of *rules* of behaviors (three core rules of conduct were designed by the participants and regurgitated by Samson in a letter the following day (see Appendix D). We considered the system of the workshop social and applied the same elements to other social systems, like churches, a movie theatre, and the school they attended. We held discussions about the interconnectedness of these elements and how their interactivity resulted in the dynamic the system emitted. In this spirit, the film treatment itself was discussed as a system. Like game designers, authors “design” narratives using design elements in particular ways to attain a particular result. For example, they use elements such as point of view, settings, and characters to activate a dynamic, which in turn emits a particular meaning to the reader. The film treatment, then, was itself seen as a homology within the context of other systems. While the assessment focus of the assignment was to gauge participants’ ability to design a narrative that depicted the interconnectedness and interrelationship between elements, the overall context of the assignment existed within a narrative discourse of homologies.

Work Sample 1 shows two examples of work scored at a Level 4 for demonstrating understanding of dynamic systems: (a) a film treatment; and (b) concept map think-aloud. Film treatments asked participants to “pitch” one of their games to a film company executive in the form of a film narrative. Film treatments were not assessed for content, style, or grammatical conventions, but rather for how well participants could use design elements to represent dynamics in their narratives. While this study did not set out to track literacy improvement among participants, we were interested in seeing how game design could support literacy development. To complete this assignment, participants moved back and forth between their games and treatments, making adjustments to both in a reflection-in-action (Schön, 1983), iterative fashion. In this work sample, Tania has assembled a game and film treatment which tells the story of the plight of trying to fend off her sister and her sister’s friends as she moves through seven rooms in her house (represented as seven levels in the game) to get somewhere where she can finally get some rest: "the relaxation center." Systems dynamic understanding is suggested in the correlations she makes between her color coding scheme and the treatment. The color coding scheme throughout the film treatment shows various elements as having multiple interactional relationships. The first sentence, for example, (see boxed sentence in Work sample 1(a)) is coded as having four distinct interacting elements: "home" is coded in purple to indicate space; "me" is coded in blue to indicate the avatar; "little sister" is coded in pink to indicate an enemy; and "my lil sister gives me an attitude" is coded in green to indicate the sister's core mechanic of the little sister ("to give attitude"). The entire film treatment indicates various levels of dynamic interactionism as the avatar strives to reach a place of rest. Additionally, Tania's work (on the next page) demonstrates appropriate use of the specialist terms that undergirded the workshop.

Figure 8. Work sample 1(a): Tania's film treatment and coding scheme

Excerpt of transcribed film treatment:

As soon as I got home, my lil sister gives me an attitude. It is my turn to stop her...I run to my room and guess what, she has trapped her friend Jessica in my room because they got into a fight....It takes me 1/2 hour to stop her because she is my lil sisters best friend. Time for dinner. My mom says "Finally". I say, but there is more to come. My mom invited Gabby over...She is like a ghost. In fact, I think she is a ghost.

Sample correlations between color coding scheme and film treatment coded as having four distinct interacting elements:

As soon as I got home, my lil sister gives me an attitude.

The concept map think-aloud, Work sample 1(b), also indicates a Level 4 skill level for system dynamics. For think-alouds participants were asked to work independently to design a map that would show the relationships between elements in a game system. Tania chose to design her concept map using the same game for which she wrote her film treatment (above). The concept map and and think-aloud (see transcript excerpt below) demonstrate dynamic loops of interconnectedness. For example, Tania shows and describes that core mechanics, rules, and goals are interrelated and share a connectedness, which she identifies as a “B” balancing feedback loop, a related systems-thinking skill I will discuss further below.

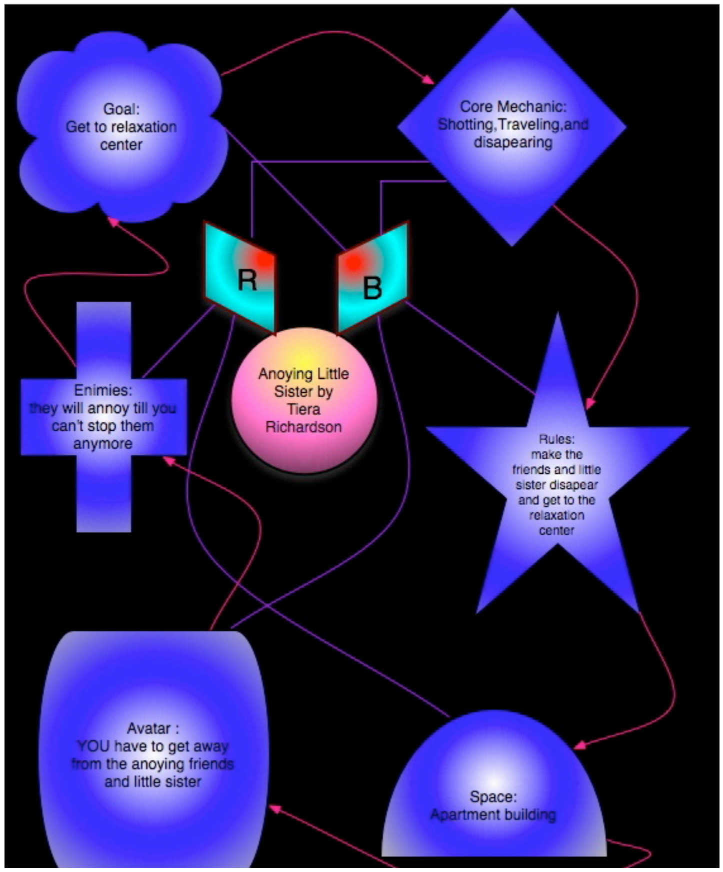


Figure 9. Work sample 1(b): Tania's concept map for think-aloud

Robert: Tell us what you were thinking about when you designated the elements to where they are and the connections and all that.

TANIA: First, I started with the goal, which is to get to the relaxation center. It was connected to core mechanics because the goal is to reach the goal block, and by doing that you have to shoot and travel and make the enemies disappear. The core mechanics is connected to the rules because as soon as you enter the game, what you first have to do is start shooting. Then the rules are to make sure all the enemies have disappeared, which is connected to the goal and all of these make a balance: the goal, the core mechanics, the rules all make a balance. So it's all connected.

Robert: What do you mean by "a balance"?

Tania: That it's not too hard and it's not too easy at the same time to do what you have to do.

Robert: Okay.

TANIA: So from the rules it's going to be connected to the space because after you tell the rules, you have to know where you have to make the enemies disappear. From the space you're connected to the avatar so you know who you are, where you're going to be, and what you have to do. And the avatar is connected to the enemies because they're both human or they're both little characters, so they're both connected to each other.

Tania's pre test mean score suggested a high level of systemic reasoning, specifically reasoning related to feedback loops and time delays. This may point to anecdotal accounts of systems-thinking scholars (Senge, 2006) who have argued that children may be naturally inclined to think systemically. Recent research, however, with middle school students conducted by Sweeny and Sterman (2007) suggests that this may not be the case. Tania scored a Level 1 on the only item she responded to regarding system dynamics, suggesting that the overall workshop experience was beneficial to her in developing this skill.

Observable in Tania's response are also a number of 21st century skills as identified by the Partnership for 21st Century Skills (P21, 2006). First, Tania is able to use two technological tools (*Gamestar Mechanic* and *OminGraffle Professional*) to design, innovate (around a game idea), account for and communicate about complex dynamics within her game. Notice the complexity in Tania's account of designing "to make a balance" between a variety of elements (core mechanics, rules, goal) she identified as existing within her game:

> The core mechanics is connected to the rules because as soon as you enter the game, what you first have to do is start shooting. Then the rules are to make sure all the enemies have disappeared, which is connected to the goal and all of these make a balance: the goal, the core mechanics, the rules all make a balance. So it's all connected.

Levy and Murnane have named complex communication (e.g. the ability to synthesize large amount of information) as one of two core skills that will be required of learners in the 21st century; indeed, a skill rarely required of students in schools today (Spires, 2008; Spires, et al., 2008). Tania's careful design of her concept and her synthetic explanation of her game suggest that using *Gamestar Mechanic* and concept maps as an assessment tool are potentially effective strategies for helping learners develop a level of "information and communication technology literacy" (defined as the ability to use technology to learn content and skills) (P21, 2006), as well as 21st century skills such as accounting for complexity, complex communication and innovation.

<u>Systems-thinking: identifying reinforcing and balancing feedback dynamics</u>

The understanding of feedback dynamics (i.e., reinforcing and balancing feedback loops) was defined for this study as the ability to identify reinforcing and balancing feedback loops, and to show how they can inform and can continually modify the workings of a system (Senge, 2006). Participants were introduced to this conceptual skill midway through the workshop by which point most demonstrated a working understanding and use of the system dynamics. I held a significant degree of concern regarding the introduction of this conceptual skill as Senge (1990, 2006) and others (Richmond, 2000; Sweeney & Sterman, 2007) have written about the difficulty most adults have in acquiring facility with the application of this skill. As a basic introduction, participants were given an example from the children's book, *A River Runs Wild,* a text that has been used to teach children how to think systemically (Sweeney, 2001) In this story the Nashua River had endured centuries of pollution resulting in contamination and the end of wild life ecologies until Marrion Stoddart began a movement to rescue it 30 years ago. Industry pollutants were described as causing a reinforcing dynamic that eventually led to the river's once natural ability (described as a balancing dynamic) to fend off the pollutants and sustain river life. Ms. Stoddart was also described as a balancing agent who helped bring life back to the river. For a few sessions after, participants were asked to come up with and dramatize examples of instances in "real life" where they knew of a reinforcing and balancing dynamic happening simultaneously. With relative ease, participants were able to identify various scenarios. One included the reinforcing and balancing dynamic between the AIDS virus and CDT-4 cells, while another depicted the greenhouse warming dynamics between carbon dioxide and the earth's atmosphere. Participants were then challenged (via a letter from Samson) to select their own real life situation that demonstrated a reinforcing and balancing feedback dynamic and use it to frame the narrative of a game they were to design in

Gamestar. Games had to show specifically where a balancing and/or reinforcing feedback dynamic was at work. Once their game was completed, participants were asked to design a concept map of one of their games depicting balancing and reinforcing feedback loops.

Before beginning their concept map designs, various visual models appearing in engineering or behavioral research journals (see, for example, Lane, 2008) depicting reinforcing and balancing feedback loops were shown and discussed with participants. As per the design of the workshop, participants in an open, social and collaborative fashion designed, playtested, formally and informally reviewed each other's games, and presented their games for whole-group critiques. The review protocol created in the early weeks of the workshop was amended to include questions regarding appropriate use of reinforcing and balancing feedback dynamics. Critical to demonstrating competency in this skill was a participant's ability to make particular observations within systems of such things as time delays, patterns, cycles, causality and feedback dynamics.

Work sample 2 below includes three examples (a through c) demonstrating levels of application of balancing and/or reinforcing feedback loops. In Work sample 2(a) Maleke demonstrates a Level 2 ability in this skill, defined as "interconnections and inter-relationships, linear chains and static (vs. dynamic) descriptions of change." This sample is based on a concept map Maleke designed based on one of his games where aliens have accidentally dropped a "cube" on to planet Earth containing their life source and other secrets. An Earth-based military unit has found and is investigating the cube. The aliens must stop them. While Maleke attempts to indicate a reinforcing feedback loop (see in transcript below: "he [Sgt. John] wanted to get pieces of the cube and that's when it gets out of whack") he didn't express this in a manner clear enough to be given a Level 3 score. However, his concept map indicates an emerging level of understanding that is beginning to reach beyond static descriptions of behavior, and inclusive of cycles and causality within systems. This is of import as Maleke's scores were among 0s and 1s during pre and post testing. Unlike during those testing periods, which were marked by a significant degree of abstraction, the concept map and think-aloud exercise seems to have enabled Maleke , who was classified as special education at the time of study, the opportunity to more concretely demonstrate systemic reasoning. Though Maleke's overall work scored at below average levels of systemic reasoning, he demonstrates here an emerging ability to use technological tools, such as his use of *OminGraffle Professional*, to make meaning out of his game, and to show interconnected complexity. Maleke worked for about an hour to complete this concept map without needing to stop. His sustained focus here was similar to his ability to do so when designing games. Maleke requested more time on a subsequent day to do further work on his concept map, but the need to allow other participants to complete concepts did not allow for more time. Of significance here and throughout the workshop, was Maleke's interest and sustained levels of engagement, something his teachers reported on various occasions that he was unable to do in academic classes. Though the limitations of this study make it difficult to predict whether more time would have enabled Maleke to make and demonstrate greater gains in systemic reasoning, it is possible to speculate that activities mediated by technological tools, such as *Gamestar Mechanic* and *OmniGraffle* – which proved to enable sustained focus and interest – could be used to help facilitate learning for Maleke. Further, his sustained interest, speaks to the need for schools to use the kinds of 21st century tools and technology platforms that students like Maleke are well accustomed to outside of school.

