2015

Making Waves, Mixing Colors, and Using Mirrors: The Self-Regulated Learning Support Features and Procedural Rhetoric of Three Whole-Body Educational Games

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MAKING WAVES, MIXING COLORS, AND USING MIRRORS:
THE SELF-REGULATED LEARNING SUPPORT FEATURES AND PROCEDURAL
RHETORIC OF THREE WHOLE-BODY EDUCATIONAL GAMES

by

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A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Department of Texts and Technology
in the College of Arts and Humanities
at the University of Central Florida
Orlando, Florida

Fall Term
2015

Major Professor: Rudy McDaniel

ABSTRACT

This dissertation investigates the question, "How can the procedural rhetoric of three whole-body educational games improve the understanding of self-regulated learning with digital technology?" It explores three whole-body educational games (WBEGs) using a quantitative study, a case study, and analyses of their procedural rhetoric to better understand the roles these types of games can have in teaching digital literacy and self-regulated learning (SRL) skills. The three WBEGs, *Waves, Color Mixer,* and *Light and Mirrors*, are each intended to teach science concepts to players. These games are similarly structured in that they all invite players to immerse themselves in the game by standing on the "screen" (the games project images on the floor). The WBEGs differ from traditional console video games because they receive input from players via motion-sensing technology, requiring players to make large movements with their bodies to influence elements within the game. This study explains SRL as a complex combination of internal (mental) behavior, external (observable) behavior, and interpersonal (social) behavior, identifying within three WBEGs the presence of elements supporting the SRL behaviors of goal setting, strategy planning, collaboration, progress monitoring, feedback, and reflection. These findings inform the understanding of SRL by revealing that each game includes a different combination of SRL-supporting elements that encourage the use of SRL skills in different ways. SRL scaffolding features are those elements within a WBEG that guide players to use certain SRL strategies, helping and supporting their efforts much like construction scaffolding supports a building as it is being erected. This dissertation also utilizes analyses of

procedural rhetoric to investigate the techniques reinforced by the underlying structure of these three WBEGs in an effort to further the understanding of digital literacy in education and sociocultural contexts. All three WBEGs appear to emphasize player agency and collaboration. *Waves* and *Light and Mirrors* encourage player strategy, while *Color Mixer* rewards speed and rote knowledge. These reinforced techniques perpetuate the underlying cultural values of accuracy, collaboration, problem-solving, autonomy, and scaffolding. This study discusses these values in the contexts of education and society.

This dissertation is dedicated to the memory of my grandparents, who continue to inspire me to do my best simply because they were so proud of who I am.

ACKNOWLEDGMENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

MMOGs: massive, multiplayer online games
ROE: rules of engagement
SRL: self-regulated learning
SRQ: self-regulation questionnaire (Brown, 1999)
WBEG: whole-body educational game
WBEGs: whole-body educational games

INTRODUCTION: FOUR INTERTWINING THEMES

The fast pace of the information age coupled with rapid advances in technology necessitates a population of lifelong learners. This velocity requires a level of efficiency in learning from citizens of the modern world not seen in past eras. Remarkably, the very technology and information that demand proficiency in complex knowledge acquisition can also facilitate the learning and improvement of these abilities. Video games of all sorts are ready platforms for practicing skills, and all video games teach something (Gee, 2003). Some simple games only teach the player the rules of that particular game, while others teach specific facts and still others teach sophisticated concepts like empathy: "At the heart of every computer game, there is a challenge that revolves around problem-solving of one form or another. …it is these problems that create the challenges that stimulate the desire in the player to play" (Whitton, 2014, p. 30). There is an entire genre of educational games intentionally designed to teach specific concepts. But how can scholars dissect and analyze these games in order to compare them or determine their efficacy? How can game designers utilize game scholarship to improve the development of future educational games? How can research enhance the design of future educational games? This dissertation addresses these questions by intertwining four main themes: whole-body educational games (WBEGs), digital literacy, self-regulated learning (SRL), and procedural rhetoric.

WBEGs are digitally-based learning games that have been designed to encourage more physical movement from players than traditional console or computer games. It is thought that by immersing players within the game (by, for example, having

players stand on a floor where the game is projected), they engage more with the game. Research on embodiment also suggests that asking players to perform specific actions during the game increases their learning. WBEGs require and also teach digital literacy skills in different ways than traditional video games.

Digital literacy encompasses the abilities and skills required to intelligently navigate the digital realm of the current information age, to leverage digital tools in meaningful and purposeful ways, and to understand the way digital tools themselves influence human activities. Lankshear and Knobel (2008) describe a variety of definitions of the concept of digital literacy, including understanding it "as a shorthand for the myriad social practices and conceptions of engaging in meaning making mediated by texts that are produced, received, distributed, exchanged, etc., via digital codification" (p. 5). This concise definition acknowledges the complexity of digitally mediated meaning making while also including the social component of digital literacy. An intriguing segment of game studies is player learning of digital literacy skills as well as science concepts. The study of various processes and strategies game players use to engage with the content presented in WBEGs holds great promise for improving the designs of future games (and even for improving educational activities in general).

Self-regulated learning (SRL) is one interesting vein of research in particular that seems to lend itself to the type of learning processes utilized by players of WBEGs. Scholars of SRL describe it as learners' processes of metacognitively monitoring and regulating their own motivation for their learning, their behavior, and their cognition; in doing so, these pupils are efficiently guiding themselves toward increased

2

understanding and knowledge (e.g., Zimmerman, 1990; Schunk, 1994; Pintrich, 1995; Winne & Hadwin, 1998). This dissertation delves into the internal or mental behavior that constitutes SRL, the external or observable behavior that is indicative of SRL, and the interpersonal or social aspects of SRL. Many educational activities and games, whether or not they were explicitly designed to support SRL, contain features that help players self-regulate their learning (feedback, for example, aids in the monitoring process, and this is a common phenomenon in both formal education and video games). SRL is an element worthy of study by the scholarly games community because it comprises an important set of skills valued by today's society that transfer with the learner from the game context to other areas of their lives. The habits of goal setting, monitoring progress, and reflecting on tasks once they are completed are valuable skills for learners of any information or trade, from the construction trade to academia and beyond. Nearly any challenge becomes more feasible when a person approaches it with a plan, monitors her progress toward the goal, alters her strategies based on self-assessments, and reflects on the completed task. Self-regulated behavior in game players also usually results in more successful game play, which is typically more enjoyable. Although he does not employ the term SRL, Gee (2003) discussed many of the behaviors indicative of SRL when explaining how most video games teach the skills players must possess in order to succeed within the game. Some of these SRL behaviors include responding to feedback, collaborating with others (virtually and non-virtually), and being motivated to continue to the next challenge.

Procedural rhetoric analysis is a way of "reading" games by doing a focused study on the underlying structure—the programming—of a game. Procedural rhetoric analysis is a method put forth by Ian Bogost (2007) where complex video games are broken down into discrete player actions. The game's programmed reactions are then inspected and interpreted to reveal the argument being made by the game. These reactions also illuminate ways that the game has been programmed to support SRL. Effective WBEGs, where players learn and retain content by playing the games, also contain features that reinforce SRL behaviors in players.

These methods have been used to inspect a small percentage of console and computer games, but very few of the games that have been analyzed by other scholars utilizing procedural rhetoric require players to use large body movements to any great extent. The detailed investigation of WBEGs in this study reveals the techniques rewarded and punished by the games' structure, an indication of the values and assumptions of WBEG creators. These values and assumptions are worth noting and evaluating by WBEG designers and scholars, who should in turn ask themselves if their games achieve the outcomes and goals they were intended to further.

Video games help teach various forms of digital literacy, calling on players to intelligently navigate their digital worlds by learning skills and using them to achieve a variety of goals. As players' digital literacy skills improve with practice, so do their abilities to learn from games and to leverage that knowledge. Additionally, video games, such as WBEGs, frequently provide support for players as they are gaining proficiency, scaffolding their digital literacy skills in many ways. Learning by practicing

4

with the help of scaffolds reinforces SRL skills. Self-regulated learners can more efficiently increase their digital literacy skills by employing a number of SRL strategies while also increasing their understanding of the concepts being taught by WBEGs. One way to break down these complex processes as they occur in WBEGs is to analyze a specific game based on its procedural rhetoric. A game's procedural rhetoric is its underlying rules structure: the programming that dictates what player actions are possible as well as the computer's reactions to player actions. Procedural rhetoric analysis derives from rhetorical analysis, and it provides a method for dissecting WBEGs based on individual actions by players, thus slowing the game down, in a sense, so that it can be "read" and better understood for the features it includes and the playing techniques it reinforces. This manner of reading a WBEG is in and of itself a dimension or genre of digital literacy. The features and techniques revealed by the game's procedural rhetoric inform the readers about the assumptions of the game designers themselves, whether conscious or unconscious, and can be used to improve future game design. These interrelationships are visualized in graphic (Figure 1) and chart form (Table 1) below.
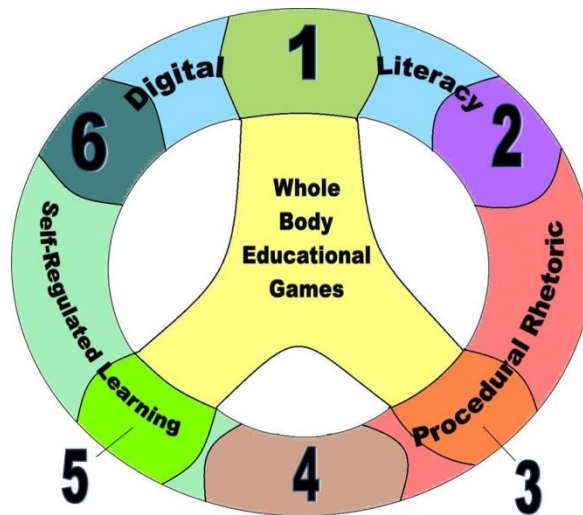
Figure 1: Relationships between the four themes

Table 1: Explanation of relationships displayed in Figure 1

Overlap #	Themes intersected	Description of intersection
1	WBEGs and Digital Literacy	Digital literacy is required to play games and learn from them WBEGs scaffold and provide practice platforms for increasing digital literacy skills Digital literacy is required to analyze the structure and techniques of WBEGs
2	Procedural Rhetoric and Digital Literacy	Digital literacy required to analyze procedural rhetoric Procedural rhetoric of games informs the field of digital literacy by providing a method of "reading" WBEGs
3	WBEGs and Procedural Rhetoric	Procedural rhetoric allows for analysis of WBEGs and the assumptions of their designers Procedural rhetoric is a way of "reading" WBEGs and understanding the techniques they reinforce
4	SRL and Procedural Rhetoric	Procedural rhetoric helps itemize game elements for analysis of SRL support features in WBEGs
5	WBEGs and SRL	SRL elements in games increase learning of game concepts WBEGs scaffold & provide practice platforms for increasing SRL skills
6	SRL and Digital Literacy	SRL can help increase digital literacy skills efficiently Some digital literacy skills and SRL skills are the same

Research Questions and Hypotheses

Studying SRL and its relationship with WBEGs using appropriate tools like the analysis of each game's procedural rhetoric furthers the understanding of digital literacy. A deeper knowledge of both digital literacy and the procedural rhetoric of games coupled with insight into their connection to SRL can help scholars and educators formulate plans for answering the demands for graduates with effective 21st century skills. This dissertation is driven by three hypotheses involving WBEGs and SRL. The primary research question grounding the three studies in this paper is:

> *How can the procedural rhetoric of three whole-body educational games improve the understanding of self-regulated learning with digital technology?*

To answer this question, three WBEGs are analyzed, with a focus on their procedural rhetoric and SRL-supporting features. Additionally, this paper focuses in more detail on one of those games and describes two studies analyzing the effectiveness of the SRL scaffolds embedded in it. The use of this three-pronged approach of a quantitative study, a case study, and an analysis of procedural rhetoric to investigate SRL within these WBEGs helps establish a deep understanding of SRL-supporting design elements that may have implications for future games and game studies. The sub-questions that lead this dissertation through each of the approaches are:

- How effective are elements designed to support self-regulated learning in a whole-body educational game?

- What does the procedural rhetoric of three whole-body educational games reveal about the underlying assumptions of the designers of these types of games?

These research questions correspond to three hypotheses driving the studies:

1) *The procedural rhetoric of three whole-body educational games can inform our understanding of self-regulated learning with digital technology by dissecting their design features and the elements that support self-regulated learning, enabling informed analysis and providing a rich description of the three games.*

2) *A whole-body educational game can effectively support self-regulated learning through design features that prompt players to plan; monitor their actions, cognition, and strategies within the game; and reflect on their performance at the end of each level.*

3) *The procedural rhetoric of three whole-body educational games tells us that these games value and rely on SRL-supporting elements to increase player familiarity with and understanding of science concepts.*

These hypotheses are tested by three different studies: a quantitative study investigating the SRL support features of a WBEG called *Waves*, a follow-up case study of *Waves* to provide further depth and understanding of the results from the quantitative study, and an analysis of the procedural rhetoric of three WBEGs: *Waves*, *Color Mixer*, and *Light and Mirrors*. These three studies in addition to the review of literature provide a detailed picture of the relevance of SRL to WBEG studies while also explicating a method that can be used in future studies of WBEGs.

Chapter One: Literature Review

Chapter One delves into the scholarship behind the paper's four central themes. Video games are discussed as well as the research behind the idea of embodiment, a key theory in the study of WBEGs, which rejects the once-common downplaying of a learner's body when designing and studying learning activities. Digital literacy is then defined and contextualized within the themes of this paper. Next, Chapter One provides

an overview of SRL scholarship. It begins with the researched connections between SRL and academic motivation and continues with the behaviors of SRL including use of learning strategies and feedback, then turns to the components of cognition, metacognition, and monitoring and explaining the roles they play in SRL. It also describes the social aspects of SRL and SRL's connection to WBEGs. The chapter closes by discussing procedural rhetoric, explaining its origins and how this method of analysis can be used to interpret the programming decisions made by the developers of the three WBEGs.

Chapter Two: Making Waves

This chapter describes a quantitative study on the WBEG *Waves*, detailing the procedures carried out in an effort to examine the efficacy of SRL scaffolding elements that are embedded within the game. Chapter Two also contains the account of a follow-up case study that investigated specific behaviors of two players collaboratively playing level two of *Waves*. This case study is included to augment the numerical data obtained from the quantitative study and to contextualize that data in such a way as to clarify its implications. The results of both studies are presented in Chapter Two but discussed in depth in Chapter Four.

Chapter Three: The Procedural Rhetoric of Three WBEGs

Chapter Three explains the procedure behind the analysis of the procedural rhetoric of all three WBEGs (*Waves*, *Color Mixer*, and *Light and Mirrors*). This procedure generates a chart for each game to shed light on the process and to allow

the reader to understand (and, if desired, to dispute) the analyses presented in this paper. The interpretation of each game's procedural rhetoric follows each chart, which includes analyses of the techniques reinforced by each game as well as the ways the games' procedural rhetoric supports SRL. These results are also discussed in greater detail in Chapter Four.

Chapter Four: Discussion

This chapter contemplates the collective results of all three studies, organizing them by the techniques that the WBEGs were found to reinforce. Chapter Four discusses the meaning behind these techniques through educational, sociocultural, and rhetorical contexts. Finally, the research questions and hypotheses are revisited.

Chapter Five: Conclusions and Future Research

Chapter Five brings the paper to a close by drawing final conclusions about WBEGs, digital literacy, SRL, and procedural rhetoric from the body of research investigated here. This chapter also describes potential areas for future research.

CHAPTER ONE: LITERATURE REVIEW

Digital humanities scholars take an interdisciplinary approach to their research, pulling perspectives, theories, and methods from a variety of fields to create new approaches uniquely situated to tackle many of the current and future challenges of our rapidly evolving world. As mentioned above, the need for citizens to possess the skills to leverage the information that is constantly being discovered and to adapt to technological changes will only increase with time. Technology makes many solutions accessible, but only to those who can utilize it well. Modern citizens need to be able to learn efficiently without relying on others to explain how to solve each new challenge that they face. This requires the self-monitoring of learning strategies, behaviors, and progress, which is known as self-regulated learning.

Self-regulated learning (SRL), the regulation of motivation, behavior, and cognition for efficient learning, can be supported by whole-body educational games (WBEGs); in fact, in many cases, WBEGs naturally include elements that scaffold SRL. This dissertation combines theories from digital literacy, game studies, psychology, and education in an effort to better understand the design features that can be embedded in WBEGs to support SRL. In doing so, this dissertation describes a method of "reading" WBEGs with a focus on game elements that support SRL. A main theorist in this endeavor is Ian Bogost (e.g., 2007); his methods of analyzing the procedural rhetoric of video games are particularly appropriate in the analysis of WBEGs and these SRL features, as it allows for quantification of abstract game elements. Procedural rhetoric is essentially the argument being made by a video game; by analyzing the structure of a

game's programming this argument can be exposed. The examination of the programmed game reactions to player actions exposes which player actions a game rewards and which the game penalizes. These rewards and punishments bring to light the techniques that a game reinforces. For example, Bogost (2007) analyzes the procedural rhetoric of a simple but powerful political video game called *Kabul Kaboom.* In this game, the player's character is an Afghani citizen after 9/11 who is trying to obtain air-dropped food while avoiding bombs. The game ends when the player is dismembered by a bomb. Bogost concludes that *Kabul Kaboom* "is a commentary on the post-9/11 U.S. attack on the Taliban in Afghanistan" and that it "highlights the simultaneity and inconsistency of aggression and relief" (p. 85). The game only lasts for a few seconds before a "barrage of bombs simply makes it impossible to collect the food" (p. 85) an intentional design feature with that message. This process of procedural rhetoric analysis permits a critical reading of games, viewing games as promoting an argument of some sort, representing something in the real world. The way the game is structured to do this often reveals biases and assumptions of the game's creators, facilitating a deeper level of understanding about game design and even society. Conducting analyses such as these is worthwhile because they afford future game design a unique opportunity to choose if WBEGs should continue to perpetuate these values or if different values should be reinforced. This choice cannot exist without first inspecting WBEGs to discover their implicit ideologies. Tools capable of making these assessments of WBEGs and their values exist in the field of literacy studies. The scholarship on digital literacy, more specifically, points to methods of

understanding society and culture through critical analysis of digital artifacts such as games.

Video Games

Games in general have been used throughout history as learning tools (e.g., Vankúš, 2005). They allow learners to experience novel situations in low-risk environments and to experiment with different strategies for handling the problems and situations these games present. This is referred to in psychology as a "psychosocial moratorium," where a learner is free to take risks with fewer consequences (Erikson, 1968, p. 156). This is similar to game scholar Huizinga's (1955) idea of a magic circle, an imaginary border around the players of a game within which specialized rules apply. For example, in the children's game of Freeze Tag, when the player who is "it" taps another player, that player must stop moving immediately. Outside of the game's magic circle, this behavior would be considered ridiculous, but within the boundaries of this game, it is normal and expected to follow this rule. The act of being caught—failing— within this magic circle has little negative consequence. Salen and Zimmerman (2004), after much deliberation, arrived at the definition of a game as "a system in which players engage in artificial conflict, defined by rules, that results in a quantifiable outcome" (p. 80). When participating in a game, players agree to enter an *artificial* realm that differs from the "real world"; players also consent to following specific sets of *rules* that structure gameplay and dictate permissible actions as well as rewards and consequences for those actions. *Conflict* is essentially what makes a game a game— some type of struggle for power—though games can include cooperation as well as

competition. A game's *quantifiable outcome* refers to the players achieving or not

achieving the game's goal: a player wins, loses, or earns a score of some kind (Salen &

Zimmerman, 2004, p. 80). The term "game" has been chosen over "simulation" as the

primary referent for the WBEGs studied in this paper because all three of these digital

environments possess the required conflict, rules, and quantifiable outcomes. Video

games are becoming more common vehicles for learning specific content such as

science (e.g., Muehrer, Jenson, Friedberg, & Husain, 2012) and history (e.g., Huizenga,

Admiraal, Akkerman, & ten Dam, 2009), as well as more abstract concepts like

reasoning skills (Bottino & Ott, 2006).

Video games are efficient teaching mechanisms, adjusting challenge levels to

keep gameplay at an optimal level for each player (Granic, Lobel, & Engels, 2014). This

optimal level, where the game is challenging but not too difficult and the player

possesses the prerequisite skills for accomplishing each new task when it is presented,

is termed the "zone of proximal development" and has been a much sought-after

property in all forms of learning since it was popularized by psychologist and learning

theorist Lev Vygotsky (1978). Vygotsky encouraged educators to design learning

activities at an appropriate level of difficulty for students, where activities were

achievable for students yet not so easy that they were boring; additionally, assignments,

he argued, should not be so challenging as to be (or to seem) unattainable to students.

The special affordance of video games in relation to this zone of proximal development

is their ability to regulate their obstacles in such a way as to keep players in that ideal

zone consistently (Granic et al., 2014). Video games do this by incorporating difficulty

14

settings that players can select, providing practice sessions where players can receive

training on skills required in the games, and by presenting different contexts where

players are required to utilize the same or similar skills, ensuring mastery (Eichenbaum,

Bavelier, & Green 2014). Salen (2014) proposes a framework of guiding design

principles for "game-like learning," arguing that those who design educational games as

well as other stakeholders in education need to shift their perspectives on games and

learning (p. 200). The interactive nature of video games requires players to actively

participate, while the dynamic nature keeps difficulty levels challenging but attainable.

These features, along with variably timed rewards, keep players engaged and motivated

to continue playing (Eichenbaum et al., 2014).

Video games also appear to have cognitive benefits for players. Przybylski,

Rigby, and Ryan (2010) suggest that video games can provide the psychological needs

of autonomy, competence, and relatedness that motivate players to spend time playing

them. Some studies have even found that while playing video games, players' brains

release reward chemicals that are "essential in permitting brain plasticity and thus

learning" (Eichenbaum et al., 2014, p. 52; Koepp et al., 1998). Studies have attributed

improvement in cognitive flexibility skills such as multitasking, task switching, and

working memory to video games (e.g., Strobach, Frensch, & Schubert, 2012; Chiappe,

Conger, Liao, Caldwell, & Vu, 2013). According to a review of recent scholarship

conducted by Eichenbaum et al. (2014), video games even appear to enable players to

transfer skills between contexts, a phenomenon that does not typically occur with

traditional learning methods, though the specific skills they cite to support this claim are

general perception and cognition abilities (Eichenbaum et al., 2014; Chiappe, Conger, Liao, Caldwell, & Vu, 2013). Fullerton (2014) also discusses the benefits of games, though she cautions us against overly utopian expectations for games to revolutionize traditional education. She explains that when designers or educators simply use a game format to reproduce ineffective classroom activities, such as memorizing abstract facts without connecting or applying them, they forfeit many of the aspects of games upon which they are trying to capitalize. Games encourage critical thinking, Fullerton argues, because of the lack of direct instruction they give to players. Players acquire and improve critical thinking skills by interpreting the game for themselves and deciding for themselves what courses of action and strategies they will utilize to overcome game challenges. There are several promising features of games that have captured the imagination of scholars and educators alike, for example, the seven listed below by Fullerton (2014):

1) "lure," something that entices the player to play the game

2) a promise of an engaging experience

3) a "feel of fun"

4) a feeling of understanding the game's patterns—this is also where she believes games can be aligned with learning concepts

5) manageable challenges, exposed in increments

6) assessment and feedback

7) providing players "the need and the opportunity to share such knowledge" in a place where that knowledge is valued, often reigniting the initial lure of the

16

game for players and allows the opportunity for deeper learning; Fullerton

cites Gee's (2003) discussion of affinity groups that provide players these

opportunities.

WBEGs

The term WBEGs as it is employed in this paper refers to digitally programmed

games that require substantial physical movement from the games' players beyond

pressing keys or using a joystick. Many WBEGs seek to involve the entire body by

requiring players to move their arms and legs in various motions. In fact, numerous

games have been created as part of rehabilitation programs for neurodevelopmental

disorders such as cerebral palsy (e.g., Sandlund, Dock, Häger, & Waterworth, 2013).

While all three WBEGs cited here involve player motions of standing, walking, and

making various motions with their arms, it is assumed that these games could also be

played from a sitting position if a player required this accommodation (perhaps with

some adjustment of the motion-capture equipment), though the arm movements would

prove more difficult to substitute or modify. Accommodating players with disabilities is

another vital aspect of WBEG study that deserves further study beyond the scope of

this paper (see, for example, Torrente, Serrano-Laguna, Vallejo-Pinto, Moreno-Ger, &

Fernández-Manjón, 2014). By providing players with the affordances of video games as

well as embodied learning, mixed reality simulations and games such as the three

WBEGs discussed here hold immense educational promise for learners of all types.

They facilitate embodied learning in non-traditional environments while sharing many of

17

the affordances of console video games that have already been recognized by game scholars.

WBEGs possess many of the advantages of traditional video games. Research suggests that video games are interactive, dynamic, engaging, motivating, and can have cognitive benefits for the players (e.g., Eichenbaum, Bavelier, & Green, 2014; Granic, Lobel, & Engels, 2014). Video games offer the unique advantage of being "*interactive* in the sense that when we act, the simulation reacts, and then we react to the reaction, and then it reacts again, and so on" (Shaffer, 2006, p. 67, emphasis in original). WBEGs, too, are interactive in this sense. The physical position of the player in the game, standing on a dynamic game floor and using bodily motions to effect change within the game, augments the player's motivation, as the player seems surrounded by the game and therefore feels like a part of the game. Colella (2000) describes these phenomena seen in digital games that are not limited to a computer screen as "participatory simulations" (472). These attributes make the player less likely to give up on a challenge or walk away from the game without completing it. Player action within WBEGs also usually require a more deliberate physical action of the player in order to initiate the game's reaction. This heightened sense of effort and therefore purpose in player action can make each action seem more important to the player. For example, it requires more effort to walk on the game board of a WBEG than it does to push an arrow on a handheld controller, so the player is likely to put more thought into the direction and speed of her walk in a WBEG than in a console game where she can quickly and easily push buttons that execute a number of different player actions.

18

WBEGs, too, can have positive cognitive effects. The embodied nature of these games has an additional impact on cognition that is discussed below. Scholars have noted enhanced recall in learners who used an embodied motion-sensing learning system to memorize a list of action phrases (Chao, Huang, Fang, & Chen, 2013); the combination of affordances from embodied experiences and video games present in WBEGs position them to become effective educational platforms.

Embodiment

Learning games that incorporate multiple senses and/or involve the whole body in the learning environment (such as WBEGs) are poised to capitalize on the science of embodied cognition (e.g., Lindgren & Johnson-Glenberg, 2013). In the past, traditional education has commonly focused on the mind and its inner workings without much pedagogical emphasis on the rest of the learner's body. Students are commonly expected to use their bodies in minimal ways while at school, sitting still, utilizing their eyes and ears only as portals for information absorption. Embodied cognition is a perspective on learning that breaks from this tradition and does not de-emphasize the physical body. Theorists in this field recognize the fact that the brain must receive all of its information through the body in some way—it is mediated, however unnoticeably, through one's physical form. Scholarly work focusing on the mind-body relationship is not limited to psychological or educational fields, however. Linguist and games scholar James Paul Gee (2003) argues that we make meaning from the world via embodied experience, emphasizing context. He explains that the most effective way to learn is

through embodied experiences and by making connections between new concepts and past experiences.

Theorists working in the humanities also ponder what it means to negotiate physical and mental worlds. Donna Haraway (2006) defines the cyborg as a "cybernetic organism, a hybrid of machine and organism, a creature of social reality as well as a creature of fiction" (p. 117). Haraway uses the metaphor of the cyborg to question the concepts of identity and boundary, especially in politics. Binary pairs used to describe large groups of people, such as black/white, she asserts, excludes a myriad of people who are neither—or both. She asserts that we are all cyborgs of some sort, blurring the strict boundaries of these labels and examines the implications that this loss of distinction has for humanity. The ubiquity of technology really has made most people into human-machine cyborgs; glasses and hearing aids are technological advances that enhance our abilities to see and hear. Print and digital writing, too, are extensions of our minds, augmenting our capacities of memory, logic, and analysis.

N. Katherine Hayles (1999) also investigates the impact that digital technology has on our understanding of our physical states. She grapples with the idea of "uploading" human consciousness into some kind of virtual space that could create "disembodied immortality" (p. 5) and looks at embodiment in the contexts of culture, place, and time. She asserts that even our abstract consciousness is firmly connected to our physical bodies. In other work (2012), Hayles extends this thought to argue that it is also impossible to separate our consciousness from the world in which we live. She explains, "all cognition is embodied, which is to say that for humans, it exists throughout

20

the body, not only in the neocortex. Moreover, it extends beyond the body's boundaries in ways that challenge our ability to say where or even if cognitive networks end" (p. 17). The extension of our physical boundaries and cognitive networks is especially apparent in the environment of a WBEG, where players' physical bodies are extended, cyborg-like, onto the projections of the various game elements over which they exert control. Players need to be active agents within the WBEG environment and to utilize the cues within the game to identify their level of success or failure and adjust their actions accordingly, just as the self-regulated learner must be sensitive to the feedback given during an instructional task in order to monitor her progress and adjust learning strategies accordingly. Active learning incorporating body movement has been attempted in traditional education under the term of kinesthetic learning, and an entire psychological field of embodiment and embodied learning exists to study the ways the body mediates information as people learn.

Embodied learning differs slightly from kinesthetic learning. Kinesthetic learning approaches derive from Gardner's (1983) theory of multiple intelligences, where bodily-kinesthetic intelligence is one of seven (later expanded to eight or nine) possible intelligences that a student may favor (Gardner, 2003). This theory of intelligence evolved into a series of pedagogical practices favoring the tailoring of teaching and classroom activities to students' individual learning styles; thus, a pupil with high bodily-kinesthetic intelligence was thought to learn more efficiently if the lesson involved body movement such as building or role playing (e.g., Shirley, 1996). Gardner (1995) himself did not entirely agree with many of the ways his work was interpreted in the classroom,

21

writing, "I have seen classes in which children are encouraged simply to move their arms or to run around, on the assumption that exercising one's body represents in itself some kind of MI [multiple intelligences] statement. …random muscular movements have nothing, to do with the cultivation of the mind" (p. 7). Embodiment as it exists today refers to all learners, not just those who are more coordinated or prone to fidgeting, and is supported by quantitative studies utilizing brain imaging technologies as well as other methods from the fields of cognitive science and psychology; embodied cognition is the study of thinking with a focus on the body's role as mediator between the learner's physical and mental worlds (e.g., Abrahamson & Lindgren, in press; Lindgren & Johnson-Glenberg, 2013; Alibali & Nathan, 2012; Hauk, Johnsrude, & Pulvermüller, 2004). Gestures themselves are thought to stimulate certain areas of the brain; therefore, as Lindgren and Johnson-Glenberg (2013) explain, "if physical movement *primes* mental constructs, such as language, then it may be that increasing an individual's repertoire of conceptually grounded physical movement will provide fertile areas from which new knowledge structures can be developed (p. 446, emphasis in original). Asking students to make specific gestures while learning appears to improve their learning (Goldin-Meadow, Cook, & Mitchell, 2009; Plummer, 2009, Shoval, 2011; Richards, 2012). The ability of WBEGs to include gestures and therefore activate linguistic and other areas of the brain differently than traditional education makes these games especially capable of teaching concepts and scaffolding self-regulated learning.

22

Multiplayer Games

Multiplayer games requiring two or more players are also thought to enhance player learning (Steinkuehler, 2005). Collaborative learning is thought to increase critical thinking skills (e.g., Vygotsky, 1978; Gokhale, 1995; Johnson & Johnson, 1999) and it continues to be championed among teaching's "best practices" (e. g. National Education Association, 2015). Multiplayer video games encouraging players to collaborate in order to solve problems and achieve goals are thought to enhance player learning (Steinkuehler, 2005). In line with this research, many mixed-reality and augmented reality games are designed to be played collaboratively (Rosenbaum, Klopfer, & Perry, 2007; Squire & Klopfer, 2007). Birchfield and Megowan-Romanowicz (2009) assert that mixed reality games can enhance collaborative learning opportunities, finding significant achievement increases in students participating in a collaborative, embodied learning scenario. Dalgarno and Lee (2010) likewise report results indicating that 3-D virtual environments improve collaborative learning because they "require that each group member's efforts be indispensable for the success of the group in achieving its goals and that each member make a unique and valued contribution" (p. 22). This idea of positive interdependence within an educational group activity has been studied extensively as an aspect of formal education (e.g., Johnson & Johnson, 1994; 1999; Jacobs, Power, & Inn, 2002) and can certainly be applied to learning games of all types.

All games, according to Salen and Zimmerman (2004) are "systems of conflict" (p. 250). Staged conflict within games, they argue, is what makes gameplay

meaningful. They identify two types of conflict in a game, competitive and cooperative,

ultimately declaring that all games are both. They are able to make this claim by

defining "competitive" as a descriptor for player struggle against losing, be it against

another player or against activities within the game, and "cooperative" as the players'

collective submission on the rules and meanings of the game—termed "systemic

cooperation" (Salen & Zimmerman, 2004, p. 256). It is noted in an aside that they are

not attempting to conflate this specific type of cooperation with the more commonly held

notion of cooperation as that of working together. Salen and Zimmerman label this

specific idea of players working together to achieve a joint win or loss "player

cooperation" (p. 256). Zagal, Rick, and Hsi (2006) take a different perspective on these

terms and differentiate between competitive, collaborative, and cooperative games.