Maleke:	Then here, you have Sergeant John. He wanted to get pieces of the cube and that's when it gets out of whack.
Robert:	Really? When he wants to get pieces of the cube? Why does it go out of whack?
Maleke:	They catch him. When they catch him sneaking the cube.
Robert:	What do they do that makes things go out of whack? They being the robots.
Maleke:	Shooting and killing.

Figure 10. Work sample 2(a), Maleke's concept map

Work sample 2(b) below shows an excerpted transcript and concept map designed by Nola. The sample is based on one of Nola's games. In this game, the player takes on the identity of Yuu, a racer who must move through the game's space without getting paralyzed. His goal is to fend off enemies (sent to cripple him by his competitors) while making his way to a racetrack to run "the race of his life." This narrative, as others Nola based her games on, is related to a news story she recalled from living in Russia. This sample was rated a Level 4 by inter-raters. Of note is Nola's application of a reinforcing feedback loop. She explains that "the sky, the underground, and the boss' house and the locker room is also the reinforcing, because you get lost and you have to start over." The grouped interactions of sets of elements (one set represents a reinforcing and the other a balancing feedback loop) create a conflict that represents the overall challenge and play dynamic of her game. Her color choices also accentuate a type of flow in a looping fashion. Colors assigned to elements are fused in the arrows to show interconnectedness and flow movement through a looping cycle.

Robert:	Nola, you were going to tell us about the choices you made to create this graphic and to show – it look like you have a reinforcing feedback loop here?
Nola:	Yeah. I have the reinforcing loop here. The goal is reinforcing because you have to get to the the race before Yuu gets paralyzed. Sometimes, if he gets paralyzed, you have to start all over again and stuff. The sky, the underground, and the boss' house and the locker room is also the reinforcing, because you get lost and you have to start over. The components are Yuu - which is the name of the character - and that's a balancing loop along with the core mechanics, which are jumping, running, and shooting.

Figure 11. Work sample 2(b), Nola's concept map for think-aloud

In Work sample 2(c) below, Xano explains his concept map. The real-life situation with which he chose to depict a balancing and reinforcing dynamic is an incident he had with his sister in which he broke a prized pot his mother owned. In the story, he tries to fix the pot, but his sister, in her quest to makes sure he gets in trouble, hides the pieces of the pot and recruits her friends to help her keep Xano from finding them. As he explains, the increasing number of (his sister's) enemy-friend components he inserts into the game, along with the challenging game space he designed, correspond to a reinforcing dynamic while the core mechanics (zapping, collecting and avoiding) he has assigned to his avatar (who he names after himself) offer him the power to generate a balancing dynamic. His concept map shows these dynamics and draws them into closed, interacting loops. He is able to articulate the opposing nature of these dynamics – a conceptualization that had not been an explicit part the workshop. This work sample was scored a Level 4 by the inter-raters.

Work sample 2(c), Xano's think-aloud and concept map

Xano: Then the avatar and the core mechanic make the balancing feedback loop.

Robert: Why is that?

Xano: Because the avatar is zapping, collecting, and avoiding. With all of those together, they will make the balancing feedback loop of all of the core mechanics. You can make it to the goal and collect all of the pieces of the pot. I think the goal and the rules are almost the same thing, so I put an arrow here to say that these two are connected both ways. For the other ones, there are thousands of enemies, which are my sister's protectors. With this and the bad space, then New York City would make a reinforcing feedback loop. So I made this with this.

Robert: Why is this reinforcing? What do you mean by reinforcing? What's going on that is creating a reinforcing feedback?

Xano: There are a lot of my sister's protectors, which are her friends that protect all the pieces. And the space is really bad, so it's reinforcing.

Robert: So all of these different things are creating...

Xano: The reinforcing feedback.

Robert: What do you mean by reinforcing?

Xano: Out of whack and stuff.

Robert: Is it because it's like building on itself and creating a harder and harder situation? Is that what you mean?

Xano: Yeah.

Robert: Tell me more about what you mean about balancing over here.

Xano: I think that balancing is like the opposite of reinforcing: not out of whack. So if the avatar Xano has the core mechanic of zapping, collecting, and avoiding, he could avoid and get the pieces and nothing would go out of whack. So it is the balancing feedback loop.

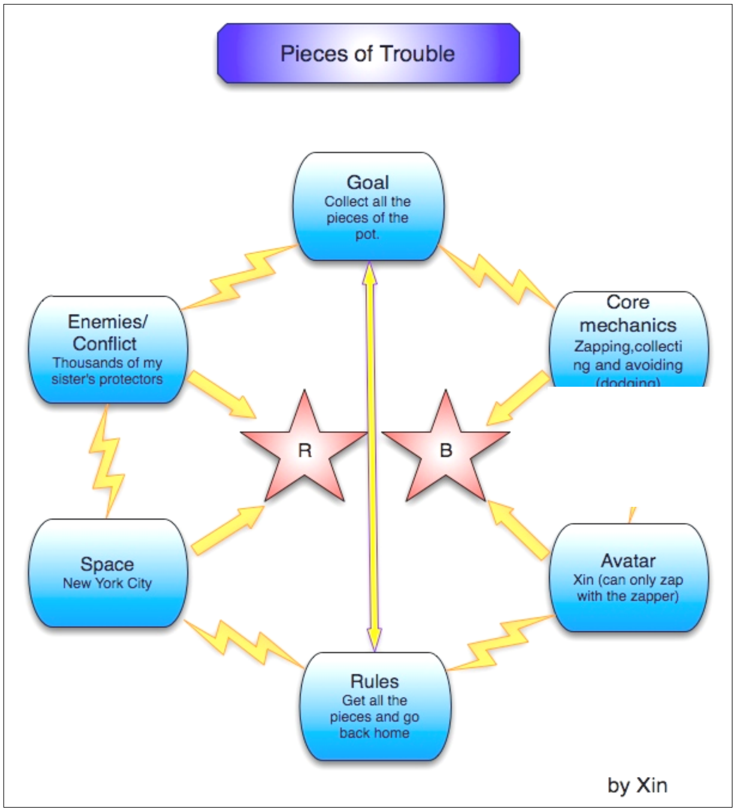


Figure 12. Work sample 2(c), Xano's concept map for think-aloud

Various systems-thinking researchers have noted that identifying dynamic simultaneity within a system is a difficult skill for adults to exhibit (Forrester, 1994; Sweeney & Sterman, 2000). Yet, Hawking (2000) and others (Rambihar & Rambihar, 2009) have stressed that the ability to think in complex, systemic terms – to master "the science of the 21 century," as they have called it – will define those who shape the economies and cultural movements of this century. To be sure, these work samples, generated during this 35-session study, show but an emergent quality of understanding and accounting for complexity. Even in this nascent form, however, it is encouraging to see that when conditions such as that of a nodal learning ecology are designed and anchored by a generator node (such as *Gamestar Mechanic*) it is possible to have young learners explore complex thinking concepts and skills as sophisticated as reinforcing and balancing feedback dynamics.

<u>Systems-thinking skill: identifying homologies</u>

Homological understanding was defined for this study as the ability to determine that system dynamics can exist in other systems that may appear to be entirely different. Earlier in this chapter I discussed how the opportunities to identify homologies – that system elements like core mechanics, space, rules exist in all systems, and that the interactivity of these homological elements create the unique dynamics of the system – largely propelled discourse in the workshop. While assignments were designed to give participants multiple means through which to make meaning of this concept, pre and post tests formally tested for the development of this skill; that is, the ability to identify how sets of similar elements in different systems. Sandra's pre and post test transcripts below demonstrate an increased level of sophistication when responding to the questions, "When I say 'system' to you, what comes to mind?" and "Can you give me an example?" Participants were told to consider games as a system, but were also to choose a comparative (homological) example that was not a game.

Sandra received a Level 1 for her attempt to exhibit the ability to express a homology during her pre test, and a Level 4 at her post test. Unlike other participants who chose to describe different types of systems for their pre and post tests, Sandra chose to describe a computer both times. The researcher did not remind Sandra of her use of a computer example during the pre test. Notice her ability to articulate during her post test that a computer has "a bunch of different little parts that have their own job that are inside the laptop that makes the laptop work"; and further, "They [all the little parts] have to be programmed to work together." This is markedly different from her pre test response which though potentially correct (a computer internally has "a lot of different things that are [or could be] called systems"), her post test response is more precise and indicates her ability to perceive a computer as system of interacting element have been "programmed to work together."

Pre test (February 27, 2008)

Robert: When I say the word "system" to you, what comes to mind?

Sandra: A computer.

Robert: How come a computer?

Sandra: Well like any machine, the system I think it reminds me of a computer because with a computer, you work with a lot of different things that are called systems.

Post test (June 16, 2008)

Sandra: When I say the word "system" to you, what comes to mind?
I think it means a bunch of different parts working together to create something. Like a bunch of different parts coming together, a

bunch of different parts that are together to create something else.

Robert: What do you mean by something else?

Sandra: Something different than what made it.

Robert: Than the individual? Give me an example.

Sandra: A laptop. Because they have a bunch of different little parts that have their own job that are inside the laptop that makes the laptop work. So that is a system.

Robert: That is interesting. Here is a laptop right here. If I just had this key, it would just be the key. Is that what you mean? If I just carried this one key around?

Sandra: Yes. It wouldn't be a laptop anymore it would just be the key.

Robert: You are saying that the parts together...?

Sandra: All the parts together make the laptop, not just one.

Robert: So how do the parts relate to each other?

Sandra: They have to be programmed to work together. They have to fit together so that they produce the same thing as all other laptops.

As discussed in her biographical sketch, Sandra was awarded a special achievement award for best use of pattern programming (referred to in the workshop as the ability to design a "hidden dimension") in her games. The example above also shows Sandra's preoccupation with programming (parts "have to be programmed to work together"). A comparison of her pre and post responses above also indicates a greater level of understanding that systems are *designed entities*, programmable by "you" to achieve a certain result. This is suggestive of a degree of understanding that actual people versus mysterious out-in-the-world forces are responsible for the design of systems. While assessing for the development of agentive indicators was not a focus of this study, it was certainly an implicit goal, especially in light of scholars who have pointed to design and systems thinking in particular as vehicles capable of broadening one's sense of agency in the world (The New London Group, 1996).

Assessing for homological understanding for this study was done to see if participants were able to use this skill when identifying other systems and their operational dynamics – albeit at a surface level. The goal was to ascertain if a systems-thinking curriculum using *Gamestar Mechanic* could support skill development at this level. Sandra's ability to draw a comparison between a game and a computer from the vantage point of a system programmed to yield a result suggests that assessing for homological reasoning is a viable goal when using such tools. Further research is necessary to expand on these results. Given the findings documented by various researchers, however, as to the difficulties adults and children alike demonstrate in conceptualizing systems and system dynamics even in general terms, Sandra's response, especially in the context of her overall mean score in the workshop of 3.5, is indeed promising.