Competitive and collaborative games, they argue, are opposites, while cooperative

games belong somewhere in the middle. Competitive games identify a sole winner,

pitting players against one another. Collaborative games reward the effectiveness of a

team and result in a group that wins or loses. Cooperative games also result in a sole

winner but require players to work together to complete various tasks. Thus, players do

collaborate but also compete in these cooperative games where practices of free riding

and backstabbing are considered viable strategies, unlike in collaborative games. The

WBEGs analyzed in this dissertation are defined as collaborative—players work

together to seek a common goal in all three. Research suggests that the collaborative

nature of multiplayer games, including massive multi-player online games (MMOGs)

designed purely for entertainment, results in efficient learning (e. g., Steinkuehler,

24

2004). Collaborative efforts, Steinkuehler (2004) argues, focus players' attention on the

task and encourage utilization of other resources such as manuals as secondary;

participating in these activities with other players is the only way to achieve expertise.

Johnson-Glenberg, Birchfield, Tolentino, and Koziupa (2014) speculate that player

collaboration was a primary reason for significant learning achieved by players of two of

their "embodied mixed reality learning environments," (p. 87) which could also be

described as WBEGs.

Collaborative, social learning is also an aspect of SRL. Gaming environments

naturally provide opportunities for players to self-regulate their learning, embedding

practice exercises within the game to teach players the skills they need to move from

level to level. Video games such as WBEGs require and therefore teach a level of

digital literacy to enable players to be successful in the games. This makes games an

enticing vehicle for the acquisition and strengthening of digital literacy skills—skills that

exist under the umbrella term for a variety of digital abilities and can include the ability to

conduct an Internet search, the skills required to successfully complete a game, and

everything between and beyond. This can make for a less effective and even unwieldy

definition of digital literacy. The intertwining of WBEGs and digital literacy goes further

than this, as noted in the Introduction chapter. Digital literacy is also required to

understand the structure of a WBEG and to unpack the sociocultural values embedded

within the games.

Digital Literacy

Roland Barthes (1977) opened the door for scholars to read non-textual genres such as images and music. His extension of critical methods of analysis encouraged further scholarship in reading other multimedia genres as texts. This dissertation builds on the foundation Barthes laid, extending his ideas of reading non-alphabetic texts to WBEGs. His three meanings of a text, for example, can be applied to games. Barthes's first meaning, denotation or semiotics, is the act of gaining literal meaning from an image. A player of a WBEG engages in this type of reading when discerning what the various images are within the game environment. For example, *Waves,* one of the three WBEGs discussed in this paper, is intended to teach players about wave interactions by having them each create their own wave, represented by a blue or green line projected on the floor. As players step side-to-side, their waves reflect the speed and size of their motions. Players need to coordinate their wave speeds and sizes in order to achieve success in the game. The denotative understanding of *Waves* would be the player's knowledge that the game includes three differently colored lines that move. The second layer of meaning that Barthes defines is that of connotation or symbolism. The significations of these colored lines in *Waves* are the non-virtual entities they are meant to represent, generic waves (sound, light, etc.). Finally, the third meaning, an obtuse and difficult one to describe, is that of significance. These wave icons may relay some type of message, conscious or unconscious, to the player. The player may be able to articulate this message or it may just be a "vibe" or feeling he gets while playing the game. Ideally, a player of *Waves* will experience a third meaning that

imparts content knowledge, an understanding of how waves move and interact in the real world.

Walter Ong (2002) traces the evolution of communication technologies beginning with purely oral cultures that relied on memorized narrative accounts to preserve their cultural history and to pass it down by generations. He studies orality (the spoken word) as it has been influenced by centuries of technologies advancing the written word. The invention of alphabetic writing, Ong argues, was a pivotal moment in human history; the technology of writing, be it on stone, bark, parchment, or paper, forever changed the thinking patterns of those who became literate. These ways of thinking were again altered, he explains, with advances in writing technologies such as the printing press, the typewriter, the word processor, and the computer (Ong, 2002). Ong championed the idea of writing as technology in an era where the term technology had begun to have negative connotations for many mainstream scholars who feared the worst from electronic media such as television and computers. Ong's work can be extended to better contextualize electronic technology in the larger history of the progression of communication to position new media as simply the next step in this evolutionary process. This line of thought is extended by Gregory Ulmer (2003) to *electracy*, his term for digital literacy. He examines the changes in thought that have taken place under the influence of the computer's abilities to change the way media—not just text— is written and read. Ulmer calls for non-traditional methods of scholarly analysis to match these new, non-linear ways of communicating and thinking.

The position of this study, that digital literacy skills can be learned by working directly with technology itself, can be linked to N. Katherine Hayles's (2012) conceptualization of technogenesis, the idea that humans and technology continually influence one another. She discusses changes taking place in the field of literacy studies as a result of digital technologies, asking scholars to "rethink what reading is" in the context of 21st century literacy—today's visual and auditory media (p. 79). She points out that digital literacy borrows techniques from traditional literacy studies, forever intertwining the two fields. Hayles envisions this as a productive feedback loop between the traditional and digital humanities, explaining that, "digital networks influence print books, and print traditions inform the ways in which the materiality of digital objects is understood and theorized" (p. 32). It is because of this that she advocates for the very definition of literacy studies to be expanded to include literacy of a variety of genres and formats (e.g., traditional print and digital). It must also encompass, she argues, a broader repertoire of reading practices such as close reading, hyper-reading, and machine reading to enable scholars to examine the patterns, meanings, and contexts of these genres.

Close reading, also termed New Criticism, is the type of reading traditionally practiced and taught by humanities scholars. It places a given text within a rich context, connecting it to things like other texts, historical events, and even the author's personal beliefs or supposed intentions when creating the work. Another traditional form of reading not explicitly mentioned by Hayles is reader-response. This manner of reading came in vogue as New Criticism's popularity waned. Reader-response theory

views the reader not as a "passive recipient" (Rosenblatt, 1994, p. 4) of the author's completed work but an active participant in a transaction with the author and text. The reader brings her own background and opinions to the text and together with the author, has a conversation with the text to discover a richer meaning within it. The newest form of reading, hyper-reading, requires access to a vast amount of related texts. Hayles (2012) explains that hyper-reading involves reading a given text in the context of many other texts. An example of this would be the way one reads the results page of a search engine: numerous different texts are connected simply by being listed together, and there is very little context for each of them. This type of reading "enables a reader quickly to construct landscapes of associated research fields and subfields; it shows ranges of possibilities; it identifies texts and passages most relevant to a given query; and it easily juxtaposes many different texts and passages" (Hayles, 2012, p. 62). Finally, machine reading utilizes technology to seek patterns in one text or many texts, such as how frequently a certain word or phrase appears.

The digitally literate scholar, according to Hayles, must be able to perform *all* of these types of reading, as each informs the other to create deeper and richer understandings of texts. The reading of technology such as WBEGs involves the more traditional close reading of a very nontraditional text; the research surrounding this dissertation required hyper reading of a variety of scholarship and database searches; and the database searches themselves could not have been done nearly as efficiently if it were not for the machine reading that produced lists of texts based on the input of keywords. When playing a WBEG, a player also reads the text of the game closely,

29

being aware of the context in which the game exists as well as reflecting on the game to more deeply understand what is happening in the game itself. The WBEG player also engages in hyper reading, quickly skimming the game environment to discern what actions will result in successful gameplay. It could also be argued that the game mechanics of the WBEG engage in machine reading of the player's actions, reacting to those actions as dictated by the rules and structure within its programming. A deep understanding of this machine reading requires the scholar to perform close reading of the game's structure, its procedural rhetoric, which is yet another thread in the rich tapestry of what we term digital literacy.

Digital literacy itself is difficult to define. Many scholars have attempted to pin down a definition of digital literacy or at least sketch out a list of skills that a digitally literate person possesses. For example, Meyers, Erickson, and Small (2013) delineate three perspectives of digital literacy by different disciplines: "1) Digital literacy as the acquisition of 'information age' skills. 2) Digital literacy as the cultivation of 'habits of mind.' 3) Digital literacy as engagement in digital cultures and practices" (pp. 358-360). Meyers et al. assert that they believe a complete definition of digital literacy would include all three of the listed elements, "technology skills, critical thinking capabilities and contextually situated practices" (p. 361). They argue for a definition of digital literacy that combines these three perspectives and creates a "holistic perspective" (p. 361). Lankshear and Knobel (2008) also describe multiple definitions of digital literacy, resorting to pluralizing the term itself and distinguishing conceptual definitions from standard operational definitions of digital litera*cies*. Chase and Laufenberg (2011)

humorously discuss the "squishiness" of digital literacy definitions, deciding to characterize digital literacy as simply one genre of literacy, like poetry or the short story, although they admit that this does not make it any easier to define using concrete terms (p. 535). Thus, many definitions of digital literacy can be boiled down to a contrast between technical abilities, like operating the technology itself, and mental processes, such as the "cognitive and socio-emotional aspects of working in a digital environment" (Lankshear & Knobel, 2008, p. 2). Selber (2004) distinguishes three separate categories of digital literacy: functional, critical, and rhetorical literacy. Functional literacy, he explains, is the more process-oriented literacy comprised of technical skills. Critical literacy is a humanistic, critical approach to technology that inspects computers and digital tools for sociocultural gains and losses, among other things. Rhetorical literacy is defined by Selber as the ability to reflect on the design of digital environments, evaluate it, and ultimately effect change in the technology itself. Full digital literacy, according to Selber, is a combination of functional, critical, and rhetorical literacies. The digitally literate student is one who can competently use the technology, intelligently question and critique it, and use these two skills to become "reflective producers of technology" and to improve it (Selber, 2004, p. 182).

The scholarship delves deeper into this idea of digital literacy as a set of mental processes to investigate its relationship with 21st century learning as well as sociocultural values. Critical digital literacy is required to analyze embedded values in digital media. Scholars such as David Berry (2011), for example, highlight the implicit biases underlying every single digital object. The code that underlies these digital

technologies, he explains, carries the sociocultural biases of its programmers. Selfe

and Selfe (1994) make similar arguments decades earlier in their analysis of the politics

of the computer interface. They examine the ways that technological systems

propagate negative as well as positive ideologies, citing research that shows the stark

differences in the ways computers are utilized in schools with students of differing

socioeconomic statuses. American schools where the student population is primarily

minorities are found to utilize computers for lower-level cognitive activities where

students practice basic skills; schools with students who are primarily of the ethnic

majority, on the other hand, tend to use computers for higher-order thinking exercises.

Selfe and Selfe (1994) notice the personal computer's bias toward the more privileged

socioeconomic citizens. The business-oriented organization of computer functions and

programs, including the use of icons such as a file folder, briefcase, and even the very

metaphor of the desktop interface all privilege white-collar culture. The desktop's

omission of organizational systems more familiar to those of lower socioeconomic

status such as a workbench, a kitchen counter, etc. devalues the knowledge and

cultural experiences of large groups of people. Just as traditional critical literacy is

required to analyze the perspectives and biases of authors, critical digital literacy is

necessary to study this commonly-ignored aspect of digital media. It is especially vital

that light is shed upon these hidden values within digital media as the media itself is

becoming more ubiquitous and more often utilized as tools for learning. Thinking

patterns and ways of learning changed when humans began to write alphabetically

(Ong, 2002), and they are evolving again with digital technology and electracy (Ulmer,

2003). The filing cabinet of papers is being replaced by the file folder icon of digital

documents; the authority of print publication by the digital publication of the masses.

Digital literacy is a foundation for 21st century learning. Digital literacy skills are

often acquired using non-traditional avenues; frequently, learners gain digital literacy

skills through experience, that is, they discern on their own which actions they need to

take in order to accomplish their goals. These learners seek help as needed, and that

assistance is commonly found using the very digital technology they endeavor to

master. For example, a student may acquire digital literacy skills while using the

Internet to research a topic. If her goal is to locate information about a certain period in

history, she will likely type that time period into a search engine and read through the list

of pages that the search returns. If the student is unsure as to the accuracy of a given

website, she likely believes (as many people do) that one can find information about

almost anything on the Internet and may perform another Internet search for resources

about how to distinguish reliable websites from non-credible sources. In this instance,

the Internet itself teaches the student (at least partially) the digital literacy skill of

critically reading websites for credibility. Interestingly, this student, who knows when

she needs to seek additional resources, shows traits of a self-regulated learner who

self-monitors her understanding and progress. To relate this example to those

elements of a more complete digital literacy as championed by Selber (2004), this self-

regulating student is functionally literate, using the technology of the Internet and a

search engine to achieve her learning goals. She is also using the Internet to acquire

and then leverage new skills in critical literacy as she works to discern the credibility of a

website. Perhaps she will at some point fully develop more rhetorical literacy skills and work to make it easier for others to discern the validity of the information on websites. This hypothetical example of a motivated learner also demonstrates Selber's (2004) conceptualization of digital literacy as functional, critical, and rhetorical, and we can view her level of literacy through his social lens. As discussed previously, SRL strategies and digital literacy are becoming more necessary in our current world. Technology has the potential to help learners improve their SRL skills in addition to their digital literacy skills, as evidenced in this example. Technology like games can also scaffold learning, requiring and teaching skills in a similar manner.

Games are another digital platform that simultaneously require and teach digital literacy skills. Gee (2003) discusses this at length, explaining that video games effectively support players' acquisition of skills required to play the games. Video games, he points out, present various challenges to the player that generally match the player's abilities. Thus, the first level of a game is much less difficult than subsequent levels and provides players with ample opportunity to improve the skills that will be required later in the game. The final level of the game, then, will require the player to utilize all of the specialized techniques honed over many hours of practice when completing the prior levels. As discussed above, this scaffolding keeps the player in Vygotsky's (1978) zone of proximal development, the coveted position of traditional learning activities. Maintaining game difficulty in this zone provides players with challenges achievable enough to keep the game interesting—not too easy or boring and not too difficult and frustrating—retaining players' attention.

Digital literacy skills, because they are often acquired by learners through non-traditional avenues and informal learning settings, place increased responsibility on people to educate themselves. Learners who can self-regulate are more efficient self-educators. SRL describes a series of processes that efficient learners undertake when acquiring new knowledge. Self-regulating learners utilize specific cognitive and metacognitive strategies such as goal setting and progress monitoring to identify when they need additional resources and to locate those resources most suitable for their needs. Thus, the ability to self-regulate one's learning is a distinct advantage for learners in contemporary society. Digital tools themselves possess great potential for improving SRL skills in a large number of learners; some of this potential is explored in this dissertation as it focuses on the SRL-supporting capabilities of three WBEGs. Some research has been done on the teaching of SRL skills using technology (e.g., Azevedo, 2005; McLoughlin & Lee, 2010; Dabbagh & Kitsantas, 2012) and to teach media literacy (e.g., Willem, Aiello, & Bartolome, 2006), but the similarities between SRL and digital literacy skills have yet to be highlighted by scholars of either field. Digital literacy is embedded in social, economic, and political contexts and has different definitions in each context. Digital literacy reflects cultural values and norms. Digital literacy enables learners to utilize digital tools (including WBEGs) to gain knowledge, and when learners are able to self-regulate their own learning, they become much more digitally adept while also improving their learning efficiency. In essence, digital literacy skills and SRL skills are similar—a learner who is digitally literate and a learner who has SRL skills will both be described as knowing "how to learn;" they are both knowledge

35

seekers who know when they need assistance and how to obtain it. By teaching and

scaffolding SRL skills, learners can become habitually reflective and in turn can become

fully digitally literate, "reflective producers of technology" (Selber, 2004, p. 182).

Self-Regulated Learning

Studies of self-regulated learning (SRL) historically focus on the ways it

influences academic achievement (e.g., Zimmerman, 1990; Mega, Ronconi, & De Beni,

2013). In fact, SRL has been defined as "the self-directive process through which

learners transform their mental abilities into academic skills" (Zimmerman, 1998, p. 2).

It is the ability of learners to mindfully proceed through learning tasks, continually

checking their understanding as they advance. Self-regulated learners are active

learners, seeking out additional learning opportunities and additional resources when

they encounter difficulty (Zimmerman, 1990). Digital literacy and SRL have much in

common, and the intertwining of these subjects can have great benefits for education.

As technology, science, and knowledge of our world continue to evolve, so must the

expertise required of today's citizens and tomorrow's graduates. Digitally literate, self-

regulating learners, as opposed to individuals who merely memorize information, are

required in today's world. These skills are needed to sift through the immense amount

of information constantly bombarding us today. One skill it is certain we need now and

in the future is the ability to learn efficiently, especially in digital environments. The

nonlinear nature of the online environment, advanced by capabilities such as hyperlinks

and search functions, necessitates that learners monitor and regulate their

understanding of the information, the relevance of the information, and the progress

they are making toward their learning goal as they seek information via digital media (Moos, 2011, p. 267). Hayles (2005) calls this combination of skills hyper reading. No longer are the standard research methods dictated by reference books or other printed sources. Nor is information bound to the linear structure of the printed page or essay or refereed by traditional gatekeepers such as publishers or trusted scholars. The digital age allows nearly anyone to publish nearly anything without having to first convince a publisher that an opinion is valid and worth sharing with the public. Editing and fact-checking, if they occur before digital publication at all, are not done as thoroughly as in the past; even print publications do not seem to be policing their works as strictly anymore (e.g., Fyfe, 2012). Therefore, knowledge seekers, who must click from page to page "surfing" the vast ocean of material, need to have the digital literacy skills to discern between credible and non-credible sources and also to synthesize bits and pieces of information together into a coherent understanding. It is worthwhile for scholars of all fields to consider ways that these skills can be improved; the dissemination of research can only occur through the existence of an audience capable of finding and understanding it. Another set of skills the present information age emphasizes are those of analysis and synthesis. The plethora of information readily available to the average learner is overwhelming. The digital learner needs to be able to quickly sort through vast amounts of information, analyze the arguments being made, and synthesize them into an understandable body of knowledge. Fortunately, SRL skills can be taught, scaffolded, practiced, and improved (e.g., Zimmerman, 1990). SRL

is comprised of a complex combination of internal processes, external behaviors, and interpersonal interactions.

Internal Behavior

There is no absolute certainty about what takes place in a person's mind during learning (or at any time, for that matter), but scholars continue to attempt to explore and understand the cognitive processes of self-regulated learners. The self-regulation of cognition is one of the defining features of a self-regulated learner, according to Pintrich (1995), who describes this mental activity as involving the "*control of various cognitive strategies for learning*" (p, 7, emphasis in original). Garcia and Pintrich (1994) dissect components of SRL into many categories including two areas of cognition: conceptual knowledge (content and disciplinary knowledge) and cognitive learning strategies (rehearsal, elaboration, and organization) (p. 129). It is of course important that students not only know about the existence of these cognitive strategies but also how to apply the strategies to the learning task they wish to accomplish (Hofer, Yu, & Pintrich, 1998). Boekaerts (1996) suggests a model of self-regulation that includes components of both cognition and motivation. The cognitive components in her model include *content domain*, which involves conceptual and procedural knowledge as well as misconceptions and "inert" knowledge, which she describes as knowledge obtained in traditional school settings that does not extend a student's "conceptual knowledge base" (p. 105). Boekaerts's model also contains *cognitive strategies* and *cognitive self-regulatory strategies*, which are discussed below (p. 106).

38

Cognitive Strategies

Cognitive strategies utilized by self-regulated learners are understood by SRL researchers as falling into three categories: rehearsal, elaboration, and organization (Weinstein & Mayer, 1986). Many of these strategies are specified above in greater detail; this section describes cognitive strategies to highlight how they differ from metacognitive strategies. Karabenick and Collins-Eaglin define cognitive strategies of SRL as the methods learners use to "attend to, encode, store, and recall" new information (p. 74). The cognitive strategies listed in Boekaerts's (1996) model of self-regulation comprise selective attention, decoding, rehearsal, elaboration, structuring, generating questions, activation of rules and their application, repair of a rule (re-applying, applying a new one, or deciding no rule exists), and creating a procedure for a skill (p. 103). Cognitive strategies appear to be conceptualized by most scholars as the more overt, conscious activities that learners undertake in an effort to understand a new concept or complete an academic assignment. Not all cognitive strategies, however, are appropriate for every learning task. Self-regulating learners are able to select from a range of strategies that they have acquired over time (Vassallo, 2013). They are able to take into account the strengths and limitations of their own abilities, evaluate the task at hand, and leverage this knowledge to choose the best strategy to complete the assignment (Vassallo, 2013). As learners become more familiar with a specific subject area, they grow increasingly versed in the strategies best suited for acquiring knowledge in that domain, improving their learning efficiency (Boekaerts, 1996). Their prior knowledge of the concept and general familiarity with the field itself spurs their use

of appropriate cognitive strategies (Boekaerts, 1996). Once again, the use of a variety of cognitive strategies can be seen in the digitally literate. The student performing the Internet search described above realized she lacked the knowledge to be able to tell if a website was credible, so she performed another Internet search to acquire the additional resources she needed to make that judgment. As is seen in learners excelling more rapidly in subject areas that are more familiar, video game players, too, become more familiar with a game genre and are therefore able to employ more operative strategies to overcome challenges and to play more efficiently from the start of the game. Players familiar with a racing game such as *Need for Speed* will be at an advantage when playing a different racing game, such as *Gran Turismo,* for the first time. The use of appropriate cognitive strategies requires a level of cognitive self-awareness, or metacognition. Metacognitive knowledge and strategies, then, drive the selection of cognitive learning strategies and are discussed below.

Metacognition

Like cognitive strategies, metacognitive strategies are difficult to articulate and study because they deal with internal thought processes. As mentioned above, not every cognitive learning strategy is suitable for every learning task. Metacognitive strategies, especially planning and monitoring, are used by self-regulating learners to select the most apt methods for each learning situation (Karabenick & Collins-Eaglin, 1995). Students gain metacognitive understanding over time as they increase their abilities to more appropriately match cognitive strategies to assignments. This increases their efficiency for completing learning tasks as they vary by subject and

classrooms, as each is accompanied by unique procedures, requirements, goals, tasks, and contexts (Garcia & Pintrich, 1994). As new learning strategies become more familiar with repeated use, students are more likely to call upon these strategies in the future and apply them to new learning assignments and settings. Garcia and Pintrich (1994) discuss metacognitive knowledge in terms of the way students perceive tasks and strategies, respectively, as well as the way metacognition allows for regulatory learning strategies such as goal-setting, planning, monitoring, and self-testing. They dissect metacognition into two parts, knowledge about cognition and self-regulation of cognition (p.142). Metacognitive knowledge about cognition is viewed by Garcia and Pintrich (1994) to be a collection of static conceptions of the features of tasks and strategies, influencing the learner's level of involvement in a task or the extent of her use of a strategy. Self-regulation of cognition, however, deals with more dynamic elements of learning such as self-efficacy. This in turn influences motivation and therefore the amount of effort learners are willing to invest in the task and just how determined they are to see it to completion (Garcia & Pintrich, 1994). Self-regulation of cognition is also investigated by Boekaerts (1996), who considers it to be "goal-directed behavior" (p. 107). She considers cognitive self-regulation to be goal-focused, whether the goals are set by the learner or the instructor (Boekaerts, 1996). Boekaerts (1996) identifies three complex skills involved in regulating cognition:

    1. The learner must "form a clear mental representation of the learning goal" and be able to redefine it as needed.

2. The learner must be able to establish an action plan and revise it as necessary.

3. The learner must monitor his behavior, identify gaps between his performance and the desired outcome, and discern progress toward the learning goal (p. 107). Metacognition encompasses students' self-knowledge of their cognitive processes as well as their control of these processes by way of monitoring and modifying (Weinstein & Mayer, 1986). Monitoring of learning is essential for SRL and is an important part of the metacognitive processes SRL entails.

Monitoring

Metacognitive monitoring is what drives SRL. Planning, monitoring, and regulating are three strategy categories of metacognitive control generally agreed upon by scholars (Hofer, Yu, & Pintrich, 1998 p. 67). Students who are unable to monitor their own attention, thinking, understanding, and progress are unable to effectively self-regulate their learning. Metacognitive monitoring is also referred to as comprehension monitoring, which involves learners setting goals, self-assessing their progress toward the goals, and adapting their behavior in order to achieve their goals (Weinstein & Mayer, 1986, p. 323). This requires learners to perform constant self-assessments while simultaneously making adjustments, demanding a tremendous amount of flexibility (Boekaerts, 1996). The ability to adapt learning strategies and behavior is a hallmark of self-regulating students. Boekaerts (1996) includes *cognitive regulatory strategies* in her model of self-regulation and describes these strategies as a learner's mental representation of learning goals, design of an action plan, and monitoring

progress and evaluating goal achievement (p. 103). Self-monitoring notifies the student

when progress is being impeded and adjustments need to be made to her attention or

thinking to improve understanding and progress toward the learning goal (Garcia &

Pintrich, 1994). Examples of specific monitoring behavior include learners self-checking

their attention in class, self-questioning for comprehension while reading, and

comparing their test-taking speed with the exam time allotted (Garcia & Pintrich, 1994).

Self-regulating learners "monitor attention, understanding, effort, and behavior and

when found wanting, engage compensatory strategies to remain on task" (Anthony,

Clayton, & Zusho, 2013, p. 360). Finally, in order to create the most learning-conducive

context for their academic endeavors, self-regulated learners engage in monitoring of

their learning environment, which includes their physical, visual, and auditory study

surroundings as well as social surroundings; learners who self-regulate will often pursue

study groups (Pintrich, 2004). Additionally, students who monitor their progress on an

assignment and discover a discrepancy will seek additional help or even additional time

to ensure success (Pintrich, 2004; Anthony, Clayton, & Zusho, 2013). Metacognitive

monitoring and control is especially vital when learners employ digital learning tools,

due to the nonlinear nature of this media and the necessity of utilizing available

hyperlinks appropriately (Moos, 2011). Digital media adds another aspect of learning

that must be monitored: "the relevancy of the information in the environment," along with

the self-monitoring of thinking, comprehension, attention, etc., is an important aspect of

digital literacy (Moos, 2011, p. 267). Video game players, too, must employ a variety of

metacognitive and monitoring strategies and processes to successfully play a game,

43

utilizing the game's feedback and their repertoire of cognitive strategies to solve complex problems within the game. Good feedback within a game or an educational task helps the learner remain cognizant of their progress, and it therefore facilitates self-monitoring by communicating to players where they are in relation to the goal.

Motivation

Motivation is a key component of SRL, which is often described as a combination of skill and will (e.g., Garcia, 1995; Zimmerman, 1990). Students who are effective self-regulated learners are also adept at utilizing motivational strategies and are often described by others as self-motivated. Learning tasks frequently include the risk of "performance outcomes [that] have emotional consequences in terms of self-worth," and the "emotional consequence" of failure is avoided by most self-regulated learners through proactive behavior intended to achieve success (Garcia, 1995, p. 29). Motivation can be understood in more detail by dividing it into three components: self-efficacy, task value, and goal type (Pintrich, 1999).

Self-efficacy, the learner's confidence in her own abilities, can be a strong source of motivation, while a learner's lack of self-efficacy can greatly diminish motivation (e.g., Pintrich, 1999). Students with high self-efficacy often more willingly undertake learning tasks and even actively seek them. Low self-efficacy is more likely to be exhibited by learners who avoid participating in learning activities and situations (e.g., Hagen & Weinstein, 1995). Pintrich (1999) reviewed SRL literature that encompassed over 3,000 college students and over 1,000 middle school students and found that self-efficacy was very closely tied to SRL-supporting activities including cognitive strategies, self-

44

regulatory behavior, and high academic performance. It is human nature, after all, to

enjoy doing things that bring success and to avoid doing things that result in failure.

Thus, "student perceptions of self-efficacy are both a motive to learn and a subsequent

outcome of attempts to learn" (Zimmerman, 1990, p. 6). Learners who have high self-

efficacy generally put forth greater effort and are more persistent in their work than their

counterparts with lower self-efficacy (Schunk, 1994). This feedback loop of self-efficacy

as both stimulus and result makes it difficult but not impossible to alter one's degree of

self-efficacy in a certain task or subject. The planning, or "forethought" stage

(Zimmerman, 1998) becomes "realized as self-efficacy for achievement in the

performance and *self-reflection* phases (Schunk, 1998, p. 142, emphases in original).

The performance and self-reflection phases, then, provide feedback to the learner that

may alter the learner's self-efficacy in the future. There are some caveats to the

relationship between high self-efficacy and high SRL. It is possible that learners who do

not have total confidence in their abilities to complete certain tasks may find that this

sense of doubt is actually a motivating factor for *increasing* effort and therefore realizing

a more positive outcome (Schunk, 1994). Garcia (1995) asserts that for some learners,

low self-efficacy acts as a catalyst to increase academic effort, as learners who do not

believe they are capable of performing a certain task will work harder to avoid failure.

She refers to learners exhibiting this behavior as "defensive pessimists," students who

have low self-efficacy but are generally high achievers (pp. 30-31). These defensive

pessimists, like learners with high self-efficacy, also wish to avoid failure and usually do,

but they do so by mentally preparing for the worst-case scenario and harnessing that anxiety into academic action (Garcia, 1995).

Task value, the second of Pintrich's (1999) components of motivation, entails the learner's assessment of the importance of the task. The literature suggests that task value has a positive influence on SRL. This concept can also be further delineated into the components of importance, interest, and future value (Pintrich, 1999). First, the learners' perceived value or importance of the task is highly influential in determining their overall motivation for undertaking and finishing it. This is why it is common to see a lack of motivation in traditional school students for completing tasks such as rote exercises that they view as "busywork." Next, the learners' perceived importance of the task is also a factor in their motivation. If students do not find a particular task to be interesting, often expressed by statements such as "I don't *like* this," they are not motivated to complete it. Third, the learners' perceived future value of the task, or how completing the current task will benefit them at some later time, also influences their overall motivation. If learners view a certain task as a stepping stone to accomplishing a future goal, whether distant (it will allow them to excel in desired careers) or immediate (it is required to pass a course), they will more readily accept the task. Pintrich (1999) found that these facets of task value correlated to use of SRL strategies as well as task performance.

Goal setting is a key method used by self-regulated students, and in fact setting goals is often included in the very definition of SRL: "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and

control their cognition, motivation, and behavior, guided and constrained by their goals

and the contextual features in the environment" (Pintrich & Zusho, 2002, p. 64-5).

Pintrich and Zusho reference learning goals twice in this definition of SRL; efficient

learning requires learners to not only *set* goals but also *use* those goals to guide and

focus their behavior. Goal setting is closely tied to motivation, and in fact *goal type* is

the third aspect of motivation and is further broken down by Pintrich (1999) into mastery

goal orientation, extrinsic orientation, and relative ability orientation. Learners with a

mastery goal orientation are defined by Pintrich (1999) as being intrinsically attentive to

understanding the concept and learning from the task, judging their success using their

own standards. Extrinsically oriented students, on the other hand, focus their efforts on

the outcome of the task, such as earning a high score or pleasing their teachers. These

students do not worry as much about obtaining the knowledge being taught in the

learning situation, viewing their learning more like something that must be endured to

obtain their desired goals. Relative ability orientation is understood to be a motivating

factor for competitive learners. These learners focus on comparing their abilities or

performances with their peers. They are motivated to out-perform their peers on a task.

Hagen and Weinstein (1995) also discuss goal types in their relation to motivation and

SRL, using the dyad of mastery and performance. If a learner's goal is to master the

concept being taught, the primary focus is on actually learning the material, usually

selecting the more demanding assignments when given the choice and not focusing as

strongly on things like grades or comparing her performance with that of her peers.

Mastery-oriented students are concerned with the learning process leading up to a

complete understanding of a concept. A learner with a performance goal, conversely, is primarily focused on the task's outcome: a passing or failing grade. The actual knowledge he is gaining en route to his final goal is not emphasized and is likely to be forgotten after the goal is reached. Schunk and Zimmerman (1994) define a similar duo of goal types: learning-oriented goals and task-oriented goals. Learning-oriented students described here mirror the mastery task students of Hagen and Weinstein (1995) while task-oriented learners are defined in a similar way as the performance task learners. It should be noted that most students embody both orientations at different times and in different contexts and even at the same time, which, as the authors explain, can be useful: "while it is important that students value learning the material, it is also important that they achieve particular levels of performance" (Hagen & Weinstein, 1995, p. 43).

Motivation is also required for spending both leisure and academic time playing a game. Pintrich's (1999) three components of motivation (self-efficacy, task value, and goal type) can be applied to the playing of games. Players who have high self-efficacy for a particular game, value the game's tasks in some way, and possess either mastery goal orientation, extrinsic orientation, or relative ability orientation, are more likely to stay motivated to persist through challenges within the game and therefore achieve success. As discussed above, many entertainment games seem to have mastered the "formula" for ensuring player motivation, causing educators and scholars to analyze the mechanisms within the games that appear to do this (e.g., Gee, 2003; Eichenbaum et al., 2014; Granic et al., 2014). Scholars have noted specific game mechanisms as

48

having positive motivational effects on players, such as reward systems, lack of

stigmatizing failures, and scaffolding of abilities. Mandinach (1984) found that players

who were more successful in a computer game (i.e., discovered a correct solution),

demonstrated SRL skills; they generally "assessed risks, made appropriate logical

inferences, considered alternative solutions, and planned toward a solution" (p. 24).

The motivation and attention associated with SRL, along with their links to digital

literacy, are important to include in the digital literacy toolbox, as is the crossover of the

traits of the self-regulated learner and the digitally literate learner.