Systems-thinking skill: determining quality of a system

This systems-thinking skill has been defined for this study as the ability to identify when the relationships within a system are or are not working at optimal levels. One item on the pre and post tests assessed participants' ability to determine the level of quality in a game's system. Called The (Metacognition) Design Exercise, participants were shown a game I designed in *Gamestar Mechanic* with a set of design problems. Among other issues, the game was difficult to beat, damage blocks had too much power, other blocks were placed randomly with no clear purpose, and coins scattered in the game were irrelevant to the apparent goal of reaching a goal block. This pre/post test item intended to gauge participants' ability to assess the entire design of the game's system and identify issues which they had to frame in the form of three different questions to the game's designer. The transcript below shows Noel's responses to this item. Inter-raters scored Noel a Level 2 for his pre test response and Level 3 for his post test response. While I did not explicitly support participants to develop this skill– that is, in the form of lecturettes or any other device that would highlight "system quality" as a special term or concept, participants routinely evaluated each other's games using the game review protocol, and during "critiques." Of note below is the qualitative change in Noel's response to this item from T1 to T2. While his initial response identified a basic design problem ("How are you supposed to complete the game if you can't get past the blocks?"), the post test shows how Noel's concern about this same problem becomes more precise ("how did you make the space, like if you make one move it's over"). He follows this up by offering that he would change the game, pointing specifically to the fact that "right now there is no point to the points" and that more coins (which he calls points) along with life packs would make the game both more challenging and playable.

Pre test (February 27, 2008)

Noel: How are you supposed to complete the game if you can't get past the blocks? Whatever they're called, they're spiky.

Robert: These are damage blocks.

Noel: What were you thinking when you created made the game? And how do you think the game will affect the people who are playing it?

Robert: Anything you would change to the game?

Noel: No, not really.

Post test (June 17, 2008)

Robert: So what's your first question?

Noel: What were you thinking when you made the game? And how did you make the space, like if you make one move it's over.

Robert: Ok, and question number three?

Noel: I would change the game. Right now there is no point to the points. I would put more life and more points, so that it could be more challenging. I like that look, but it [life packs] can also help people.

Of note in Noel's post test response is his approach to the problem of space design. Space design served as a point of entry for Noel in his development as a game designer throughout the workshop. Space and the experiences and possibilities a player would encounter informed his design work. See, for example, the transcript below taken from a description of one of his games early in the workshop:

Noel: I used something that could float because of course I wanted you to float to see the background. And of course I wanted you to get up and see everything and win the game. But I want it to feel like you're a guy in space, like you're an astronaut. You can go up, and you keep on going up.

Robert: So you really wanted to give a player the feeling that they're traveling through space, that they themselves are an astronaut?

Noel: Yes. That's why this game - I gave it a certain look and feel, because every little thing that I did, the core mechanic and rules are all connecting to what my idea was….Also, I wanted to make it feel like you're in space, so I did a whole bunch of stuff. If you make a mistake and fall, you might feel like you're dying, but when you come, you just see everything that's around you. You see your surroundings….You see everything that's here. It's really amazing. That's why I like *Gamestar Mechanic*, because you can use your mind in any possible way. Even if you say you can't make a game, after you go on *Gamestar Mechanic*, you feel like you can do it. You can fly.

Within the professional domain of game design, as is true for any domain, members specialize in distinct areas. For Noel, it is possible to speculate that a trajectory of expertise in game design could include space design or, more appropriately, "world design," or graphical illustration's of "game art." This "intellectual" concern of his allowed him to use it as a lens through which to consider the design of games in general – his and others'. Moreover, Noel used this same lens as synthesizing tool to evaluate the overall quality of the post test "design problem" game. "*I like that look*" he says referring to the space design, "*but*" life packs can also help people.

Noel's post test response also indicates a greater and immediate sense of comfort ("I would change the game") with iterating on the game's design. The workshop was designed in such a way that identifying design issues within games and addressing them immediately via changes (or "tinkerings") and playtesting drove the nature of all activity. Finally, both of Noel's post test and in-workshop transcripts exemplify an emerging expertise through a synthesizing lens of space design. As discussed earlier, complex communication and expert thinking (Levy & Murnane, 2004) have been identified as key 21st century skills. Noel's use of *Gamestar* to demonstrate an emerging acquisition of these skills speaks to the potential this platform may serve in aiding this kind cognitive development. This is especially significant in light of the fact that he is considered a "low academic achiever" by his teachers. While Noel's performance on school assignments generally received low scores, his overall mean score in this workshop was a 3.7. This suggests that further research as to the potential of tools such as *Gamestar* – tools, that is, that Noel is quite used to using out of school – would be useful in determining if these types of tools could help in increasing overall levels of academic achievement and increased development of complex, system-thinking skills. Indeed, as noted earlier, these are skills not explicitly taught in schools (Spires, 2008; Spires, et al., 2008), but critically necessary in today's global society.

In sum, this chapter presented participant learning gains from T1 to T2. Within a context of 21st century skills, examples were given of artifacts created during the workshop that exemplified instances of systemic reasoning. Overall results show that 83% of participants of focus made learning gains in four distinct systems-thinking skills, with 66% showing a change in levels of systemic reasoning of .5 points or more within the 0 to 4 scale and 33% demonstrating a change of 1 or more points on the scale. Specific work samples demonstrated qualitative systemic skill reasoning for each participants of focus. The discussion chapter that follows will offer implications for teaching and learning and assessment, potential directions for future research and limitations of the study.

CHAPTER VI

DISCUSSION

At its core, the games and learning field is acutely concerned with advancing contemporary theories of learning. Anchored in the learning sciences, this emerging field draws from a vast and varied history of research deeply interested in altering the discourse of learning research and processes from a reductionist to a more holistic enterprise. With NCLB, the Bush years did much to fortify behaviorist and cognitivist appeals for more of the same type of learning environments – test, drill and kill – that keep students alienated from school, especially urban students for whom school is often the only place they have to engage in academic work (Noguera, 2003). Certainly, claims herein do not assert that cognitivist or behaviorist approaches have literally killed or caused physical harm to anyone, but the current state of educational failure does point squarely to the degrees to which they have contributed to squelching students' interest and the joy that can and should be a part of learning. As such, this study has drawn and thus has taken to task the direct link between theory and the current outcomes the American education system produces, with critical concern for the failure of providing relevant, high-quality educational opportunities to those who need it most.

Gamestar Mechanic, the online game design video game that actuated this study, is an example of an educational learning tool realized by learning scientists and industry professionals. Using a situated learning model, this study investigated whether a group of middle school students could develop systems-thinking skills as a result of designing games within *Gamestar*. Of particular concern was the question of context, especially as it helped to answer the question of *how*: How did participants come to develop systems-thinking skills? Post test scores and workshop work samples show promising results. Post test scores indicated that 5 of 6 participants of focus showed gains in systemic reasoning. Four demonstrated gains of .5 points on a scale of 0 to 4 and two demonstrated gains of 1 point, with five of the six showing overall mean scores of 3.1 or higher. In-workshop work samples showed that five of the six participants achieved systemic reasoning levels of 3.8 points or higher. An average of post test and in-workshop scores indicated that 5 of the six participants established overall standings of 3.57 points or higher on the 0 to 4 scale. Most significantly, three of the six participants moved from scoring at levels 0 to 2 of systemic reasoning skills to levels 3 to 4. This suggests that using a video game designed to teach middle and high school-aged students game design skills may serve to facilitate the development of systems-thinking skills.

A design-based research method was used for this study. As is customary for this approach to research, this study sought to closely examine the design of the learning environment in which the study, framed as an educational intervention, took place. The term "educational intervention" in design-based research is meant to signify explicit aims to implement and test a type of educational innovation. As such, examining the context in which learning takes place not only offers clarity as to the conditions designed for learning, but points to the potential viability the learning environment might hold. In this way, new theories might begin to emerge that can extend current ones, but that should also be held to scrutiny.

Situated cognition framed this study. In addition, Bronfenbrenner's bioecological system theory (1998), White's social networks theory (2008), and Gee's theory of discourse analysis (1999, 2005) served to give shape to a design of a nodal ecology. *Gamestar Mechanic* was described as serving as the ecology's generator (Gee, 2007) node. As such, the online social network that is *Gametar Mechanic*, instantiated all of the seven nodes in the ecology; nodes in which participants repeatedly practiced "taking on" a variety of productive identities – identities mediated by modes of material productions, including games, critiques, evaluations of *Gamestar* itself, and written narratives we called film treatments. The seven nodes in the ecology created what I referred to as a condition of *ecological constancy*. That is, each node in the ecology, in spite of its difference in feel and appearance, activated similar perceptual experiences for participants across nodes, creating cognitive redundancy and predictability. I argued that without the condition of constancy – without bidirectional relationships and redundancy between nodes – learning game design and systems-thinking would have been limited.

The notion of ecological constancy tries to extend beyond notions that context is important (Barab & Plucker, 2002) when attempting to understand deep learning and tries, instead, to position it as a phenomenon that occurs via a means of travel through a set of related experiences. We might consider that we travel through many nodes in our lifetime. In each, we interact with people, tools, symbols, and discourses. But actually learning the contents of those nodes is predicated not only by the repeated experiences in each one node, but more significantly, by the relational ties – by the bidirectional redundancy (and therefore) predictability of content – nodes begin to form. We might call those "clusters of nodal ecologies" defined by a particular kind of knowledge (or constancy) such as game design. White (2008) writes that meaning is made in the "switchings" between "netdoms"; as a result of resolving the tension individuals experience from switching from one netdom to the next. This suggests that cognitive structures emerge as one moves from one netdom (or, in the case here, from one node) to another. Ecologies with constancy – which are themselves types of dynamic learning systems – then can be said to house cognitive structures that individuals "take on." More to the point, the learning ecology activated by this study was itself a cognitive structure from which situated meanings, products and identities emerged. In this way "cognition" – the results of individual and collective perceptions, learnings, reasonings – and cognitive structures emerge and take form as a result of situational and individual interactions within a defined ecology. It is not a stretch to say that how learning is defined in education policy and in teacher development programs – if it is defined – is by far anything close to this definition, let alone anything that considers as central the role of context in learning.

Situated meanings were not imparted, but rather, emerged from the domain of game design. In the process of creating actual products – games – participants, in a context that encouraged trial and error "tinkered" with possible designs, invented narratives, gave and solicited feedback from other designers local and virtual, and iterated. These products mediated an understanding of design processes and facilitated the development of systems-thinking skills. Moreover, framing learning as an "act" of *doing and constructing* (Gee, 2003; Papert & Harel, 1991; Perkins, 1986), the study's learning ecology was explicitly designed to enable participants to "take on" and "act out" various identities. "Game designer" was the core identity participants were asked to step into, and as a result, they were asked "to learn to be" versus "learn about" game design. But game designers are also critics, writers, artists and members of a greater community that determines and assesses what it means to be a good designer. In fact, game designers (as is the case for professional researchers, architects, tennis players or engineers) don't take tests to determine who meets the industry's standards. Instead, the community of practitioners themselves act as the assessors (Gee, 2009). Imagine sixth graders, via a national social networking platform, such as is *Gamestar Mechanic*, in a community of practice with other middle and high school students and invited historians, producing and debating over what it means to do good historical analysis. This is the kind of practice novice game designers engaged in as a part of this study.

Implications for teaching and learning

Cognitivist and behaviorist notions of learning have led to the establishment of an American public school system that continues to struggle with making good on its promise to offer even an adequate education to its citizenry. Critically questioning not only its results, but the theoretical foundations on which the system yields results is necessary. The implications of taking a theoretical turn toward situated cognition are vast for teaching and learning, but perhaps even more critically, for schools of education, teacher credentialing agencies and even state government law makers who govern these agencies. Indeed, learning about teaching vs. about learning in a rather procedural manner characterizes the vast majority of teacher education programs who themselves have been found to be egregiously lacking in quality and substance (Levine, 2006). Lobbying to make changes at governmental levels may be aided by increased research utilizing situated notions of learning, particularly research using new technologies that allow for the kind of distributed learning spaces explored in this study. Such research, however, should be done not only in afterschool programs, but in larger school settings attempting to innovate at the levels of the design of learning environments using situated teaching and learning practices that are mediated by new technologies of the types youth are increasingly engaged with: games, social networks, and mobile devices.