External Behavior

Self-regulated learners are observed to exhibit certain behaviors during the three

SRL phases of *forethought, performance or volitional control,* and *self-reflection* and to

actually cycle back through these stages within the task in an effort to increase their

learning or performance (Zimmerman, 1998, p. 2). Learners who self-regulate exhibit

some of the same behavior such as strategy and feedback use.

Strategy Use

High-achieving learners have been studied for decades as researchers continue

to strive to quantify specific behaviors that enhance their performance. Zimmerman and

Pons (1986) conducted research on groups of advanced and non-advanced high school

students, interviewing them about their study strategies. Student responses fell into 14

categories of SRL-supporting strategies (Table 2), most of which were reported by the

students in the more advanced group. Student use of these SRL-supporting strategies

49

alone could predict to which academic group they belonged 93% of the time, suggesting

that high-achieving students are self-regulated learners and perhaps also signifying that

the use of SRL strategies can result in high academic achievement.

Table 2: The 14 SRL-supporting strategies (Zimmerman & Pons, 1986, p. 618)

1.	Self-evaluation: students appraise their own work, reviewing it before submitting it, estimating its quality, etc.
2.	Organizing and transforming: students reorganize information given by their teacher such as creating an outline or rearranging class notes.
3.	Goal-setting and planning: students begin studying in advance of a test; students plan "for sequencing, timing, and completing activities related to those goals."
4.	Seeking information: students utilize additional resources not directly given by the instructor such as the library.
5.	Keeping records and monitoring: students take notes in class or keep a list of their incorrect answers.
6.	Environmental structuring: students take control of their study space by turning off music, moving to an isolated/quiet location.
7.	Self-consequences: students reward or punish their achievement or non-achievement of goals, indulging in a leisure activity after earning a desired grade.
8.	Rehearsing and memorizing: students work to memorize information by rewriting it or creating and using flashcards.
9.	Seeking social assistance from peers: students ask peers for help.
10.	Seeking social assistance from teachers: students ask teachers for additional help.
11.	Seeking social assistance from other adults: students ask a parent or other adult for help.
12.	Reviewing tests: students reread past tests to study.
13.	Reviewing notes: students reread their notes to study.
14.	Reviewing textbooks: students reread textbooks to study.

In an effort to digest this itemized list of strategies, it can be helpful to mentally

follow a self-regulating student's actions from receipt to submission of an assignment.

On receiving the assignment, the student will take action to *prepare* for successful

completion of the assignment. He will set goals (strategy 3 above), select and structure

a study environment (strategy 6), organize his available resources in the way most

conducive to successfully completing the assignment, and select self-consequences for

succeeding or failing to meet her goals (7). Having prepared, he will *progress* through

the assignment, engaging in actions such as memorizing (8) and keeping records (5),

but he will constantly *monitor* his performance by comparing his current product to the outcome described by his goal. If the gap appears too large or the student finds himself having difficulty, he will *seek help* by pursuing additional information from the library (4), peers (9), teachers (10), other adults (11), old tests (12), class notes (13), or his textbooks (14). He will *conclude* his assignment not when it is finished, but after he has undertaken some self-evaluation (1), and he will at some point follow through with his previously planned self-consequences (7). Thus, these fourteen explicit strategies can be grouped into five kinds of activity: *prepare*, *progress*, *monitor*, *seek help*, and *conclude.* These categories correspond with the three phases of forethought (prepare), performance control (progress and monitor), and self-reflection (conclude) described by Zimmerman (1998). The ability to select strategies appropriate for the assigned learning task as well as the learner's capabilities is a key component of effective use of SRL strategies and is discussed below with cognitive strategies. Again, analogies can be drawn between efficient learning and efficient gameplay; like self-regulating learners, successful players employ appropriate strategies for overcoming challenges presented by games. Likewise, digitally literate learners utilize the resources afforded by digital tools to improve their understanding. Similar to digitally literate leaners and efficient game players, self-regulated learners engage in a cyclical process where feedback on learning performance is utilized to determine the need for additional modification of behaviors and/or strategies.

Use of Feedback

Self-regulating learners rely on feedback in order to monitor the progress of their developing understanding (e.g., Zimmerman, 1990; Butler & Winne, 1995). Learners seek to match their performance with a perceived successful outcome, whether it is the completion of a concrete learning task or something more abstract such as the mental mastery of a concept. Self-regulated learners conduct constant self-assessments of their learning progress. As described above, they use specific and cyclical strategies during all parts of a learning task with three cyclical phases of forethought, performance or volitional control, and self-reflection (Zimmerman, 1998, p. 2).

One effective means to explore and comprehend the complex topic of feedback as it applies to SRL is to study work written by and for educators. Scholarship utilizing this perspective includes instructions and suggestions about how to improve SRL in students via feedback with specific characteristics, and therefore sheds light on the different components of feedback important in fostering SRL. For example, Skinner (2013) advocates timely and frequent feedback by instructors as a means of developing strong SRL skills in students. She explains that a steady flow of feedback can strengthen the learner's self-regulation as well as self-efficacy skills which can improve SRL. Skinner (2013) and others (e.g. Sadler, 1989; Nicol & MacFarlane-Dick, 2006) point out that simply providing feedback, even if it is delivered in a timely and consistent way, is not enough. The ability to interpret feedback into meaningful guidelines for future learning tasks is a separate skill in and of itself that must be acquired and supported throughout one's education. Skinner (2013) suggests that educators ask

52

their students to show understanding of their feedback as soon as it is received. To develop SRL skills, learners need to absorb outside feedback and generate their own interpretations of it to feel ownership of both their performances and the changes the feedback indicates as necessary; she asserts that "teachers should create opportunities for students to reflect, generate their own feedback, and adjust as a result" (Skinner, 2013, p. 97). Sadler (1989) proposes that learners best benefit from academic feedback when three conditions are met. He explains, "the learner has to (a) possess a concept of the standard (or goal, or reference level) being aimed for, (b) compare the actual (or current) level of performance with the standard, and (c) engage in appropriate action which leads to some closure of the gap" (p. 121). Not only are these conditions required for the learner to effectively utilize instructor feedback, but, Sadler argues, they must all be present at the same time. These are not easy conditions to establish, but instructors can format their feedback in such a way as to help induce these conditions, especially conditions (a) understanding the goal and expectations and (b) comparing student performance against what is expected. Sadler (1989) gives two examples as means to promote optimal feedback conditions that include giving explicit descriptions of what is expected of students in assignments. The first is including detail written as if the teacher were describing a paper she had just read and assigned the top score (such as a rubric). The second is providing students with an example that meets the instructor's expectations. Nicol and Macfarlane-Dick (2006) also include a principle for feedback that solicits response from the learner to be sure the learner fully understands the feedback she has been given. This indicates just how vital feedback is in the

process of improving SRL as a learner as well as the process of scaffolding SRL as an educator.

Digital literacy is acquired by behavior similar to SRL, as learners rely on feedback from digital tools such as Internet searches and video games to help monitor the progress they are making toward their goals. In order to learn the game's rules by playing as well as to discern the player's level of success, feedback must be given promptly and consistently within the environment of the game (e.g., Gee, 2003; Eichenbaum et al., 2014; Granic et al., 2014). Just as learners must understand their instructor's feedback and recognize what they must do to improve their performance based on that feedback, so game players must be able to comprehend the game's feedback and adjust their playing in order to succeed. As discussed above, the immediacy and relevancy of feedback mechanisms is something most games do well. Players utilize this feedback to monitor their progress and to evaluate their strategies, as their actions are immediately rewarded or punished.

Interpersonal Behavior

Though it may seem antithetical given its title of *self*-regulated learning, SRL is social (e.g., Vassallo, 2013; Grau & Whitebread, 2012). Peer-to-peer interactions can serve as avenues for students to collaborate with classmates who serve as role models for this type of behavior. Collaboration also typically provides learners with valuable feedback, which, as mentioned above, is a key component of SRL (Bransford et al., 2000). When students engage in collaborative activities such as structured critique, they are able to reflect on the quality of their own work while also viewing and

evaluating the work of peers (Quintana, Zhang, & Krajcik, 2005). Group learning tasks

are a powerful way to support SRL, as they usually provide opportunities for meaningful

feedback, prompting, scaffolding, and assessing of understanding. Many educational

theories view learning itself as inherently social, so it is logical that collaborative

elements within learning activities should also support SRL. Even theorists who

emphasize the "self" in SRL generally have a socio-cognitive perspective of education,

and these scholars therefore champion social factors for supporting SRL such as

context, modeling, and prompting (e.g., Zimmerman, 1998; Jackson Mackenzie, &

Hobfoll, 2000). Social learning experiences and interpersonal cultural contexts help

create conditions ripe for SRL (e.g., Delfino, Dettori, & Persico, 2008; Hadwin, Oshige,

Gress, & Winne, 2007). SRL can transpire in contexts that are individual or group

oriented and it alters the understandings and methods that learners can then apply to

new assignments and contexts, while additionally modifying the "structures and

conditions of the environment" itself (Hadwin et al., 2011, p. 68). They note that while

SRL research is commonly understood to focus on the individual and her regulatory

processes, there appear to be three categories of scholarship that analyze the social

aspect of SRL: "(a) comparisons of types of social support for prompting task

engagement and SRL; (b) macro-level investigations of social support provided in

programs or interventions for promoting SRL; and (c) explorations of social contextual

attributes that facilitate SRL" (Hadwin et al., 2011, p. 68). Social processes and

contexts are thought to support the development of individual SRL and focus on

modeling, prompts, and especially feedback as means of promoting and improving

regulatory skills in learners (Hadwin et al., 2007). Just as there are different models and labels used by scholars analyzing various aspects of SRL, and there are actually different names for learning that is regulated using these social techniques, including *co-regulation* and *socially shared regulation*, discussed below (Hadwin et al., 2011). Literature occasionally mentions "other-regulation" in the context of social regulation as well, but this is not a field that has been clearly or consistently defined. The idea of other-regulation dates back to Vygotsky's (1978) zone of proximal development and seems to refer to anything *other* than the self that acts as a scaffold for SRL. These socially-oriented perspectives on SRL emphasize the learner's reliance on external, social factors such as classmates, study groups, instructors, and even the environmental context to help regulate learning.

Co-Regulation

Co-regulation of learning is a dynamic process where "the social environment supports individuals' internalization of social and cultural differences" (Volet, Vauras, & Salonen, 2009, p. 218). Three types of research perspectives appear frequently in the research: sociocultural, sociocognitive, and situative perspectives (Volet et al., 2009). The sociocultural perspective of regulated learning looks at the individual within the group co-regulation process. The sociocognitive perspective emphasizes the reciprocal way regulation is shared between individuals, and finally, the situative perspective focuses on the individual's SRL within the context of a group (Volet et al., 2009). A majority of the co-regulation literature, regardless of the author's primary perspective, centers on the social learning environment. Specifically, co-regulation scholars

examine the way this context can limit or improve the individual learner's ability to self-regulate and where peers' "sociohistorical and current processes, artifacts and other environmental aspects cocontribute to engagement and participation" (Volet et al., 2009, p. 219). Co-regulation often concentrates on scaffolding of cognitive and metacognitive strategies as well as intersubjectivity, which is the process where individuals discuss their understandings of the learning activities and goals (Hadwin et al., 2007). Hadwin et al. (2011) identify three areas of focus in co-regulated learning research: 1. temporary support of SRL between individuals 2. learner regulation of other individuals and factors in group work situations 3. the interactions signifying the strengths and limitations of social contexts for SRL (p. 69).

Socially Shared Regulation

Socially shared regulation, also referred to simply as shared regulation, is where individuals in a collaborative group all participate in the regulatory process (e.g., Hadwin, et al., 2011; Grau & Whitebread, 2012). In socially shared regulation of learning, group members cooperatively identify the goals and guidelines for their learning task (Grau & Whitebread, 2012). Hadwin et al. (2011) draw out this basic definition a bit to articulate that socially shared regulation "is interdependent or collectively shared regulatory processes, beliefs, and knowledge orchestrated in the service of a co-constructed or shared outcome" (p. 69). A key difference between socially shared regulated learning and co- and self-regulated learning is that the purpose of socially shared regulation is to facilitate the group members' co-construction of strategies and understandings toward a common goal (Hadwin et al., 2011). Thus,

discussion within a group engaged in socially shared regulation of learning will focus on what collectively needs to be done and how: for example, "We have to summarize this chapter, so we should each summarize one section" (Grau & Whitebread, 2012).

As seen above, the regulation of learning is a complicated mental activity that poses many research challenges. Though varying theories and approaches exist for studying SRL, it is generally agreed upon that SRL is, in short, a combination of effective strategies for learning. SRL is the regulation of motivation, behavior, and cognition. It has social qualities and implications. SRL is a complex series of cognitive and metacognitive processes that rely greatly on goal setting, self-monitoring, and feedback. The phases of SRL, though they have been given a few names and definitions, are all cyclical; self-regulating learners monitor multiple aspects of their learning activity and move to the most appropriate phase in response to that monitoring and the feedback they are able to receive. Finally, SRL lies on a continuum heavily dependent on learning context and content as well as learner prior knowledge and self-efficacy. Learners do not exist in binary categories of "self-regulating" or "non-self-regulating," but rather along a range from strong self-regulators to weak self-regulators. Just as learning itself can and should evolve over a person's lifetime, SRL skills, too, continue to progress with practice. These things could be said about digital literacy, as well: the definitions of digital literacy vary from scholar to scholar; digital literacy has social implications; digital literacy requires a variety of cognitive and metacognitive behaviors; and digital literacy lies on a continuum. The understanding of digital literacy

58

continues to evolve with technology, requiring the digitally literate to continue to learn and acquire additional skills to utilize digital technology.

SRL and WBEGs

SRL is a common characteristic of students who are able to efficiently come to an understanding of new concepts, and relatively reliable measures exist for assessing it. This dissertation examines SRL elements in two-player whole-body educational games (WBEGs) and how effectively they support SRL as part of gameplay. Games such as WBEGs hold great promise for facilitating the growth of SRL skills in all types of learners. Embedding opportunities for learners to increase their self-regulatory abilities in a medium like a game is advantageous because the improvement of SRL skills requires practice and can always be improved, two traits that become much more appealing to learners when included in a game. Games themselves are often effective learning environments; even games created purely for the purpose of entertainment must somehow teach players the rules and operational procedures of the game itself, something that is usually done *within* gameplay to avoid lengthy instructional manuals or tutorials (Gee, 2003). As mentioned above, the traits of a self-regulated learner can also be seen in an effective game player. To complete challenges and levels presented within a game, the player must possess a clear goal (often provided by the game), a variety of cognitive strategies from which to draw, the metacognitive ability to choose those cognitive strategies most appropriate for each task, the capability to self-monitor game performance and progress, and the habit of reflecting on completed tasks. Though some research has been done on games or simulations and SRL (e.g., Bell &

Kozlowski, 2008; Nietfeld, Shores, & Hoffmann, 2014), and common analogies can be

drawn between games and SRL, as above, little research exists directly linking WBEGs

to SRL. The platform of WBEGs makes them especially conducive to facilitating SRL;

as mentioned above, the embodied nature of educational activities such as WBEGs

increases learning. The more purposeful motions of the WBEG player, too, encourages

thoughtful game action rather than mindless guessing, forming an environment highly

conducive to the SRL processes of forethought, progress monitoring, and reflection.

The specific games analyzed here are multi-player and therefore encourage and often

require collaboration between players, which supports learners in the social aspects of

SRL discussed above. In addition to the affordances of typical games that support SRL

processes by providing feedback, motivation, etc., the way that the embodiment of

WBEGs facilitates cognition also puts them in the position to enhance SRL skills in

players. By examining and comparing three WBEGs and their features that support

SRL, this dissertation strives to advance the understanding of learning with digital

technology and to lay the groundwork for improved support of SRL within future

WBEGs. Twenty-first century learning requires digital literacy, and digital literacy skills

can be obtained and improved by learners who utilize procedures described as self-

regulating. WBEGs can scaffold learners' acquisition of SRL skills. One method for

understanding and assessing the effectiveness of this scaffolding is to analyze a

WBEG's procedural rhetoric.

Procedural Rhetoric

The concept of procedural rhetoric stems from procedural literacy, a scholarship trend beginning in the 1980s from the idea that the ability to program computers was not only a useful professional skill but also an important type of literacy on its own (Sheil, 1980). Bogost stretches this traditional idea of procedural literacy to include the ability to "read" the cultural values that are represented in games through their procedures. He extends this broader definition of procedural literacy to indicate the capacity to "use such an understanding to interrogate, critique, and use specific representations of specific real or imagined processes" (p. 246). The ability to analyze and critique procedural rhetoric in this way, Bogost argues, is becoming more and more vital as the popularity of the digital and procedural increases over the linear and analog. A theory of procedural rhetoric is necessary to be able to appropriately understand the software we interact with on a daily basis.