Schools and other learning programs interested in taking an ecological approach to designing learning environments would need to consider and create the multiple and distinct nodes beyond the classroom. Educators designing curriculum would need to design these nodes to ensure their inter-connectedness. A generator node like an interactive online software program that is used to teach specific skills should denominate nodal activity. This has substantive implications for teacher professional development programs which will need to be created or reframed to train teachers on (1) the complex work required to design effective learning environments, (2) understanding learning as a situated phenomenon, and how to account for situated learning processes, and (3) assessment practices that capture learning in context.

Out of school we are seeing a radical expansion of the collaborative and creative capacities of young people who are eager to learn and participate. Studies show that the majority of online teens between the ages of 12 and 17 are content producers of such things as blogs, webpages, original artwork, photos, stories, or videos, authoring original content or remixing content found online into new creations (Jenkins, et al., 2006). Interestingly, these same studies found that urban and lower-income youth – who are among the most likely to drop out of school – tend to engage in these activities at greater rates than their suburban and rural counterparts. It is crucial that schools take notice, and, accordingly, that wholesale efforts are put in place to redirect teaching and learning methods that take advantage of both students' interests, and of the affordances provided by new technologies.

Implications for assessment

By far the greatest factor defining the American public school system is its assessment regime. Though measuring student academic ability using standardized measures has been the norm since the early 1900s, NCLB has exacerbated this trend. The greatest consequence of this is that tests – designed mostly to assess basic reading and math skills – have come to dominate curricular design and goals, especially in inner-city schools. Worse yet, the tests have come to define the standards for determining a ranking systems for schools. In his book, *The Global Achievement Gap*, Wagner (2008) tells about his visits to schools considered the very best schools in the country, only to find that these schools were doing very little to teach students the kinds of 21st century skills – complex thinking and communication, collaboration, information and media literacy and innovation – necessary not only for work in today's economy, but critical in what is now a global world increasingly inundated with information, complexity and possibility.

While this study did not explicitly seek to make claims about effective context-based assessment methodologies, it used these kinds of tools (video recorded think-alouds and concept maps) to capture learning. Both strategies were mediated by media tools – video recordings by *ScreenFlow* and concept maps by

OminGraffle Professional. In this way, assessment tools were contextualized within our game design work and sought to capture learning relevant to the work at hand. More to the point, if schools are interested in better understanding the degrees to which students are acquiring skills necessary for participation in this century, they are hard pressed to use methods that measure deeper levels of reasoning.

21st century learning

Throughout the presentation of this study, I have sought to show how using *Gamestar Mechanic* within a nodal ecology offers the potential to teach and assess middle school-aged students systems-thinking. Systems-thinking skills have been identified as a core 21st century skill (Salen, 2007). The choice to study the development of systems-thinking skills was largely driven by the consensus that learning basic reading and math is by far no longer sufficient in light of the global and technological changes (Goldin & Katz, 2008). As well, an underlying discussion in the study posed that systems-thinking may support agentive behaviors.

In the last decade, countless reports and various books cited throughout this study, have decried the crisis in which the American public school system finds itself. Numerous "21st century skills" lists have been generated, but a holistic analysis would indicate that one core skill would rise among the rest: the ability to synthesize (to see and account for) the vastness of available information for the purpose of learning. No one teacher, class, book or website will provide all the necessary information necessary to understand something deeply, but understanding this fact and employing the ability to navigate, evaluate and account for technological and informational complexity will. Designing learning environments that teach for the understanding and assessment of complexity is the challenge we face.

Design principles for creating the modern school

A core practice discussed throughout this study involved the idea that people learn by "learning to be" versus "learning about" something. Learning to be (a game designer, biologist or engineer) requires that a learner understand reasonably well the epistemic make up of the domain in which one wishes to participate and, more importantly, to contribute. Understanding the epistemology of a domain requires deep awareness of domains as designed systems (Gee, 2003). Such an awareness can only come, however, in the process of engaging and producing knowledge within the domain from the perspective of membership; that is, from the vantage point of taking on the kinds of roles that exist in a domain. As practicing educators, we don't have a name for this kind of learning. Some of us in the games and learning field have referred to it as "game-based learning" to denote the resonance it has to the kind of learning required of players in the process of completing many of the current commercially available games. A more neutral term may be "domain-based" learning. Whatever we call it is less important than what it implies – that learning is a situated process that necessitates learning on two levels: (1) understanding the world as functionally designed by people, and (2) understanding the world from the perspective of one's agency within it – of one's sense of the limitations and possibilities the world affords for the purposes of enacting change within it.

To be more specific, I offer a set of design principles below that schools, school districts, and government agencies would do well to consider. These principles summarize in large part the precepts under which this study was designed and seek to give tangible form to types of findings discovered as a result of the study.

1. Domain Membership: Learning environments should provide authentic opportunities for *becoming* part of a knowledge domain.
2. Domain-Based Learning: Traditional disciplines such as history and mathematics should be framed as knowledge domains in which real people work and produce knowledge in specific kinds of ways within a framework of standards and values designed by members of those domains.
3. 21^{st} Century Youth-oriented Platforms: Learning environments should critically look at new media technologies, including games, online networks and mobile devices to maximize the ways youth are currently engaging these tools.
4. Learning for Innovation: Reframe learning from a process of consumption to a process of design, systems reasoning and innovation. Indeed, curricular programs should insist that youth be challenged with the design of innovations necessary for the 21^{st} century.

5. 21st Century Assessment: Mobilize the political will to radically change assessment practices that effectively measure 21st century skills – reading, writing, complex communication, information synthesis, systems-thinking, innovation, and collaboration – using both standardized and locally situated methods.

Further research

Learning ecologies and emergence

This study offered insights into the potential a game, framed within a learning ecology, may have on helping middle school students develop systems-thinking skills. While post test data suggests that this may in fact be feasible, data regarding the nodal ecology itself was offered through a descriptive analysis. Further research on "nodal" learning ecologies may offer greater insights into the effectiveness of ecologies by seeking to understand which nodes, for example, were more effective than others. Such inquiries may study the amount of time students spend in each node and how discourses qualitatively differed from one to the next. The question of emergence also needs further exploring. For example, an additional (lunch) node unexpectedly arose in the study. What are the conditions that lead to this kind of emergence, where participants' levels of participation "tipped them over" far enough to take matters into their own hands.

Game-based pedagogy

A game-based pedagogy that framed the study's curriculum into a series of "quests" was used. Gee has argued (2003, 2007a) that work in the games and learning field is less about using games – though many good commercial games hold promising opportunities in facilitating learning – and more about learning from the learning principles imbedded in games to design learning environments that are more game-like. As in many games, use of a quest structure attempted to create a reason for learning, a reason for needing to know how to do something. In the case of this study, participants, for example, needed to first understand what we meant by balancing and reinforcing feedback loops to be able to (1) incorporate them into their games and (2) to be able to explain and evaluate how well they *and their peers* used these dynamics in their games. This study, however, is not able to draw any incisive conclusions as to the effectiveness of this strategy. Further research on how to effectively create the conditions that lead to a need to know would do much to serve the goal of making learning more game-like.

Gamestar Mechanic in schools

This study was conducted over a six-month period within a school whose curriculum did not inform the design of the study. Though promising results emerged, more research is needed to understand how using *Gamestar Mechanic* to teach game design and systems-thinking practices can be implemented on school-wide levels. Research of this kind would consider if using *Gamestar Mechanic*-based game design and systems-thinking practices could (1) impact overall levels of student achievement, and (2) support school-wide curriculum design. Additionally, models of teacher professional development would need to be designed and tested using the model employed by this study.

Limitations

As is the nature of emerging fields, small-scale projects are necessary to test the viability of new tools and practices. The sample size of focus for this study was made up of six participants, therefore, claims such as increased gains in performance levels, though promising, are not generalizable. While playing video games or engaging with other interactive media has become a regular activity for most teens (Roberts, et al., 2005), the recruitment strategy based on self-selection used for the study may have been skewed in favor of attracting participants with substantively greater experiences with playing games. Of the 16 participants, only three were female. Though this study did not set out to focus on gender-based differences in participation, allowing for self-selection may have deterred females from more actively signing up since males played a greater role in recruiting their own male peers.

As a sole researcher, pre testing was challenged by a need to coordinate several things at once, including administering the protocol, video taping, conducting sound checks in a fairly loud corner of a room in which two classrooms, divided by temporary walls, were in session. This resulted in making some pre test data inaudible and forcing me to disqualify otherwise usable data. I experimented with the possibility of re-testing one participant, but his responses had qualitatively improved from having only experienced the pre-test the day before. This resulted in my choosing to not include him as one of the six participants of focus. His data, however, were used to train the inter-raters employed for the study. The point here, however, is that technical support is needed to more effectively administer and video-record pre and post tests.

Finally, as the lead instructor for this study, I had a tremendous impact in the overall implementation of the study's instructional design. It is impossible to eliminate myself as a key interacting element among the many others that activated the learning system. This is another reason why continued research testing the viability of *Gamestar Mechanic* and the type of curriculum created for this study is necessary.

Final thoughts

Understanding context means understanding inter-relational dynamics between elements within a specified location. To understand context in essence then means to understand systems. Though not necessarily framed in these terms, a theory of learning as situated, is a theory concerned with the output of systems. Yet, reductionist theories across the natural and social sciences – which have otherwise been enormously valuable in helping us understand discreet components of phenomenon – have by and large made it difficult to account for phenomenon in systemic ways. Papert (2006) has urged the learning sciences to mature and identify a central "mathetic" – a central research construct such as the speed of light in physics – from which to generate research and theories. We might do well to look to a model in the natural sciences, molecular biology, that has in the last decade done away with "naïve reductionism" (Strange, 2005) in favor a systems-oriented view. This view takes the position that in spite of the large-scale genomic sequencing efforts that culminated in the 1990s, these efforts tell "very little about the functional behaviors of cells and multicellular organisms; that is, what [researchers] really want to know about biological systems" (Ehrenberg, et al., p. 2377). Now called "systems biology," this new view has revolutionized and integrated once disparate fields from physiology to engineering (Brent, 2004; Ehrenberg, Elf, Aurell, Sandberg, & Tenger, 2003). Still in its infancy, systems biology – which is in essence a fusion of biology and technology – is on a course to change the biological sciences forever. This study was encouraged by Papert's challenge to find a central mathetic. A traditional research field like molecular biology has significantly turned to a systems perspective to better understand complex phenomena. As learning scientists we indeed may benefit from a systems view of learning, both at the level how individuals understand complexity and the situated processes that facilitate understanding.

On a micro level, this study sought to investigate the potential of using a game to help middle school students develop systems-thinking skills. In a macro sense, it drew a parallel between learning systems-thinking and learning as a necessarily systems-based phenomenon. Could it be that our mathetic — the contstruct that will allow us to understanding how learning happens — lies at the intersection between understanding how humans effectively develop systems-thinking and understanding the systems that enable particular understandings? Much more research is needed, but the learning sciences and the games and learning field in particular are poised and committed to usher in a new era of understanding what it means to learn.

BIBLIOGRAPHY

Agre, P. E. (1997). Living math: Lave and Walkerdine on the meaning of everyday arithmetic. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives*. Mahwah, NJ: Lawrence Erlbaum Associates.

Ahern, L. M. (2001). Language and agency. *Annual Review of Anthropology, 30*, 109-137.

Anderson, C. A., Gentile, D. A., & Buckley, K. E. (2007). *Violent video game effects on children and adolescents: Theory, research, and public policy*. New York: Oxford University Press.

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher, 25*(4), 5-11.

Assaraf, O. B.-Z., & Orion, N. (2005). Development of system thinking skills in the context of Earth system education. *Journal of Research and Science Teaching, 42*(5), 518-560.