Procedural rhetoric as conceptualized by Bogost (2007) is a sub-field of rhetorical analysis like visual rhetoric and digital rhetoric. He defines procedural rhetoric as "a general name for the practice of authoring arguments through processes" (pp. 28-29). Stemming from humanism, procedural rhetoric examines arguments that are made by video games not explicitly in words, but in programmed rules, models, and responses. In short, procedural rhetoric is the argument made by the structure of a game, such as its rules, scoring system, and physical layout. For example, Bogost (2007) analyzes the video game *Antiwargame* created by Josh On, and asserts that it "makes a number of interrelated claims about the nature of the post-9/11 political and

social environment, each claim simple and direct" (p. 83). In this game, the player is the President of the United States as the country is engaged in a war against terrorism overseas. The player's popularity is continuously monitored by a gauge that stays on the screen, where windows also display the attitudes of businesses and the media. The player can adjust government spending in three categories, military/business, social spending, and foreign aid. Support from businesses in the game drops if the player chooses not to utilize troops to obtain the overseas oil that drives business. Bogost claims these features suggest "a fundamental tie" between them (p. 83). Furthermore, it is difficult in the game to keep troops motivated overseas, and the player can attempt to do so in the game; however, Bogost explains, "too many orders will cause the troops to revolt against their leadership. This mechanic invokes the estrangement of the Vietnam draft and suggests a correlation between the contemporary war in the Middle East and the Cold War" (p. 84). By examining the structure of the game, its programmed reactions to player actions, Bogost is able to discern clear messages or arguments within the game itself. Based on this analysis, he is able to conclude that "together, the game's rules form a systemic claim about the logic off the war on terrorism, namely that the purported reasons for war—security and freedom—are false. Unlike other pacifist arguments, the Antiwargame's opposition to war is not based on antiviolence; rather, it opposes war by claiming that a broken logic drives post-9/11 conflicts" (p. 84). The rhetoric of *Antiwargame* "emerges through the player's performance of political gestures that produce unexpected effects" (p. 84). This method provides a way of articulating some of the more abstract elements of games in a manner that enhances scholarly

62

understanding, discussion, and comparison of games. Elements scaffolding SRL skills embedded in the game can also be brought to light using this analytic process. By examining specific actions and reactions within the three WBEGs, the techniques the game reinforces as well as the arguments they make can be inspected.

Other scholars also investigate the rhetoric of video games for messages. For example, McAllister's (2005) grammar of gameworks goes beyond the critique of a single game and targets the entire video game industry, including game designers, players, marketers, vendors, etc., which he refers to as the computer game complex. McAllister explains that the grammar of gameworks is designed to "study intentionally how the computer game complex—in part or in total—changes and is changed by the dialectical [truth-seeing] struggles that are at work around it" with the goal of altering them "through critique-driven action" (p. 65). Bogost's method, as it is applied in this dissertation to investigate the underlying assumptions of game designers through three WBEGs, is similar to McAllister's grammar of gameworks in that it looks for "ideologies that reproduce themselves through the medium of the game" (McAllister, 2005, p. 69).

It should also be noted that scholarship exists arguing for a more player-centered approach designing and understanding games rather than procedural rhetoric (e.g., Sicart, 2011). Sicart (2011) contends that the utilization of procedural rhetoric in game analysis "often disregards the importance of play and players as activities that have creative, performative properties" and over-emphasizes the game's rules (The Proceduralists section, para. 17). In his view, this distorts the meaning and intent of "play" itself, creating "an understanding of play, and leisure, as mechanical outcomes of

63

processes" which "turns the act of playing a game into a labor-like action, into work towards an externally decided, predetermined, and rational outcome designed by others than the players. (Sicart, 2011, Understanding Instrumental Play section, para.10). Sicart interprets game rules as means of structuring, facilitating, focusing, and framing play but not *determining* it. The human player, he asserts, understood as "a living, breathing, culturally embodied, ethically and politically engaged being that plays not only for an ulterior purpose, but for play's sake" is missing altogether from procedural rhetoric analyses (Against Procedurality section, para. 4). Thus, he insists, "play is activity between rite and reason, between rationality and emotion—and as such, it cannot, and ought not to be instrumentalized" (Understanding Instrumental Play section para. 31).

Sicart's argument is compelling, and this dissertation recognizes the importance of human players of games and that people generally do not conceptualize their leisure playing of a game as time spent following rules any more than they would view coloring in a coloring book as an exercise in fine motor skill practice to stay inside the lines. The fact is, the rules and the lines exist and to a large extent influence participant behavior. Unlike the lines in coloring books, player actions within a game are necessarily limited by its programming. Each action the player chooses to and is able to execute within the game activates a specific reaction by the game. This study focuses on this transaction of actions and reactions through Bogost's theory not as the *only* way to analyze a video game, but as a way to make these design decisions more apparent and concrete so that they can be explored and evaluated. The rules and limitations created by these

64

design choices are also the focus of this study. The inclusion of digital literacy studies, especially the critical and sociocultural analyses, is intended to rejoin the human aspects of not just the players but also the game designers and programmers into the discussion of video game structures. By examining the procedural rhetoric of these WBEGs and how they are structured to respond to and therefore influence player behavior, the assumptions of the game designers regarding the way learning should be scaffolded as well as the techniques that should be reinforced by each game can be brought to light. The understanding afforded by this analytical perspective emphasizes the internalized beliefs of those who created these games for our immediate critique as well as our consideration when designing games in the future.

In sum, techniques and theories from digital literacy and specifically procedural rhetoric provide the basis for this investigation of WBEGs. Bogost's methods of analyzing procedural rhetoric allow for comparison between games and game elements. SRL is similar to digital literacy learning and also an efficient way to acquire and improve one's digital literacy skills. Digital media such as WBEGs can teach and reinforce these skills in learners. This dissertation applies the procedural literacy methods of Bogost (2007) to "interrogate, critique, and use" the representations of the processes presented in *Waves*, *Color Mixer*, and *Light and Mirrors* (p. 246). The majority of Bogost's scholarship, and indeed the scholarship of game and simulation studies in general, has been focused on more traditional game platforms (played using a console and television or computer and screen). This is to be expected because the majority of digital games themselves exist in these formats. This study of the

procedural rhetoric enacted by WBEGs builds on and extends the existing literature to a slightly different medium and informs future design of this genre of games. It is also the goal of this investigation of three WBEGs to further the understanding of digital literacy. The combination of this analysis of procedural rhetoric with a quantitative study, a case study, and an examination of SRL components is intended to enhance these contributions to the field.

CHAPTER TWO: MAKING WAVES

This chapter includes both a quantitative study and a follow-up case study of the same whole-body educational game (WBEG), *Waves* (Lindgren, 2015), which was developed in a research studio affiliated with the University of Central Florida, funded by the National Science Foundation, and adapted for the study of SRL scaffolding by the author. *Waves* is a 2-player WBEG designed to teach a middle-school aged audience about how generic waves (light, sound, water, etc.) can interact and influence other waves in an interactive way. Players' movements are detected by the game via Xbox Kinect game consoles mounted in the ceiling above the game. For levels 1 and 2, players stand side by side on one end of the rectangular (10' x 15') floor (Figure 2); for level 3, players face each other and stand on opposite ends of the floor (Figure 3). Two SRL-scaffolding features were added to this game by the author: 1) instructions and questions (prompts) that periodically appear in the center of the floor, and 2) an interactive, 3-action checklist is displayed throughout each level in front of the players' feet. During gameplay, completed and future actions are grayed out, while the "in-progress" action is highlighted. A facilitator is also present to listen to the players' verbal answers to the game's prompts, clarify those answers, and act as a guide as needed.
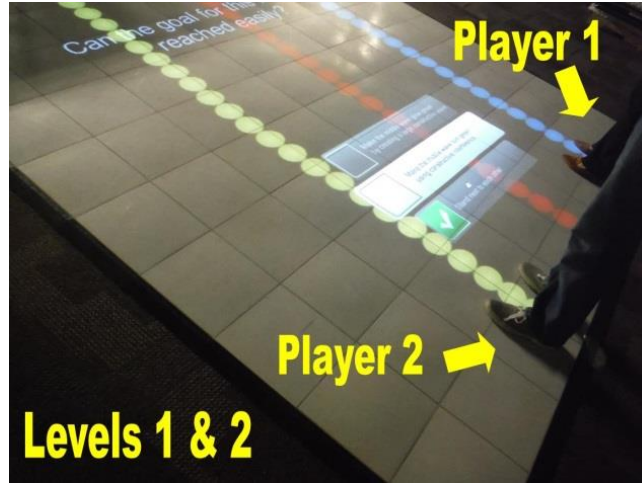
Figure 2: Player positions in levels 1 & 2
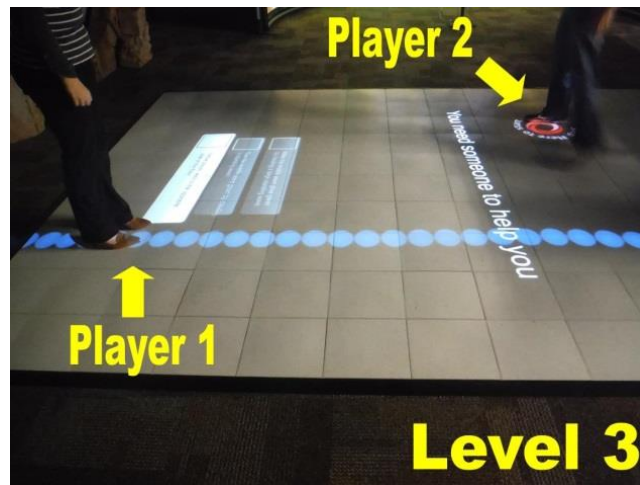
Figure 3: Player positions in level 3

Each player controls a wave (blue or yellow) by stepping from side to side, with larger

steps creating larger waves and smaller steps creating smaller waves. If a player

stands still, so does her wave; if she takes large steps side-to-side, her wave appears

larger (there is more distance between the top of her wave's crests and the bottom of its

troughs); if she steps side-to-side quickly, the crests and troughs appear more rapidly

and more are visible on the game floor. A third, red wave appears between the two

players that is influenced by the players' waves: the force of each player's wave is combined into the third wave, and it is this wave that players are required to work together to manipulate. This is intended to allow players to intuitively understand how waves interact with one another; if the two player waves are moving in the same direction with their crests and troughs aligned, the middle wave will become very large. If the player waves move in the opposite direction or if the players are offset, this causes the crests of one player's wave to align with the troughs of the other player's wave and will result in a very small middle wave. Each level challenges players to create a certain type of wave using a certain type of movement: large constructive wave, small destructive wave, and standing wave, respectively. The middle (red) wave will turn green when players move in the correct directions (same as or opposite of each other to create a constructive or destructive wave), and it will glow green when it has been influenced to a preset amplitude (Figure 4); when it has remained at that amplitude for a preset time, colorful "success stars" appear all over the screen to indicate the players have successfully completed that level (Figure 5). To complete level one, players must use constructive interference to make the middle wave large. This requires players to take large steps in the same direction at precisely the same time (i.e., both step left, then both step right). Level two asks for a small destructive wave, which can be created only when players take small steps in the exact opposite direction of one another at the same time (i.e., both step toward one another, then both step away). Level three moves the players to opposite sides of the floor, where they face one another and must create a large standing wave using destructive interference.

69

This means they need to take large steps in exact opposite directions, and can only succeed when two nodes of the wave appear to stand still.

In an effort to support and scaffold self-regulated learning during gameplay, two elements were added by the author: a task bar and a series of prompts. The task bar appears on the floor directly in front of the players' feet with three concrete tasks they need to complete in order to be successful in that level (e.g., "Turn the middle wave green by creating a standing wave"). The current task on which the players should be focused is highlighted while the next task to be accomplished appears but is grayed out. When a task is completed, a green check mark appears to the left of the task and the next task is highlighted (Figure 6). This continues until the level's goal has been met. All three tasks remain legible throughout the level in dual effort to encourage players to plan how they would execute the upcoming task (Zimmerman, 1998) and to remind players of tasks already completed, which has been used in software to support SRL in online learning activities (e.g., Manlove, Lazonder, & de Jong, 2007; Quintana et al., 2005).
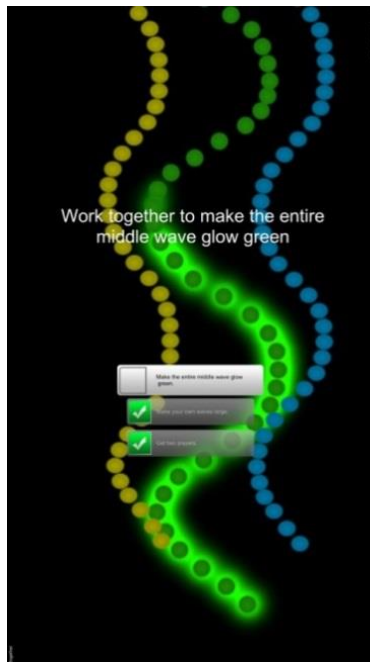
Figure 4: Middle wave begins to glow green

Figure 5: Stars indicate success
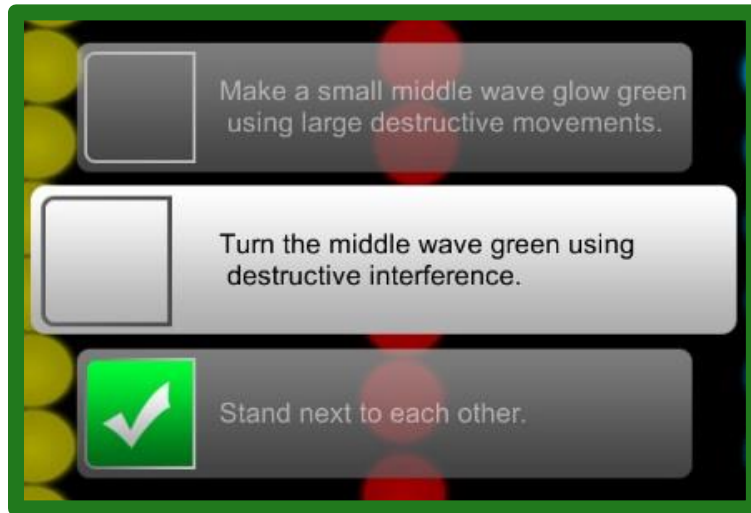
Figure 6: Task bar with 1 task completed

Figure 7: Prompting players to monitor their progress

A second scaffold for self-regulated learning is the appearance of prompts throughout the game. At the a) beginning b) middle and c) end of each level, prompts appear designed to encourage self-regulated learning, specifically to remind the players to a) check their understanding of the level's goal and reinforce the planning encouraged by the task bar b) check their progress toward the goal and c) reflect on the level as a whole. This design choice is supported by Zimmerman's (1998) explanation of self-regulated learning cycle phases of forethought, performance or volitional control,

and self-reflection (p. 2). Prompts to help scaffold these three phases of SRL appear in question form in the middle of the game floor above the task bar, for example: a) "Can the goal for this level be reached easily?" b) "Is the wave getting close to reaching the goal?" c) "How does this level work?" (Figure 7).

Additional prompts appear at certain time intervals after the progress (b) prompts to provide further support for players who have not yet achieved success in that level (e.g., "Is there anything different that could be tried here?"). These additional prompts reflect the importance of constant self-monitoring by self-regulated learners (Zimmerman, 1998). The prompts were also consciously composed to avoid personal pronouns. The rationale behind this is twofold. First, the prompts need to appear as innocuous as possible, not resembling classroom quiz questions, to promoting a game atmosphere that avoids self-consciousness or embarrassment on the part of players who did not know how to answer them. Second, the questions seem more integrated in the game itself when worded this way (e.g., "Is the wave doing what it should be doing?" versus "Are you moving the right way?"), which was important to help produce a feeling of flow while playing the game. The decision to use short, generic prompts was also purposeful, as Ifenthaler's (2012) research suggests that prompts encouraging general activities like planning and reflecting are more effective than prompts that give task-specific instructions or hints.

Quantitative Study

Participants

The participants in this quantitative study consisted of 20 students within the age range of 10-12 years old. These participants represent a convenience sample of children and the friends of children whose parents work in various buildings located within the University of Central Florida's Research Park. The study took place in a research lab affiliated with the university in an environment designed to seem like a small science center. While participants waited for their turn take the pretest and play the WBEG (or after they completed the study), they were given the opportunity to play other games in development by the research team at this particular lab. Participants were told that they were playtesting a game called *Waves* and that it was designed to teach them about waves. The facilitator asked players to try and discern how to play the game but did say she was there if they needed help. The participants selected their own partners prior to seeing the game, and the facilitator encouraged them to work together and to vocalize their thought processes while they played.

Materials

All participants were given a paper-and-pencil pre-test (Appendix B) and post-test (Appendix C) designed to assess their knowledge about waves. Both measures include four author-developed, open-ended, short-answer concept items asking about waves in general, e.g., "What are the parts of a wave? List as many as you can" as well as more specific short-answer questions focused on the terms used within the *Waves*

game itself, e.g., "What is a constructive wave?" All four of these questions appear worded exactly the same on each pre- and post-test and in the same order. Additional author-developed concept questions on both assessments ask participants to draw what a wave would look like certain scenarios. There are three drawing items on the pre-test and four on the post-test.