Bakhtin, M. M. (1986). *Speech genres and other essays*. Austin, TX: University of Texas Press.

Barab, S. (2006). Design-based research: A methodological toolkit for the learning scientist. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences*. Cambridge, England: Cambridge University Press.

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground *The Journal of the Learning Sciences, 13*(1), 1-14.

Barab, S. A., & Plucker, J. A. (2002). Smart people or smart contexts? Cognition, ability, and talent development in an age of situated approaches to knowing and learning. *Educational Psychologist, 37*(3), 165-182.

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development, 49*, 193-224.

Brenick, A., Henning, A., Killen, M., O'Connor, A., & Collins, M. (2007). Social evaluations of stereotypic images in video games: Unfair, legitimate, or "just entertainment"? *Youth and Society, 38*(4), 395-419.

Brent, R. (2004). A parntership between biology and engineering. *Nature Biotechnology, 22*(10), 1211-1214.

Bridgeland, J. M., DiIulio, J. J., & Morison, K. B. (2006). *The silent epidemic: Perspectives of high school dropouts*. Washington, DC: Civic Enterprises, LLC.

Bronfenbrenner, U., & Morris, P. (1998). The ecology of developmental processes. In W. Damon & R. M. Lerner (Eds.), *Handbook of Child Psychology*. New York: John Wiley & Sons.

Brookover, W. B., Beady, C. H., Flood, P. K., Schweitzer, J., & Weisenbaker, J. (1979). *School social systems and student achievement: Schools can make a difference*. New York: Praeger.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions. *Journal of the Learning Sciences, 2*, 141-178.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Carnagey, N. L., & Anderson, C. A. (2004). Violent video game exposure and aggression: A literature review. *Minerva Psichiatrica*(45), 1-18.

Christoph, J. N., & Nystrand, M. (2001). Taking risks, negotiating relationships: one teacher's transition toward a dialogic classroom. *Research in the Teaching of English, 36*(2), 249-286.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9-13.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences, 13*(1), 15-42.

Cope, B., & Kalantzis, M. (2000). Designs for social futures. In I. B. Cope & M. Kalantzis (Eds.), *Multiliteracies: Literacy learning and the design of social futures*. New York: Routledge.

Coté, J. E., & Levine, C. G. (2002). *Identity formation, agency, and culture: A social psychological synthesis*. Mahwah, NJ: Erlbaum.

Daiute, C. (2004). Creative uses of cultural genres. In C. Daiute & C. Lightfoot (Eds.), *Narrative analysis: Studying the development of individuals in society*. Thousand Oaks, CA: Sage Publications.

Damasio, A., & Damasio, H. (2006). Minding the body. *Daedalus, 135*(3), 15(18).

Derry, S. J., & Steinkuehler, C. A. (2003). Cognitive and situative theories of learning instruction. In L. Nadel (Ed.), *Encyclopedia of cognitive science* (pp. 800-805). England: Nature Publishing Group.

Dewey, J. (1916). *Democracy and educaiton: An introduction to the philosophy of education*. New York: Free Press.

Doyle, J. K. (1997). The cognitive psychology of systems thinking. *System Dynamics Review, 13*(3), 253-265.

Driscoll, M. P. (2005). *Psychology of learning for instruction* (3rd Edition ed.). Boston: Pearson Eduction, Inc.

Duckworth, A. L., Peterson, C., Matthews, M. D., & Kelly, D. R. (2006). Grit: Perserverance and passion for long-term goals. *Journal of Personality and Social Psychology, 92*(6), 1087-1101.

Ehrenberg, M., Elf, J., Aurell, E., Sandberg, R., & Tenger, J. (2003). Systems biology is taking off. *Genome Research, 13*, 2377-2380

Engestrom, Y., Miettinen, R., & Punamaki, R. L. (1999). *Perspectives on activity theory*. Cambridge: Cambridge University Press.

Ericsson, K. A., & Simon, H. A. (1984, 1993). *Protocol analysis: Verbal reports as data*. Cambridge, MA: MIT Press.

Federation of American Scientists. (2006). *Harnessing the power of video games for learning.* Paper presented at the Summit on Educational Games, Washington DC.

Forrester, J. W. (1994). *Learning through system dynamics as preparation for the 21st century*. Paper presented at the Concord Academy, Concord, MA.

Forrester, J. W. (1996). *System dynamics and K-12 teachers*. Paper presented at the University of Virginia School of Education.

Freire, P. (1970). *Pedagogy of the Oppressed* (M. B. Ramos, Trans. 30th ed.). New York: The Continuum Publishing Company.

Gagné, R. M., Wager, W. W., Golas, K. C., & Keller, J. M. (2005). *Principles of Instructional Design* (5th Edition ed.). Belmont, CA: Wadsworth/Thomson Learning.

Gee (1990, 1996). *Social linguistics and literacies: Ideology in Discourses*. New York: Routledge Falmer.

Gee (1999, 2005). *An introduction to discourse analysis: Theory an method*. New York: Rutledge.

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

Gee (2004). *Situated language and learning: A critique of traditional schooling*. New York: Routledge.

Gee (2005). Semiotic social spaces and affinity spaces: From the Age of Mythology to today's schools. In D. Barton & K. Tusting (Eds.), *Beyond communities of practice: Language, power and social context*. New York: Cambridge University Press.

Gee (2007a). *Good video games + good learning*. New York: Peter Lang.

Gee (2007b). Video games and embodiment. University of Wisconsin, Madison.

Gee, J. (2005). *Why video games are good for your soul*. Vancouver: Common Ground Publishing.

Gee, J. (2009). Human action and social groups as the natural home of assessment: Thoughts on 21st century learning and assessment. Unpublished White Paper. MacArthur Foundation.

Geist, E. (2000). Lessons from the TIMSS videotape study. *Teaching Children Mathematics, 7*(3).

Gentile, D. A., & Gentile, J. R. (2008). Violent video games as exemplary teachers: A conceptual analysis. *J Youth Adolescence, 37*, 127-141.

Gibson, J. J. (1986). *The ecological approach to visual perception*. Hillsdale, NJ: Erlbaum.

Goffman, E. (1974). *Frame analysis: An essay on the organization of experience*. New York: Harper & Row.

Goldin, C., & Katz, L. F. (2008). *The race between education and technology*. Cambridge, MA: Harvard University Press.

Goldman, R. (2007). Video representations and the perspectivity framework: epistemology, ethnography, evaluation, and ethics. In R. Goldman, R. Pea, B. Barron & S. J. Derry (Eds.), *Video Research in the Learning Sciences*. Mahwah, NJ: Erlbaum.

Goldman-Segall, R. (1998). *Point of viewing children's thinking*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Greene, J. P. (2002). *High School Graduation Rates in the United States*. New York: Center for Civic Innovation at the Manhattan Institute.

Greeno, J. G. (2006). Learning in activity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences*. Cambridge, England: Cambridge University Press.

Gutierrez, K. (2008). Developing a sociocultural literacy in the third space. *Reading Research Quarterly, 43*(2), 148-164.

Hammond, D. (2003). *The science of synthesis: Exploring the social implications of general systems theory*. Boulder, CO: University Press of Colorado.

Hanson, B. G. (1995). *General systems theory: Beginning with wholes*. Washington DC: Taylor & Francis.

Hawisher, G. E., & Selfe, C. L. (2007). Introduction: Gaming lives in the twenty first century. In G. E. Hawisher & C. L. Selfe (Eds.), *Gaming Lives in the twenty first century: Literate connections*. New York: Palgrave Macmillan.

Hawking, S. (2000). Science in the next millennium. Retrieved December 20, 2008, from http://clinton4.nara.gov/Initiatives/Millennium/shawking.html

Hayes, E. (2005). Women, video gaming and learning: Beyond stereotypes. *TechTrends, 49*(5), 23-28.

Hayes, E. R. (2005). *Tony Hawk Underground: Situated language in the context of socially situated identities.* Paper presented at the American Educational Research Association, Montreal, Canada.

Hayes, E. R., & Games, I. A. (2007). *Making computer games & design thinking: A review of current software and strategies*. Paper presented at the Games, Learning and Society conference.

Hirsch, E. D. (1997). Traditional education is progressive. *The American Enterprise, 8*(2), 42-45.

Hirschfeld, L. A. (2000). A cognitive theory of cultural meaning. *American Anthropologist, 102*(3), 620-629.

Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to learn about complex systems. *The Journal of the Learning Sciences, 9*(3), 247-298.

Hoadley, C. M. (2004). Methodological alignment in design-based research. *Educational Psychologist, 39*(4), 203-212.

Holstein, J. A., & Gubrium, J. F. (1997). Active Interviewing. In D. Silverman (Ed.), *Qualitative Research*. London: Sage.

James, W. (1890). *The Principles of Psychology*. Cambridge, MA: Harvard University Press.

Jenkins, H. (2006). *Convergence culture*. New York: New York University Press.

Jenkins, H., Clinton, K., Purushotma, R., Robison, A. J., & Weigel, M. (2006). *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century*. White Paper sponsored by The John D. and Catherine T. MacArthur Foundation.

Kafai, Y. B. (1995). *Mind in play: Computer game design as a context for children's learning*. Hillsdale, NJ: Lawrence Earlbaum Associates, Inc.

Kafai, Y. B. (2006). Constructionism. In K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences*. Cambridge, England: Cambridge University Press.

Kirshner, D., & Whitson, J. A. (Eds.). (1997). *Situated cognition: Social, semiotic, and psychological perspectives*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Kozol, J. (2006). *The Shame of the nation: The restoration of Apartheid schooling in America*. New York: Crown Publishers.

Kutner, L., & Olson, C. (2008). *Grand theft childhood: The surprising truth about violent video games and what parents can do*. New York: Simon & Schuster.

Lane, D. C. (2008). The emergence of use of diagramming in system dynamics: A critical account. *Systems Research and Behavioral Science, 25*, 3-23.

Lave, J. (1990). The culture of acquisition and practice of understanding. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives*. Mahwah, NJ: Lawrence Erlbaum Associates.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Lehrer, R., & Schauble, L. (2005). Developing modeling and argument in the elementary grades. In T. A. Romberg, T. P. Carpenter & F. Dremock (Eds.), *Understanding mathematics and science matters*. Mahwah, NJ: Lawrence Erlbaum Associates.

Lenhardt, A., & Madden, M. (2005). *Teen Content Creators and Consumers*. Washington DC: Pew Internet and American Life Project.

Lenhart, A., Kahne, J., Middaugh, E., Macgill, A. R., Evans, C., & Vitak, J. (2008). Teens, video games, and civics. Retrieved December 20, 2008, from http://www.pewinternet.org/PPF/r/263/report_display.asp

Levine, A. (2006). *Educating school teachers*. Washington, DC: The Education Schools Project.

Levy, F., & Murnane, R. J. (2004). *The new division of labor: How computer are creating the next job market*. Princeton, NJ: Princeton University Press.

Magnusson, D., & Stattin, H. (1998). Person-context interaction theories. In W. Damon & R. M. Lerner (Eds.), *Handbook of Child Psychology*. New York: John Wiley & Sons, Inc.

McWhorter, J. (2000). *Losing the race: Self-sabotage in Black America*. New York: Simon & Schuster, Inc.

Meier, D. (1996). *The Power of Their Ideas: Lessons for America from a small school in Harlem*. Boston, MA: Beacon Press.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks: Sage Publications.

National Institute on Media and the Family (n.d.). Effects of video game playing on children. Retrieved December 19, 2008, from http://www.mediafamily.org/facts/facts_effect.shtml

Newell, J. (2002). Rubric development and inter-rater reliability issues in assessing learning outcomes. *Chemical engineering education, 36*(3), 212-215.

Noguera, & Wing, J. Y. (Eds.). (2006). *Unfinished business: Closing the achievement gap in our schools*. San Francisco, CA: Jossey-Bass.

Noguera, P. (2003). *City schools and the American dream*. New York: Teachers College Press.

Noguera, P. A. (2008). The state of education in America. NYU Podcast retreived November 20, 2008 from http://odeo.com/episodes/23422735-The-State-of-Education-in-America-with-Pedro-Noguera. New York: New York University.

Norris, N. D. (2004). *The promise and failure of progressive education*. Lanham, MD: Scarecrow Education.

Papert, S. (1998). Does Easy Do It? Children, Games and Learning. *Game Developer* (June 1998).

Papert, S. (2006). Afterword: After how comes what. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences*. Cambridge, England: Cambridge University Press.

Papert, S., & Harel, I. (1991). *Constructionism*. Toronto, Canada: Ablex Publishing Corporation.

Partnership for 21st Century Skills (P21). (2006). A state leaders action guide to 21st century skills. Retreived December 10, 2007 from http://www.21stcenturyskills.org/index.php?option=com_content&task=view&id=221&Itemid=116

Perkins, D. N. (1986). *Knowledge as design*. Hillsdale, NJ: Erlbaum Associates.

Phillips, S. (1976). The contributions of pyschology to education. *Oxford Review of Educaiton, 2*(2), 179-196.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher and learning? *Educational Researcher, 29*(1), 4-15.

Rambihar, V. S., & Rambihar, V. (2009) Complexity science may help in defining health. *BMJ.* Retrieved January 28, 2009, from http://www.bmj.com/cgi/content/full/338/jan09_1/b32

Ravitch, D., & C. E. Finn, J. (1987). *What do our 17 year olds know?* . New York: Macmillan

Reich, G. A. (2007). *(Dissertation) Measuring Acheivement in history: Multi-choice, high stakes & learning unsure outcomes*. New York: ProQuest Information and Learning Company.

Reynolds, D., Creemers, B., Nesselrodt, P. S., & Shaffer, E. C. (1994). *Advances in school effectiveness research and practice*. Tarrytown, NY: Elsevier Science, Ltd.

Richmond, B. (2000). *The "thinking" in systems thinking: Seven essential skills*. Waltham, MA: Pegasus Communications.

Roberts, D. F., Foehr, U. G., & Rideout, V. (2005). *Generation M: Media in the lives of 8-18 year-olds*. Washington DC: The Henry Kaiser Family Foundation.

Rogoff, B. (1990). *Apprenticeship in thinking: Coginitive development in social context*. New York: Oxford University Press.

Rogoff, B. (2003). *The cultural nature of human development*. New York: Oxford University Press.

Ross, S. M., Stringfield, S., & Smith, L. (1996). *Bold plans for school restructuring: The new American schools designs*. New York: Routledge.

Roth, W.-M., & Lee, Y.-J. (2007). "Vygotsky's neglected legacy": Cultural-historical activity theory. *Review of Educational Research, 77*(2), 186-232.

Rubin, B. C., Noguera, P. A., & Rodriguez, A. P. (Eds.). (2006). *Structuring inequality at Berkeley High*. San Francisco, CA: Jossey-Bass.

Salen, K. (2007). Gaming literacies: A game design study in action. *The Journal of Educational Multimedia and Hypermedia, 16*(3), 301-322.

Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals*. Cambridge, MA: MIT Press.

Sawyer, R. K. (2006). Introduction: The new science of learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences*. Cambridge, England: Cambridge University Press.

Schön, D. A. (1983). *The reflective practioner: How professionals think in action*. New York: Basic Books.

Schwartz, D. L., Sears, D., & Chang, J. (2007). Reconsidering prior knowledge. In M. Lovett & P. Shah (Eds.), *Thinking with data* (pp. 319-344). Mahwah, NJ: Erlbaum.

Sclan, E. M. (1990). *Curriculum-making of the child-centered progressive educators: Contraposed to Dewey's theory of experience*. Paper presented at the AERA.

Senge, P. (1990, 2006). *The fifth discipline: The art and practice of the learning organization*. New York: Doubleday.

Shaffer, D. W. (2006). *How computer games help children learn*. New York: Palgrave Macmillan.

Shaffer, D. W., Squire, K. R., Halverson, R., & Gee, J. P. (2005). *Video games and the future of learning*.Unpublished manuscript, Wisconsin.

Shuell, T. J. (1986). Cognitive conceptions of learning. *Review of Educational Research, 56*(4), 411-436.

Singer, D. G., & Singer, J. L. (2005). *Imagination and play in the electronic age*. Cambridge, MA: Harvard Universtity Press.

Spires, H. A. (2008). 21st century skills in serious games: Preparing the N generation. In L. A. Annetta (Ed.), *Serious games*. Rotterdam, The Netherlands: Sense Publishing.

Spires, H. A., Lee, J. K., & Lester, J. (2008). The twenty-first century learner and game-based learning. *Meridian Middle School Computer Technologies Journal, view online at http://www.ncsu.edu/meridian/win2008/21st/index.htm, 11*(1).

Squire (2003). Video games in education. *International Journal of Intelligent Simulations and Gaming, 2*(1), 49-62.

Squire (2004). *(Dissertation) Replaying history: Learning world history through playing Civilization III*. Indiana University.

Squire (2005a). Changing the game: What happens with video games enter the classroom. Retrieved August 23, 2007, 2007, from http://www.innovateonline.info/index.php?view=article&id=82

Squire (2005b). Games and Learning. *TechTrends, 49*(5), 17-59.

Squire (2006). From content to context: Videogames as designed experience. *Educational Researcher, 35*(8), 19-29.

Steinkuehler, C. A. (2004). *Learning in massively multiplayer online games.* Paper presented at the The Sixth International Conference of the Learning Sciences, University of California, Los Angeles.

Steinkuehler, C. A. (in press). Cognition and literacy in massively multiplayer online games. In D. Leu, J. Coiro, C. Lankshear & K. Knobel (Eds.), *Handbook of Research on New Literacies*. Mahwah, NJ: Erlbaum.

Sternberg, R. J., & Preiss, D. D. (2005). *Intelligence and technology: The impacts of tools on the nature and development of human abilities*. Mahwah, NJ: Lawrence Erlbaum Associates.

Stone, L. D., & Gutierrez, K. D. (2007). Problem articulation and the processes of assistance: An activity theoretic view of mediation in game play. *International Journal of Education Research, 46*, 43-56.

Strange, K. (2005). The end of "naive reductionism": rise of systems biology and renaissance of physiology? *Am J Physiol Cell Physiol, 288*, C968-C974.

Sweeney, L. B. (2001). *When a butterfly sneezes: A guide for helping kids explore interconncetions in our world through favorite stories*. Waltham, MA: Pegasus Communications, Inc.

Sweeney, L. B., & Sterman, J. D. (2000). Bathtub dynamics: Initial results of a systems thinking inventory. *Systems Dynamics Review, 16*(4), 249-286.

Sweeney, L. B., & Sterman, J. D. (2007). Thinking about systems: Student and teacher conceptions of natural and social systems. *System Dynamics Review, 23*(2/3), 285-312.

Taylor, C. (1985). *Human agency and language*. Cambridge, UK: Cambridge University Press.

Thagard, P. (1994). Mind, society, and the growth of knowledge. *Philosophy of Science, 61*(4), 629-645.

The New London Group (1996). A pedagogy of multiliteracies: Designing social futures. *Harvard of Educational Review, 66*(1), 60-92.

Thernstrom, A., & Thernstrom, S. (2003). *No excuses: Closing the racial gap in learning*. New York: Simon & Schuster, Inc.

Thorndike, E. L. (1971). *The fundamentals of learning*. New York: AMS Press.

Turkle, S. (1984). *The Second Self: Computers and the human spirit*. New York: Simon & Schuster, Inc.

Tyack, D. B., & Cuban, L. (1995). *Tinkering toward utopia: A century of public school reform*. Cambridge, MA: Harvard University Press.

Vygotsky, L. (1978). *Mind in society*. Cambridge, MA: MIT Press.

Walkerdine, V. (1997). Redefining the subject in situated cognition theory. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives*. Mahwah, NJ: Lawrence Erlbaum Associates.

Walvoord, B. E., Anderson, V. J., & Angelo, T. (1998). *Effective grading: A tool for learning and assessment*. San Francisco: Jossey-Bass, Inc.

Wertsch, J. V. (1998). *Mind as action*. New York: Oxford University Press.

White, H. C. (2008). *Identity and control: How social formations emerge*. Princeton, NJ: Princeton University Press.

Whitney, P., Grimes, J., & Kumar, V. (2007). Schools in the digital age. [Research Initiative funded by the John D. and Catherine T. MacArthur Foundation]. *2007*.

Wineburg, S. S. (2001). *Historical thinking and other unnatural acts: Charting the future of teaching the past*. Philadelphia: Temple University Press.

Young, V. L., Ridgway, D., Prudich, M. E., Goetz, D. J., & Stuart, B. J. (2001). Criterion-based grading for learning and assessment in unit operations laboratory. *Proceedings of the 2001 American Society for Engineering Annual Conference & Exposition Copyright, American Society fo Engineering Education*.

Zimmerman, E. (2007). Gaming literacy. *Harvard Interactive Media Review, 1*(1), 30-35.

APPENDICES

APPENDIX A: PRE AND POST TESTING PROTOCOL

PRE AND POST TESTING PROTOCOL

The following is the study's pre and post assessment protocol activities. Please note the corresponding construct under investigation is expressed in brackets and highlighted in gray for each protocol activity.

Duration: Approximately 60 minutes

Primary Areas of Focus

1. Acquisition and use of specialist language (e.g. terms related to game design, such as rules, space, core mechanics, etc.)
2. Development of systems thinking skills.

Secondary Areas of Focus

1. Understanding of game design processes (e.g., iteration, feedback)

I. Interview One: General understanding of games and game designers (5 min)

1. Elicit oral response: What does a game designer do? [C1 (specialist language]
2. Please write a description of what you think game designer do. [C1 (specialist language]

II. Think-Aloud [C2.2 (system dynamics); C2.4 quality of relationships within systems)]:

Ask participants to <u>Design A Game</u> given a set of pieces (e.g.,index cards, dice, chips, miniature game pieces, construction and drawing paper, and markers) (10-15 mins). Give each participant 5-7 minutes to design a game. If he or she appears to need some prompting the following questions may be used:

1. What is the first thing you would do to design a game? [C1 (specialist language)]
2. Why did you choose those pieces? [C2.2 (system dynamics)]

3. Tell me about the game. [C1 (specialist language); C2.2 (system dynamics)]
4. How do those pieces go together? Why do you think those pieces work well together? [C2.2 (system dynamics)]
5. What is the relationship of piece X to piece Y? [C2.2 (system dynamics)]
6. Ask about the purpose of different elements specific to their design: Tell me about the layout of your game and why you designed it that way. [C2.4 quality of relationships within systems)]
7. Write the rules for your game. [C1 (specialist language)]

III. Interview Two: Games as Systems (20 mins)

a. We think of a game as a system with many parts that interrelate to form a whole. What does "system" mean to you? Give me an en example of a system that is not a game? Explain its parts and how they relate to each other? [C2 general systems-thinking understanding); C2.5 (homological understanding)]

b. The Hidden Dimension Exercise (Assaraf & Orion, 2005): This pre and post assessment exercise will gauge students' perception of the hidden dimension of a game system (e.g., processes, which takes place under the surface). During this interview, students will be presented with <u>an incomplete game</u> designed in *Gamestar Mechanic* along with the game's rules. Prompts for this exercise may include questions such as: (a) What are the design elements that you can see and experience in the game? [C1 (specialist language); C2.2 (system dynamics)] (b) If you were a designer of this game and you would like to finish it, what elements would you wish to add? [C2.3 (hidden dimension); C2.4 (quality of relationships within a system)]; (c) What are the relationships between the elements in this game? [C2.1 (feedback dynamics); C2.2 (system dynamics)]; and (d) Please give a title to this game [C2 (systems-thinking general)].

c. The (Metacognition) Design Exercise: This pre and post assessment question will ask students to play a game in *Gamestar Mechanic* that has <u>a set of design problems</u>. The students will be asked to play the game and pose three questions they might ask the game's designer in order to understand the original designer's design decisions [C1 (specialist language); C2 (systems-thinking general)].