Additionally, the pre- and post-tests include measures of self-regulation. These items are taken from the Self-Regulation Questionnaire (SRQ) (Brown, Miller, & Lawendowski, 1999). Interestingly, this questionnaire was originally created to analyze addictive behaviors but has since been found to effectively measure more general behaviors of self-control (*Assessment Instruments*, 2013). Others have successfully modified the SRQ for purposes of studying self-regulation of learning (e.g., Ryan & Connell, 1989). The *Waves* pre-test features 14 items from the Likert-scale SRQ, and the post-test contains 7 different items. The items were selected deliberately for wording that middle-school age students could easily understand and also so there would be an even spread of each of the questionnaire's 7 categories: information input, self-evaluation, instigation to change, search, planning, implement, and plan evaluation (Brown et al., 1999, p. 290).

The post-test also contains author-developed SRL scaffolding perception items of additional Likert-scale statements asking participants how useful they perceived the prompts and task bar to be, e.g., "The pop-ups were unnecessary because I was already asking myself similar questions while I played." These additional post-test items are intended to discern if the SRL-supporting design features truly support SRL. The

75

reasoning behind these is such that a strong self-regulated learner would not rely on the scaffolding items and thus would indicate "6-Strongly Agree" in response to the example statement above. This high score should then correlate with the same learner's high score on the SRQ items.

Results

The short-answer wave knowledge questions were scored on an author-developed rubric with a scale of 0-3. A score of 0 was given for blank or entirely incorrect answers; 1 was given to replies that were vague, simple, or very partially correct; 2 was earned by responses that were mostly correct but lacked the detail to demonstrate a complete understanding; 3 was assigned to answers that were fully correct and clearly demonstrated complete understanding of the concept being assessed. This rubric differed slightly for the item asking participants to list the parts of a wave: one point was assigned for each correct part of a wave that was listed. Participants earned an average of less than one total point on the pre-test ($M = 0.6$, $SD = 1.5$). Additionally, the total number of blank or "I don't know" answers on the knowledge section of the pretest for all participants was 48, which is an average of 2.5 unanswered questions per student.

The average total points earned by participants on the post-test for the four short-answer items was almost two and a half ($M = 2.4$, $SD = 2.5$). This resulted in a difference in means of 1.8 ($p = 0.0012$); participants scored, on average, almost 2 more points on the post-test. Furthermore, the blank or "I don't know" responses decreased to just 20 total, an average of one blank question per respondent, a difference of 1.47

blank answers. This suggests that players of *Waves* did increase their concept knowledge about waves as well as their confidence in the content knowledge.

The diagrams were scored on an author-developed rubric from 0 to 3. Scores of 0 were either entirely blank or entirely incorrect (non-wave shapes, indecipherable scribbles, etc.). A score of 1 was assigned to drawings that were mostly incorrect, a 2 for mostly correct, and a 3 for correct. There were 3 diagram questions on the pre-test and 4 on the post-test. Pre-test scores averaged 1.40 points per diagram, and post-test diagrams averaged 1.93 points each. This resulted in an average increase of 0.53 points per diagram drawing.

Items were also given from the SRQ on both the pre- and the post-test. Players' scores on these items averaged 0.2 higher on the post-test. All of the SRQ items were combined to determine participants' overall self-regulation score. This self-regulation score was nearly identical to students' average score on the SRL scaffolding perception items, with an average difference of 0.06. These results are discussed in Chapter Four.

Case Study

To further investigate the relationship between SRL and player actions, a case study was also conducted using the video recorded during the quantitative study. Due to the angle from which the video was recorded, this study could not investigate player movements and instead looked in detail at the verbal responses players gave in response to the scaffolding measures provided by the game and the facilitator. Both of the players selected for the case study were 11-year-old males. The pairing was selected because these two randomly paired participants had the closest scores on the

self-regulation questions out of the entire sample, with one participant averaging 3.5 and the other 3.47.

Level two was examined particularly because it falls in the middle of the three levels, after players have established a working understanding of the game, and because it was often the level that players took the longest amount of time to complete. The utterances of the players and facilitator were transcribed in addition to the prompts and task bar items in the order that they appeared (Appendix D).   The verbal remarks between the two players were coded using a scheme adapted from Grau and Whitebread (2012). The coding was developed by those scholars to study and isolate instances of SRL during group activities in a traditional classroom. Grau and Whitebread further sub-categorized these remarks into examples of self-regulation, co-regulation, and shared regulation. Unlike Grau and Whitebread's study, this dissertation is not concerned with the specific types of regulation (self-, co-, or shared) that participants experienced; therefore, the coding scheme below simply identifies behavior that could be classified as regulatory.

The codes and their descriptors are as follows:

- PP – player planning, goal setting, or strategizing

- PM – player monitoring progress toward goal

- PR – player regulation of behavior, use of strategy, etc.

- PE – player evaluation or reflection (Grau & Whitebread, 2012, p. 409)

Codes added for this study included:

- GS – game scaffolding

- FS – facilitator scaffolding

- "R" in front of a code – player acted in response to scaffolding

The results of this coding are charted in Table 4 below. The two players in this case study were able to begin level 2 only after successfully completing level 1; this success was indicated by colorful stars that appeared all over the game floor (figure 5 above). The level began with the highlighted task bar (figure 6) item that read "Stand next to each other," an example of game scaffolding.   Additional game scaffolding was also provided in the form of a prompt appearing in the center of the game floor that said "make the middle wave glow green using DESTRUCTIVE INTERFERENCE." As the two players in this study had not moved much since the conclusion of level 1, the first task bar item was immediately checked off and grayed, and the second item was highlighted, "turn the middle wave green using destructive interference," more game scaffolding. As the players began moving side-to-side, the facilitator said, "destructive…" scaffolding player planning by pointing their attention to the goal-setting task bar item.

The SRL-scaffolding prompt that appeared in the center of the game floor read, "Could this level be too difficult for some people?" which is more SRL game scaffolding to encourage players to plan by evaluating the level 2 goal. The players continued to move side-to-side, and the red, middle wave remained red. The facilitator asked, "So, what do you think that means?" again adding SRL scaffolding to direct players to plan. The middle wave started to change to green, checking off the task bar item "turn the middle wave green using destructive interference," game scaffolding to aid players in

79

monitoring their progress toward the level 2 goal. The third and final task bar item was then highlighted, "make a small middle wave glow green using large destructive movements" (game scaffolding) and a player responded to the facilitator's question while continuing to step side-to-side, "I think it means just going crazy." A new prompt appeared on the center of the floor, "Is the wave responding to your movements the way it should?" The facilitator replied, "Haha, leave it to middle school boys to define 'destructive'…But let's put it in the context of '*con*structive,'" again facilitating SRL by encouraging players to understand the goal and devise a plan to achieve it. The player responded while continuing to move, "Um, like, not big?" The next game scaffolding prompt appeared, reading "Could a different motion change the wave pattern?" and the facilitator suggested, "Okay so try that now. Make it not big. It's not big now, is that working?" prompting players to assess their progress toward the level 2 goal. The players kept stepping side-to-side as they thought about this, "um…" The facilitator directed them to the game scaffolding by asking, "What do your directions say?" Both players continued their motion while one read the third task bar item, "Make a small middle wave glow green using large destructive movements." That player then said, "So, opposite." Players then began moving in opposite directions that eventually allowed them to reach the level 2 goal.

Voicing internal thought processes is not often a strength of pre-teens, complicating the task of identifying instances of self-regulation during gameplay. Through the players' responses to facilitator and game scaffolding, however, it is possible to shed some light on this process. For example, when the players were asked

to define the term "destructive," one initially made a haphazard guess, saying, "I think it just means going crazy." This player seems to have latched onto the root of the word, "destroy." As gameplay continued and the players' strategy of "going crazy" or moving in random directions was not giving them success, they may have been self-monitoring and trying to devise new solutions, or not, as they did not make any noticeable changes to their movements or vocalize thoughts on the matter. It is only when the facilitator scaffolds again, by asking them to put the term in the context of "constructive," which was a term from level 1, that they begin to make progress toward the goal. A player makes another attempt at defining the term. "not big." This gets them closer to a working definition that will allow them to complete the level—they now more clearly understand the goal and will work to make the wave "not big." The next game scaffolding ("Could a different motion change the wave pattern?) and facilitator scaffolding (…It's not big now, is that working?") combine to again prompt players to check their progress. Players indicate they are thinking about the questions by saying "um," and the facilitator again scaffolds by pointing them back to the game scaffolding present in the task bar (What do your directions say?). They read the task bar item again and devise a new strategy (So, opposite)—checking their understanding of the task and planning, which are both SRL behaviors.

Results

Players' discourse indicated planning a total of 3 times, monitoring a total of 5 times, regulating a total of 2 times, and evaluating a total of 4 times (table 4). The majority of these SRL actions, 10 out of 14, were in response to prompting by the

facilitator. The other 4 SRL actions were unprompted; the game's scaffolding features

alone did not appear to directly motivate any SRL behavior. This could be attributed to

the presence of the human facilitator; her direct questions, while they often duplicated

the prompts in the game, may have been perceived by players as more urgent to

answer. These results are also limited to the verbal communication between players

and obviously cannot take into account any self-regulation that may have occurred in

players' minds. For example, it was evident in the video that the players were reading

and thinking about various prompts, especially the more instructive prompts at the

beginning of the level and in the task bar, but they did not verbalize their particular

thoughts until they were questioned by the facilitator and therefore were not coded as

SRL behavior.

Table 3: Coding results of 2 players' utterances in level 2

Code	Instances
Game scaffolding (GS)	14
Facilitator scaffolding (FS)	10
Player planning (PP)	1
Player planning in response to scaffolding (R-PP)	2
Player monitoring (PM)	2
Player monitoring in response to scaffolding (R-PM)	3
Player regulating (PR)	0
Player regulating in response to scaffolding (R-PR)	2
Player evaluating (PE)	1
Player evaluating in response to scaffolding (R-PE)	3

These results suggest that SRL scaffolding measures may be more effective

when given by a human rather than by written prompts/instructions within a WBEG, a

claim warranting additional research. They may also indicate that game scaffolding

requires more attention-grabbing elements (e.g., auditory sounds or prompts, pausing in gameplay, requiring players to answer prompts, etc.) to be most effective; this is also worthy of future study. In this particular level, the facilitator specifically directed the players' attention to an item on the task bar, "Make a small middle wave glow green using large destructive movements." This resulted in players' regulating their activity, as they made inferences from the task description the types of movements they should make. Thus, the scaffolding in the task bar did foster SRL behavior and likely would have been utilized more in the absence of a human facilitator or in the presence of one who offered fewer comments. The overall design of the SRL scaffolds, however, seems to be effective. The facilitator asked questions that were either identical or similar to those appearing within the game with the intent of promoting players to plan, monitor, regulate, and evaluate their actions within the game. To this end, the scaffolding was very effective, prompting 10 of 14 player communications indicating SRL. This suggests that a WBEG can be designed to successfully scaffold SRL. In this level, players' actions indicate SRL is occurring 14 times over a span of roughly 3 minutes. This large number is a reminder that some form of SRL behavior takes place almost constantly and therefore the scaffolding must also be nearly continuous. It is interesting that the number of SRL utterances is identical to the number of game scaffolding prompts/tasks. This indicates that the design of the game scaffolds included an appropriate number of SRL-supporting elements. Though of course this study analyzed only one pair of players, it suggests that players do engage in SRL behavior in a WBEG

situation and that this behavior can be encouraged and supported by some type of

scaffolding. These results will be further discussed in Chapter Four.

CHAPTER THREE: THE PROCEDURAL RHETORIC OF THREE WBEGS

The three WBEGs investigated in this chapter are *Waves* (described in Chapter Two), *Color Mixer* (Institute of Play, 2010a) and *Light and Mirrors* (Institute of Play, 2010b). *Waves*, a WBEG designed to teach concepts about generic waves, projects the game environment on the floor where the players stand. Player motion is tracked using Kinect game consoles mounted in the ceiling above the game floor. The other two games this chapter examines, *Color Mixer* and *Light and Mirrors*, were selected for comparison because they are also WBEGs requiring two or more players moving their bodies to manipulate items projected on the floor. They were created at the Situated Multimedia Arts Learning Lab (SMALLab) at Arizona State University (SMALLab, 2011a).

Color Mixer introduces players to the concept of additive colors, which refers to the combining of red, green, and blue to create a full spectrum of colors on television screens, computer monitors, etc. The game is designed to teach players the way these three colors mix to create a multitude of other colors; players who can quickly recall the specific combinations that create particular colors will be more successful. Three equal players, one of whom is a teacher or facilitator stand around a circle on the dynamic game floor next to circles indicating their assigned color. Players hold game pieces, "wands" that look like abstract representations of molecules, which they need to raise or lower to produce colors on the game's floor (Figure 8). The gameplay begins with the circle on the floor projecting a color, the "color target". Players have to raise and lower their wands to create that color on the initially black rim around the target, coordinating

their movements to produce a precise shade (Figure 9). Initial levels are pure red, green, blue, black, and white; colors that require "on" or "off" indications by each color (e.g., to produce green, the "green" player raises her game piece while the other players keep their game pieces low; to produce white, all players raise their game pieces, etc.). More advanced levels complicate game play by introducing colors requiring varying amounts of red, green, and blue, and also by reducing the time players have to create each color. This game is designed to teach "'additive color' from projected or emitted surfaces" to K-12 students in an embodied and socio-collaborative way" (SMALLab, 2011b).

Figure 8: *Color Mixer* player positions

Figure 9: *Color Mixer* wands in action

Light and Mirrors (Institute of Play, 2010b), the second SMALLab game to be analyzed

in this dissertation, is a two-player game with a teacher or facilitator controlling the

difficulty of each level by adjusting the placement and number of targets and walls as

well as the number of mirrors students may manipulate (Figure 10). As in *Color Mixer*,

all three participants stand on the game floor and hold wands; the teacher has an

additional device, a "clicker" that can pause, advance, or reset the game. The two

student players work together to arrange mirrors in the game in an effort to reflect a

stationary laser's beam so that it hits a target (or multiple targets). Each mirror requires

both student players to move and angle it; they must bend down in unison as if to

physically lift it, positioning their game pieces at nearly the same height and lifting and

moving at the same speed (Figure 11). Collaboration and dialogue are important

aspects of *Light and Mirrors*, as nothing can be accomplished by a solitary student

player. *Light and Mirrors* is designed to allow students in grades 3 or above to "explore

concepts such as angle of incidence and reflection" (Institute of Play, 2010b). The

game provides an experimental space where students and teachers can discuss the

way the laser is reflected by the mirrors, hypothesizing and strategizing to reach a

common goal. The teacher (or the student in control of the "teacher" wand) can devise

scenarios that are simple or complex and can assist the students as much or as little as

he wishes. By manipulating mirrors and observing the angles from which they reflect

the lasers, students are expected to come to a deeper understanding of angle of

incidence and reflection. These three games are analyzed and compared here through

the framework of procedural rhetoric.

Figure 10: Two players moving a mirror
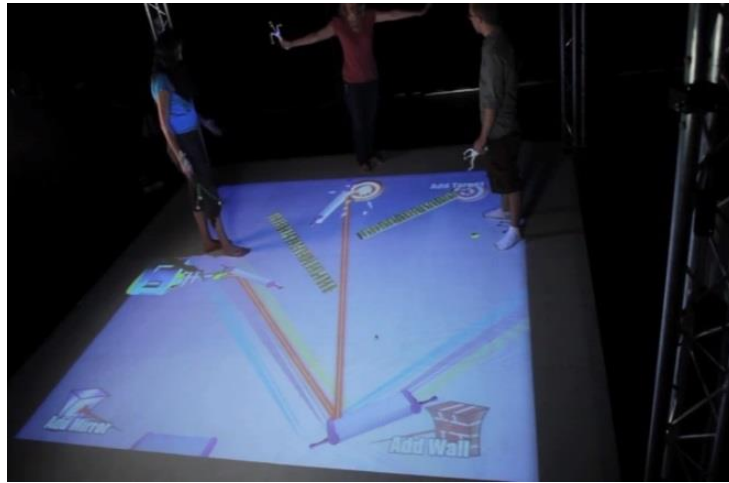
Figure 11: Laser successfully reflected around two walls by three mirrors

Procedure

Procedural rhetoric, as discussed in Chapter One, is a method used by Ian Bogost (e.g., 2006; 2007; 2008) to critically evaluate the action-reaction nature of video games. The examination of procedural rhetoric involves studying the programmed reactions to player actions, assessing the argument made by a game through its structure. For example, Bogost (2007) analyzes the procedural rhetoric of the game *America's Army*, a first-person shooter video game designed as a recruiting tool that was intended to give potential soldiers a realistic idea of what it could be like to enlist in the army. Bogost (2007) explains that the particular constraints of the game, especially its adherence to the U.S. Army rules of engagement (ROE) and use of honor points proceduralize the army's value system, its chain of command, and therefore its "moral imperative" (p. 76). This "political simulation" uses penalties and rewards to guide players into behaving in certain ways deemed appropriate for soldiers by the U.S. Army (p. 76). Bogost explains, "at specified point targets, a player character's 'honor' statistic

increases. Since honor indicates commitment and expertise, disincentives to violate the

ROE and chain of command become especially strong; losing a character through

violation would require considerable effort to rebuild" (p. 76-77). This procedural

rhetoric contrasts with most first-person shooter games which typically ignore army

policies as well as the reality of what happens when one is actually struck by a bullet,

with many games instantly granting shot players multiple chances to replay a failed level

or mission. Commercial games of this genre also tend to encourage players to shoot

rapidly and recklessly with little, if any, weapons training or mission planning. "The

correlation of honor with the performance of arbitrary and politically decontextualized

missions," argues Bogost, "offers particular insight into the social reality of the U.S.