IV. Interview Three: Natural and social system "dilemmas" (20 mins)

<u>A. Hunger and Eating</u>
Let's take a look now at the relationship between hunger and eating.

a. Begin by asking a very open-ended question: I'd like you to tell me a story about the relationship between your level of hunger and eating. [C2.1 (system dynamics)]

b. How might hunger and eating be inter-related?" or "How are hunger and eating related or connected to each other?" [C2.1 (system dynamics)]

c. If the participant is out of ideas, then you may ask: What happens next? or, "So, if you eat, what does that do to your level of hunger? What happens next? or "How long do you think it takes for this increase or decrease in hunger to happen?" [C2.1 (feedback dynamics)]

d. Can you think other situations that feel the same as this? For example, this kind of "up and down behavior" or where's there's a delay (gap, or time passes) between something that you do and the results that you see. [C2.5 (homological understanding)]

<u>B. Practice/Performance/Enthusiasm</u>

Do you (or have you) practice something regularly? Like a sport, an instrument, drama? (If participant says, "no", move on to the next question).

a. Let's think about the relationship between the amount you Desire to Practice, how well you play (Performance) and your level of Enthusiasm. How might these be interrelated?" "What do you think happens to the your enthusiasm and/desire to practice time? [C2.1 (feedback dynamics)]

b. What happens next? or So, if you practice more, what happens to how well you play and to your level of enthusiasm? [C2.1 (feedback dynamics); C2.2 (system dynamics)]

c. Can you think of other situations that feel the same as this? [C2.5 (homological understanding)]

<u>C. Room Clean Up/Parent's (or Caregiver's) Attitude</u>

Does someone at home often ask you to clean up? Establish who that person is first.

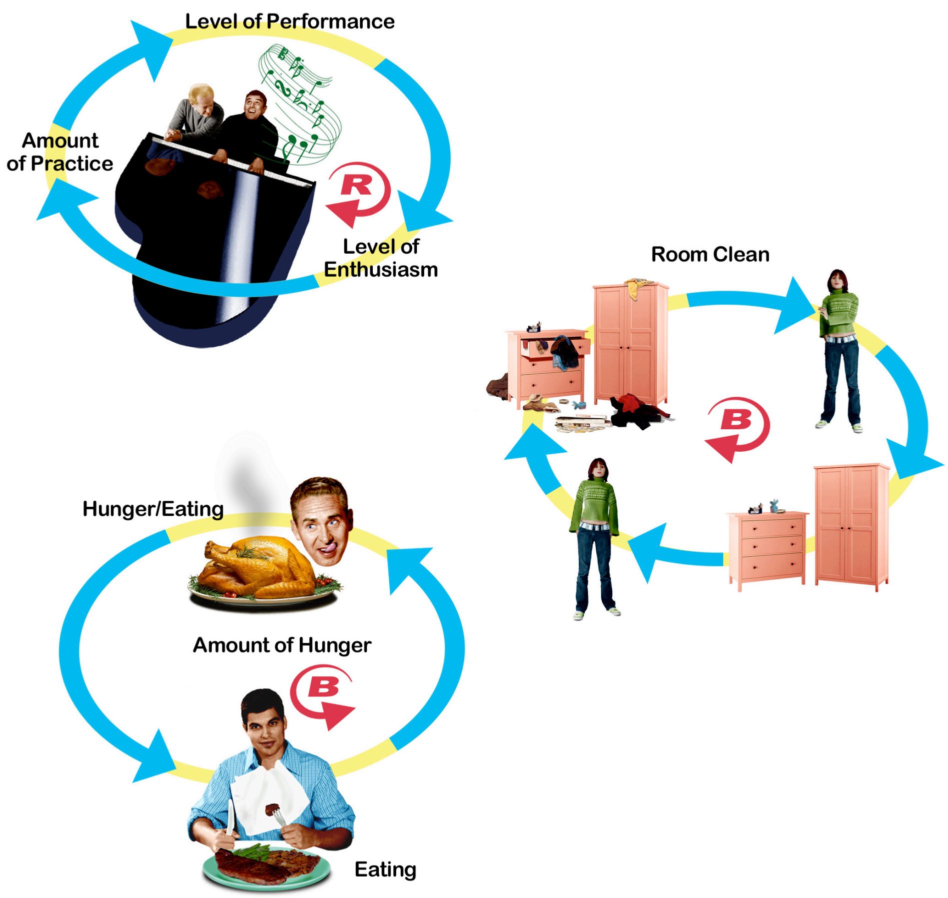
a. Tell me a story about a possible relationship between the state of a room (how clean or messy it is) and the level of happiness of the person in charge of keeping the house clean (ask: who would that be?) [C2 (systems-thinking general)]

b. How might the condition of your room and your parent's (or caregiver's) attitude be connected? What do you think happens to the these two over time? If the participant is out of ideas, then ask: What happens next? or, So, if the room is messy, then what happens? (First response may be "Mom gets mad.") Okay. So what happens next? [C2.1 (feedback dynamics)]

c. Can you think of other situations that feel the same as this? Can you think of examples that have this same kind of up and down behavior? [C2.5 (homological understanding)]

V. Interview Four: Comparison of System Dynamics (5 min)

Ask participants to consider the three everyday dynamic loops they've just discussed. This go round, you will use the following three pictures:



a. Which two of these are similar? How so? [C2.1 (feedback dynamics)];

APPENDIX B: WORKSHOP CURRICULUM

***Gamestar Mechanic* Curriculum**
February 25, 2008 to June 13, 2008 (mon, wed, fri; 3:15 to 4:30)

Introduction and Overview of *Gamestar Mechanic*
Gamestar Mechanic (G*M) is an online game that enables players to design video games within a *practice* space. Through the design process, students are able see how games are made up of a set of interacting elements. As in G*M, most games have these six common elements: Rules, Goals, Core Mechanics, Components, Conflict and a play Space. These interacting elements define the game's ***system***. All games in G*M are made in the game's **editor**. The editor allows students to define qualities of the play space, "edit" creature parameters, design their games, and playtest them.

Big Ideas

1. Games are **dynamic, designed systems**.
2. Games are made up of components that **interact** with one another within a **system** to create a particular kind of experience for a player.
3. Goals, rules, space and core mechanics, and components (e.g., creatures, blocks, etc.) are the core **design elements** of a game designed in *Gamestar Mechanic*.

Important concepts to practice

1. Games have **goals** that define when a game has been won or lost. Goals can be simple (clear the board of all enemies) or complex (collect 15 points and reach the goal block in under 30 seconds).
2. The design of the game **space** creates a visual identity for the game, creates spatial conditions for certain kinds of core mechanics and goals, and structures the relationship between creatures and space.
3. Game design is a cyclical, iterative process of design, playtest, feedback, design.
4. The amount of **challenge** a game has is something that is designed and *can be modified* by changing the specific qualities of game components and their relationships to each other.
5. Games often contain more than one **level**; games with multiple levels have an internal logic that connects the levels within a system of related ideas.
6. Designers can modify component parameters to modify how those components behave within the system and relate to other components.

Important Systems-Thinking skills to practice

1. Understanding of feedback dynamics (i.e., reinforcing and balancing feedback loops): understanding that small level changes can affect macro-level processes.

2. Understanding of system dynamics: understanding that multiple (ie. dynamic) relationships within a system.
3. Understanding hidden dimensions of a system: understanding that modifications to system elements can lead to changes that are not easily recognizable within a system. This is evident, for example, when an element in the system is modified, such as when rules are changed.
4. Understanding of the quality of relationships within a system: understanding when a system is working or not working at optimal levels.
5. Homological understanding: understanding that similar system dynamics can exist in other systems that may appear to be entirely different.

Important tasks to practice

1. Design games with an understanding of the role of each design element.
2. Evaluate games by rating them and writing game reviews.
3. Learn how to describe a game to players through writing game instructions, tips for play, introductory and concluding messages.
4. Make connections between the design elements in games and in non-game systems.
5. Students write short essays (via journal entries) of a non-game system that explains the interdependency of its parts.

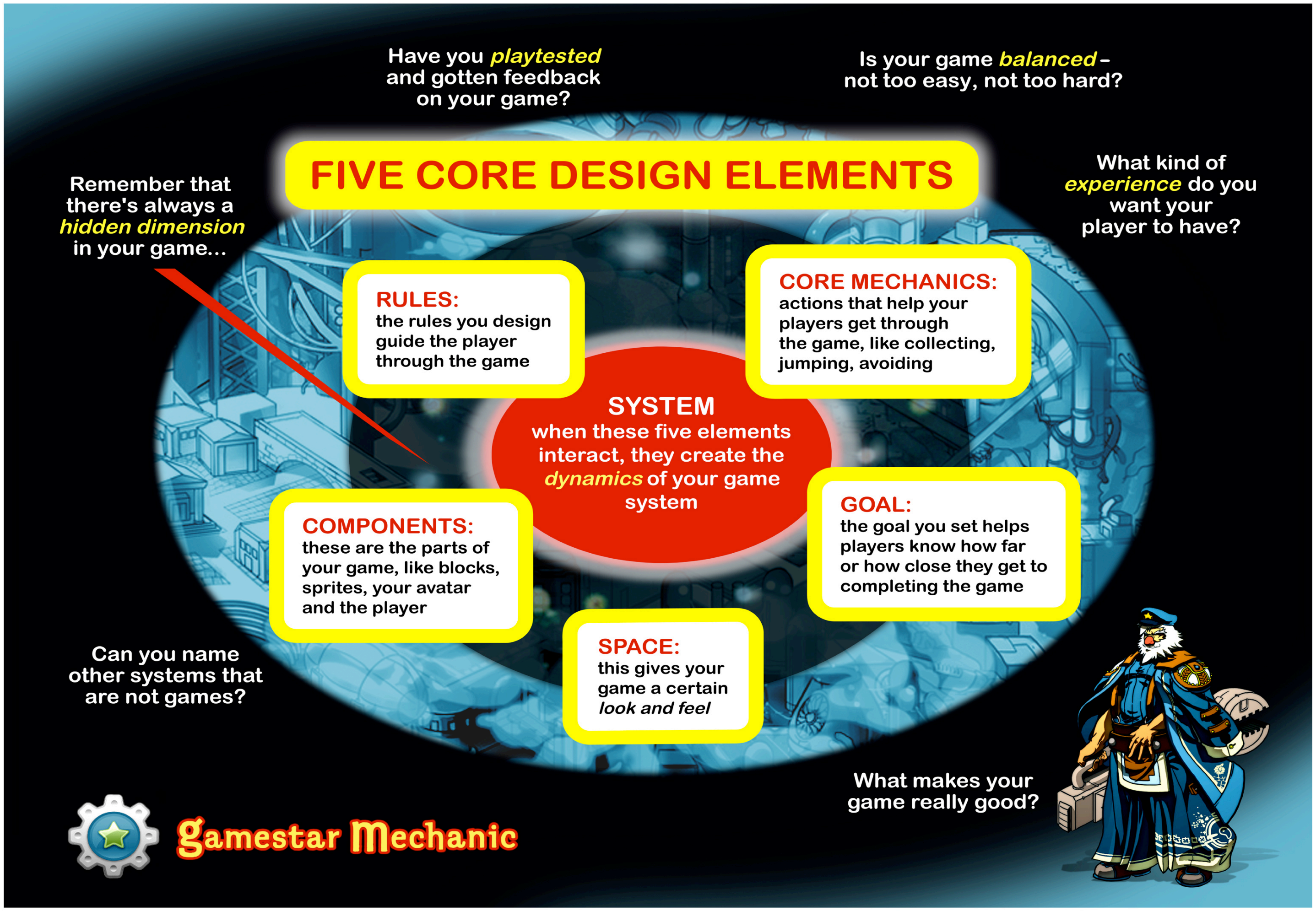
Culminating Events

1. Students design a game which they submit for competition (midpoint thru workshop + at end). They explain system and feedback dynamics for their game. Each student who submits a game has to write a game review for all other games submitted to the competition. Tally up all the scores in the game reviews to find the winner of the "best game" as determined by the reviews.
2. Completion of a web-site where kids post games and document (via journal entries, movies, photos) their experiences in the workshop.

Assessment tools

1. Pre and post testing protocol
2. Think-alouds
3. Concept maps
4. Writing samples

APPENDIX C: WORKSHOP POSTER



APPENDIX D: LETTERS FROM SAMSON

gamestar
mechanic
factory

May 7, 2008

Dear RGA Game Mechanic:

You have done a great job the past few weeks! Congratulations on completing your first major game and having it reviewed by other designers.

All of the games are fantastic. Special *Gamestar* Greetings to Nola, Edward and Sandra for their persistent and outstanding work!

Now we are moving on to understanding the **system dynamics** of a game.

Three things we you have may have heard of are:

1. **The Hidden Dimension**: the behaviors of creatures

2. **Balancing Feedback**: feedback that balances the game; AND

3. **Reinforcing Feedback**: feedback that keeps going and going and going, sometimes making things spin out of control....

These are the things in you game system that you can't always see, but are always present in your game... Or in any system!

Your QUEST for the next 3 weeks is to design a game that has sections of both balancing and reinforcing feedback! As usual, your fellow designers will review and rate your games. But there's a catch! You have to base your game on a real life situation... Robert will explain more... Good luck!

Your elder mechanic,

Samson

gamestar
mechanic
factory

June 9, 2008

Dear RGA Game Mechanic:

We are down to our last week of workshops! I will certainly miss you all very much, but let's make sure to stay in touch through Gamestar Mechanic.

This week is very important as you have to make sure you complete Quest 2 and Quest 3. For **Quest 3** you have to describe the system of your game **in the game label**. As you know, one good way to tie up all the pieces is by creating a ***story***. The game label should **make clear to the player** the goal, core mechanics, space, components and rules of the game. For this game, you should also show one place in the game where a balancing or reinforcing feedback loop is operating. Make that clear in the game label too!

Use this check off list to make sure your **game label** is complete: Does my game label make clear:

- [ ] the goal
- [ ] the rules
- [ ] the space
- [ ] the components
- [ ] the core mechanics
- [ ] the reinforcing or balancing feedback loop

Good luck with the last quest and have a great time at the EXPOSITION next week! — Samson

gamestar mechanic game review sheet

Your name:_______________________________________

Date:____

Name of Game:____________________________________

For each item below, give the game a score from 1 to 5. Justify your opinion in writing by giving reasons you believe the game should receive a particular score.

1. **Interesting space**: Is the game space interesting (is it unique, or does it make you think of interesting strategies)?

   Poor 1 2 3 4 5 Excellent

This game deserves this score because:

____
____
____

2. **Challenging but not too challenging:** Does the game have a good level of challenge?

   Poor 1 2 3 4 5 Excellent

This game deserves this score because:

____
____
____

3. **Originality**: Is the game concept is original (creates a unique experience for the player)?

   Poor 1 2 3 4 5 Excellent

This game deserves this score because:

Clear goal: Does the game have a clear goal?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

4. **Appropriate core mechanics:** Do the core mechanics work well with the space and goal of the game?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

5. **Understandable rules:** Are the rules of the game clear?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

6. **Good storyline:** Is the story of the game integral to the goal, mechanics and space?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

7. **Fitting characters:** Do the characters (avatars and enemies) fit well with the overall game?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

---

9 Beatable: Is the game beatable?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

---

10 Congruent levels: Is there a logical connection between the levels?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

---

11 Useful game label: Does the game label help you understand what the game is about?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

---

12 Effective game system: Does the way elements interact in the game produce an effective system?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

---

14. Reinforcing feedback loop: Does the feedback loop have spinning cycle?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

____

____

____

13 Balancing feedback: Does the loop create a feedback loop?

Poor 1 2 3 4 5 Excellent

This game deserves this score because:

____

____

APPENDIX F: *GAMESTAR MECHANIC* FEEDBACK RUBRIC

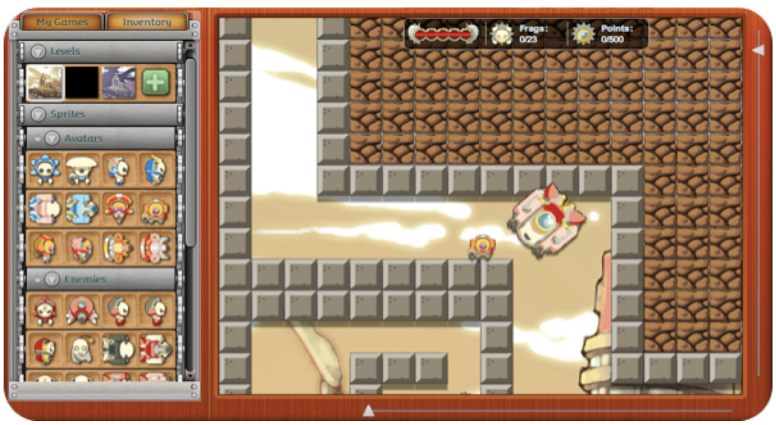
game elements	Novice (1-2)	Junior (3)	Senior (4)	Master (5)
1. **Space** (use of sprites and gravity)	• The game space is unique.	• The game space is unique. • The game space sometimes works well with the core mechanics.	• The game space is unique. • The game space works mostly well with the core mechanics. • The game space sometimes makes the player think of a variety of strategies to complete the game.	• The game space is unique. • The game space and the core mechanics work completely in unison. • The game space constantly makes the player think of a variety of strategies to complete the game.
2. **Challenging but not too challenging**	• The level of challenge is good, but could be made better.	• The level of challenge is good. • The player is somewhat interested in replaying the game.	• The level of challenge is very good. • The player is interested in replaying the game.	• The level of challenge is great. • The game makes you want to keep playing it until you beat it.
3. **Originality**	• The game concept is similar to other games.	• The game concept is somewhat original.	• The game concept is original. • The game concept sometimes creates a unique experience for the player.	• The game concept is original. • The game creates a completely unique experience for the player.
4. **Goal**	• The game has no goal. • The game's goal is not clear.	• The game has a goal, but it can be improved.	• The game has a clear goal. • The game's goal has been somewhat thought out and fits with the overall design of the game.	• The game has a clear goal. • The game's goal has been carefully thought out and fits with the overall design of the game.
5. **Appropriate Core mechanics** (jumping, flying, shooting, collecting)	• The core mechanics don't help the player get through the game.	• The core mechanics sometimes work well with the space design.	• The core mechanics work well with the space design. • The use of core mechanics are unique within the space design.	• The core mechanics and space work completely in unison. • The use of core mechanics are unique within the space design.
6. **Rules** (written in the game label)	• No rule set. • Rule set is not clear.	• The rule set is clear. • The rule set sometimes fits with the game's use of sprites and space.	• The rule set is clear. • The rule set almost always fits with the game's use of sprites and space.	• The rule set is clear. • The rule set always fits with the game's use of sprites and space. • The rules define and guide the player's experience.

game elements	Novice (1-2)	Junior (3)	Senior (4)	Master (5)
7. Storyline	• There is no storyline. • There is a storyline, but you can't really see it in the game.	• There is a storyline, but you only sometimes see it in the game.	• There is a storyline and the you can see how it sometimes fits with the goal, core mechanics, and space.	• The storyline is unique and captures the player's imagination. • The storyline completely fits with the goal, the space and the core mechanics.
8. Fitting characters (avatar and enemy sprites)	• The characters don't fit with the overall concept of the game.	• The characters sometimes work well with the overall concept of the game.	• The characters fit well with the overall concept of the game. • The characters sometimes fit with the core mechanics and space design.	• The characters completely fit well with the overall concept game. • The characters completely fit with the core mechanics and space design.
9. Beatable	• The game is not beatable.	• The game is not beatable, but makes you want to keep trying.	• The game is beatable after giving the player a good challenge.	• The game is beatable after giving the player a chance to figure out the strategy.
10. Congruent levels (logical connection between levels)	• There is no logical connection between levels.	• There is sometimes a logical connection between levels.	• There is a logical connection between levels.	• There is a logical connection between the levels. • The levels change in relation to the level of challenge.
11. Game labels (writing game descriptions, instructions, tips/hints)	• There are no game labels for the game.	• The game labels somewhat help you understand what the game is about.	• The game labels help you understand what the game is about.	• The game labels help you understand what the game is about. • The game labels are written in a way that make you excited about the game.
12. Effective game system	• The core mechanics, space, characters, goal, and rules in the game don't really fit together.	• The core mechanics, space, characters, goal, and rules in the game sometimes fit together.	• The core mechanics, space, characters, goal, and rules in the game fit together.	• The way the core mechanics, space, characters, goal, and rules interact in the game produce an exciting system.

APPENDIX G: SCREENSHOTS OF MALEKE'S GAMES

Urban War Level 1

Urban War Level 2



Urban War Level 3

PPENDIX H: SCREENSHOTS OF NOEL'S GAMES

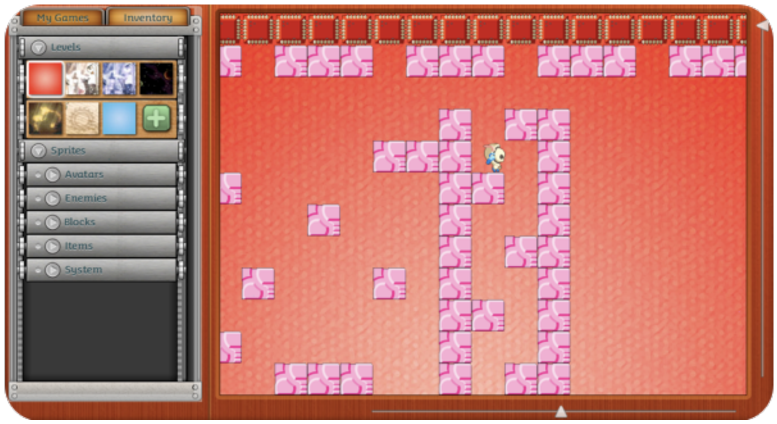
AIDS Level 1

AIDS Level 2

Meltdown

APPENDIX I: SCREENSHOTS OF NOLA'S GAMES

A Racer's Life Level 1



A Racer's Life Level 2

A Racer's Life Level 3

APPENDIX J: SCREENSHOTS OF TANIA'S GAMES

Anoying Sister Level 1

Anoying Sister Level 2

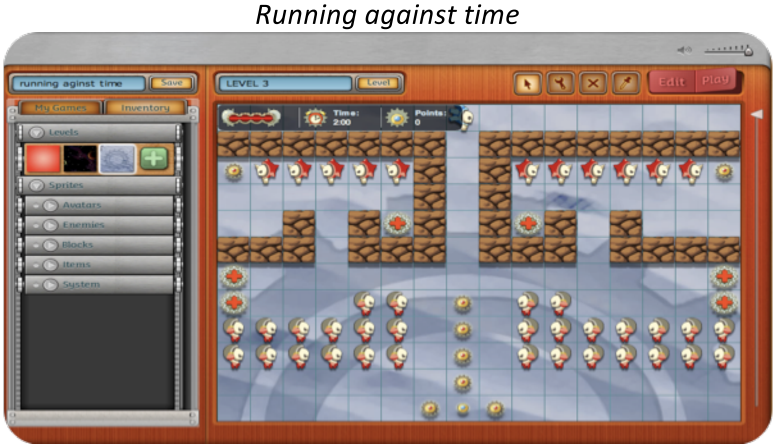
Gushers

APPENDIX K: SCREENSHOTS OF XANO'S GAMES

Pieces of Trouble (Location 1)

Pieces of Trouble (Location 2)

Running against time



APPENDIX L: SCREENSHOTS OF SANDRA'S GAMES

SHUT THEM DOWN (Location 1)

SHUT THEM DOWN (Location 2)

TAKE A RISK