Army" (p. 77). His analysis of the procedural rhetoric in *America's Army* brings to light

aspects of the game that may not be noticed by the casual player. Studying the game

in this way enables Bogost to articulate key aspects of the game in such a way as to

enable scholarly discussion and even comparison with other games.

   This chapter explores the procedural rhetoric of three WBEGs by itemizing the

player's actions and the game's reactions to the player, thus documenting each action

to help make the analytical process more concrete. The analytical model for

understanding each of the three WBEGs' procedural rhetoric is an attempt to produce

the descriptions and implications of the games like those descriptions and implications

discussed by Bogost (2007). In his exploration, Bogost highlights aspects of various

videogames that teach or reiterate the argument made by the game or game makers.

This study follows Bogost's analytic method as a means to examine the arguments

made and techniques reinforced by three WBEGs. To make the process of analyzing procedural rhetoric as transparent as possible, this chapter contains a separate chart for each game and lists the processes by which each game creates an argument (Tables 5, 6, & 7). For each meaningful player action charted, the computer's programmed reaction to that player action is also noted, as well as the concepts reinforced by that reaction, the playing techniques reinforced by that reaction, and the SRL-supporting features made apparent in each charted transaction. The charted items are then discussed and compared among games. Even though the designers of *Color Mixer* and *Light and Mirrors* do not claim that these games are designed to explicitly support SRL, they are still WBEGs designed to teach science concepts, and "self-regulation is inherent when learning is guided by goals of any sort" (Winne & Stockley, 1998, p. 107). Thus, it can be expected that the games do contain features that support SRL. As mentioned above, because games contain motivational elements that encourage players to spend multiple hours playing them, games that incorporate activities that effectively scaffold SRL skills could make an ideal tool for improving SRL skills, which are becoming more necessary as technological advances demand higher levels of digital literacy. The 21st century requires digitally literate, self-regulated learners. WBEGs have the potential to help players increase both their SRL strategies and their digital literacy.   The scholarly examination of the procedural rhetoric expressed by games in this genre will further the understanding of digital literacy itself, what it means and what skills it requires.

Procedural Rhetoric of *Waves*

        The programmed actions and reactions that comprise the procedural rhetoric of

Waves are reported in Table 5 below. For clarity, this table itemizes typical player

actions within only level 2 of *Waves.* Each row is assigned an individual letter, and the

lettering sequence is continued through all three tables for the ease of reference and to

prevent confusion. Example player actions, both successful and unsuccessful, are

itemized in the column labeled "Player Action(s)." The computer's reaction to these

player actions is listed next, labeled "Computer Reaction(s)." While there is little room

for argument about the actions listed in these second two columns, the final four

columns are a result of author interpretation and should be understood in that light.

These columns include: "Intended Denotation" which describes the presumed intent for

the computer's programmed reaction to the listed player action, "Concept(s) Reinforced"

which states the factual information about the science topic that the game is designed to

teach players, "Techniques(s) Reinforced" listing the principles (cooperation, player

agency, etc.) that the computer's reaction appears to be promoting, and "SRL Support

Feature(s)" which lists the mechanisms of the game that scaffold self-regulated learning

(SRL) in players.

Table 4: Procedural rhetoric of *Waves*: Level 2

	Player Action(s)	Computer Reaction(s)	Intended Denotation	Concept(s) Reinforced	Technique(s) Reinforced	SRL Support Feature(s)
A)	Players 1 & 2 step side-to-side at individual paces	-Instructions appear: "Make the entire middle wave glow green using DESTRUCTIVE INTERFERENCE" -Prompt 1 appears: "Could this level be too difficult for some people?" -A blue wave forms in front of Player 1 -A yellow wave forms in front of Player 2 -Middle wave remains red -Task 1 ("Create a wave") is checked off	-There is a goal for this level -Players have created individual waves and completed Task 1 -Player wave sizes and speed reflect player motions	-Waves move side-to-side -Players can alter wave speeds -Players can alter wave sizes	-Agency: player movements effect change within the game -Strategy use: Prompt 1 encourages players to think about the goal and how to achieve it	-Task bar breaks level's goal into concrete tasks -Prompt 1 reminds players of the goal for this level encouraging them to plan a strategy -Positive visual feedback indicates wave speed and size of each player's wave is a result of each player's movements
B)	Players 1 & 2 step side-to-side in sync (left together and right together)	-Player waves continue to respond to player motion -Prompt 2 appears: "Is the wave responding to your movements the way it should?" -Middle wave remains red -Prompt 3 appears: "Is there anything different that could be tried here?"	Different wave movements are required to complete this level (stepping in sync is not the correct motion for this level)	-Player motions effect change in wave patterns -Destructive interference is not created by two waves moving in the same direction	-Agency: player movements effect change within the game -Strategy use: Prompt 1 encourages players to think about the goal and how to achieve it, Prompt 2 asks players to assess the efficacy of their motions in controlling the wave	-Prompt 2 reminds players to monitor their actions within the game -Negative visual feedback shows middle wave remaining red -Prompt 3 reminds players to monitor their lack of progress toward the goal
C)	Players 1 & 2 step side-by-side in opposite directions (1 steps left when 2 steps right)	-Player waves continue to respond to player motion -Red middle wave turns green -Task 2 ("Turn the middle wave green using destructive interference") is checked off	Players are moving in the correct way to succeed in this level and have completed Task 2	-Destructive interference is created when two waves move in opposite directions	-Collaboration: players must coordinate their movements so that they are stepping in exactly opposite directions, often requiring much verbal communication	-Task bar breaks level's goal into concrete tasks -Positive visual feedback shows wave turning green

	Player Action(s)	Computer Reaction(s)	Intended Denotation	Concept(s) Reinforced	Technique(s) Reinforced	SRL Support Feature(s)
D)	Players 1 & 2 step side-by-side in opposite directions (1 steps left when 2 steps right) creating a small middle wave	-Green middle wave glows green -Task 3 ("Make a small middle wave glow green using large destructive movements") is checked off -"Success" stars appear all over the game floor -Destructive Interference Badge appears, along with the message "Congratulations! You used DESTRUCTIVE INTERFERENCE to create a winning wave!" -Reflection prompt appears, "How does this level work?"	Players are moving the correct way, have finished Task 3, and have completed Level 2	-Destructive interference is created when two waves move in opposite directions to create a small middle wave	-Collaboration: players must coordinate their movements so that they are stepping in exactly opposite directions, often requiring much verbal communication	-Task bar breaks level's goal into concrete tasks -Positive visual feedback shows wave glowing green -Positive visual feedback shows stars on game floor to indicate success in Level 2 -Reflection prompt encourages player reflection on their actions in the level

For example, row A, appearing in Table 5, describes a typical first player action in level 2: "players 1 & 2 step side-to-side at individual paces." The next column describes the computer's reaction to this movement by the players. Several things happen at almost the same time: a prompt appears on the floor in front of the players that reads, "Could this level be too difficult for some people?" At the same time, a blue wave forms in front of Player 1, moving side-to-side at the same pace as her motions; a yellow wave appears in front of Player 2 moving at his pace, and the red wave between players moves at a pace and with a wavelength that is the average of the two players' waves. Task 1, "Create a wave," appearing in the task bar on the game floor, is also grayed out with a green check mark beside it. The next column in the chart, "Intended

Denotation," gives the assumed reasoning behind these computer reactions: to encourage players to think about the goal for this level, to teach players about the game mechanics of wave sizes and speed (they both reflect player motions), and to indicate to players that they have created individual waves and therefore completed task 1 on the task bar. Next on the chart is "Concept(s) Reinforced." The computer's reactions teach players that waves, as represented in this game, move side-to-side and that the players can alter the speed and size of their assigned (blue or yellow) wave. The "Technique(s) Reinforced" column speculates that these reactions promote the techniques of player agency, i.e., player motions effect direct change within the game, and thoughtful gameplay: players are encouraged to think about the goal and how (challenging it may be) to achieve it. Finally, the "SRL Support Feature(s)" column dealing with player action A explains that SRL is supported through the game's use of a task bar that breaks the goal for the level into three concrete tasks. The prompt asking players to think about the goal for this level encourages players to plan and strategize, which is another characteristic of SRL scaffolding, and the visual feedback of the waves' motions reflecting the players' motions also supports SRL. Four other sample player actions are also listed in Table 5. In an effort to focus on the analysis of the procedural rhetoric charted in this game, now that one row has been explained in detail, these other actions will not be expounded upon in as much depth. The examination of these actions in this detail is designed to allow for interpretation of the WBEGs in order to shed light on possible assumptions (conscious or unconscious) made by the games' designers. With this perspective, the remainder of this chapter focuses on the final two

95

columns in each of the three tables: "Technique(s) Reinforced" and "SRL Support

Feature(s)."

Techniques Reinforced

The items listed under the "Techniques(s) Reinforced" column may at first glance

seem to be rather superficial and obvious. This is purposeful; these obvious indicators

within the game—which could even be considered by some to be design cues—are

delineated at this level to help provide transparency to the process of procedural

rhetorical analysis utilized in this study. In order to arrive at an assessment of the

techniques and, ultimately, the values that these games reinforce, each game's

structure must be broken down to action-reaction transactions. The game's rewarding

or punishing of specific player actions indicate underlying beliefs held by their

designers. The next chapter will discuss the meanings and implications of these

reinforced techniques and values in more thorough educational, sociocultural, and

rhetorical contexts.

The procedural rhetoric of *Waves* seems to reinforce three main techniques:

player agency, strategy use, and collaboration between players. Player agency, the

idea that players are in control of important decisions within the game, is reinforced by

computer reactions signifying that players' physical motions cause change within the

game. For example, when a player's body shifts back and forth, that player's wave

makes similar motions. When a player stands still, so does her wave. Players therefore

extend their human bodies into the digital realm of the WBEG, becoming a cyborg, to

use Hayles's (2005) term. Their body movements are represented by the motion of the

waves within the game. When the player is immersed in gameplay, the wave is seen as

not merely imitating her or reacting to her physical cues but actually a part of her—a

digital extension of her own, human self, controlled by her brain. This creates the

human-technology cyborg and sets the stage for embodied learning. Another game

element that indicates player influence is the checking off of the first item in the task bar.

This demonstrates to the player that her motions have in fact created a wave and

changed her goal to the next task. The prompt questions also encourage player

agency. These general questions are written in a generic way with a tone that seems

more like the game is asking for the players' opinions or advice rather than a quiz-like

tone assessing their understanding or intelligence. Thus, the question, "Is the wave

responding to your movements the way it should?" puts no pressure on the player to

give a "correct" response, nor does it cause the player to question her abilities or

understanding. Rather, this question empowers the player to assess an element of the

game itself, putting her in the position of the expert play-testing the game. This creates

a strong sense of player agency and control, which, as mentioned above, is an

important aspect of learning tasks in that autonomy is a fundamental psychological

necessity that also fosters motivation (e.g., Eichenbaum et al., 2014). Even the prompts

that appear when players are struggling are written in this non-threatening tone: "Is

there anything different that could be tried here?" This innocuous question helps the

player assess the situation and look for other options in a way that a more pointed

question would not (e.g., "What do you think you are doing wrong?" or "Why don't you

try moving faster?"). This tone is intended to remove any sense of "test anxiety" from

97

the game and emphasize for players that although they are being asked questions that require them to pause and think, they are still playing a game in a fun environment. Turning a WBEG like this into a replication of a traditional classroom activity would defeat the purpose of using the platform altogether.

The next technique that the procedural rhetoric of *Waves* reinforces is strategy use. The use of strategy seems like it would be something that all games reward, but many games reinforce guessing and emphasize chance. The emphasizing of player strategy is more common in educational games, but is certainly not absent from all entertainment games. Players of *Waves* are encouraged by the prompt questions as well as the task bar to think about their current actions, to assess the efficacy of those actions, and to plan ahead. The task bar and prompting questions are designed to encourage players to strategize their game play. The task bar lists small, concrete actions that the players must complete in order to achieve the main goal for the level, to help players plan ahead and think about their actions. It also helps them to assess their actions amidst gameplay; if players think that their current actions will result in completion of a task but the task has not been checked off, they are likely to try a different strategy. The prompting questions also support strategy use by asking players to think about the goal for the level (e.g., "Could this level be too difficult for some people?") and by reminding them to assess and monitor the effectiveness of their actions (e.g., "Is the wave responding to your movements the way it should?").

Finally, collaboration between players is also a technique encouraged by the procedural rhetoric of *Waves*. Inoperable by a single player, *Waves* is a two-player

WBEG. In order to complete level 2, for example, players must coordinate their motions

at a very precise level, stepping in exact opposite directions in sync until the middle

wave reaches a specific amplitude. This is nearly impossible to accomplish without

extensive collaboration and communication between players. Many players

participating in the quantitative studies discussed in Chapter Two could find success

only after verbalizing the direction they stepped, with one or both players chanting "left,

right, left, right," or some variation of this. Furthermore, players are never told what

movements they need to execute in order to complete a level, so there is an additional

body of collaboration required between players in order to discern exactly which

strategies and actions will accomplish their goal. The prompting questions and task bar

also encourage collaboration between players, as they appear in the center of the game

floor, indicating that they are tools to be utilized by both players. These items both

prompted discussion among players at various times during the studies described in

Chapter Two, as well.

Argument Being Made

The procedural rhetoric of *Waves* reinforces the techniques of player agency,

strategy use, and collaboration. Thus, *Waves* appears to be making the argument that

learning about waves in a whole-body environment requires players to understand that

they have influence and power to make key decisions within the game. This is a

necessary aspect of most games, as players require feedback to understand exactly

which of their actions will accomplish the game's goals. Agency such as this is also

empowering, boosting player confidence to experiment within the game and to work to

overcome game challenges. As discussed previously, confidence and motivation are linked together and also promote SRL. When a learner receives positive feedback, her self-efficacy increases and she is motivated to continue a challenging task.   Digital literacy, too, requires motivation to acquire and confidence to utilize. Selber's (2004) understanding of digital literacy includes the digitally literate learner's eventual ability to alter technology—to think on the level of a designer and improve technology—a daunting task that requires a great amount of confidence. The digitally literate learner and the self-regulated learner share many traits. They are both responsible for their own learning, motivated and goal-oriented enough to monitor their progress, and obtain (or improve) their skills as required to complete educational tasks. Another argument *Waves* seems to make is that players should strategize and not blindly guess which actions they should execute. The prompting questions appear throughout each level, reminding players to reflect on their actions and give thought to the next move. Reflection is a key aspect of self-monitoring and both are components of SRL. This emphasis on strategy mirrors the self-regulated learner's use of other cognitive and metacognitive strategies. Digitally literate learners also use these strategies. As they use, critique, and work to improve technology (Selber, 2004), they reflect on their processes and the technology itself, developing approaches more efficient use and planning ways it can be improved. Additionally, player collaboration is reinforced, suggesting the argument that working with others is an efficient way to learn. *Waves* is a two-player WBEG, and both players' actions hold equal influence over the center wave and therefore the outcome of the game. SRL, too, is social and utilizes peer

feedback and collaborative learning; feedback and collaboration can also help improve digital literacy skills.

From an educational standpoint, the emphasis of these techniques is indicative of the sociocultural theory of learning. *Waves* is strategically designed to induce learning; students are placed in collaborative pairs and provided opportunities to build their own understanding of how waves interact with one another. The structuring of the learning activities around learner agency reiterates the sociocultural theory of learning and even follows recommendations by the similar ideals of constructivists. Learner independence and teachers-as-facilitators are primary themes in these theories (Wang, 2007). In *Waves*, players are presented with a challenge at each level that they must overcome using their prior knowledge and the feedback cues from the game—a type of activity often referred to by educators as problem-based learning, which is a style of learning activities employed by socioculturalists as well as constructivists. The defining nature of *Waves* as a WBEG, as well, places it in the embodiment camp. Players physically move to control the wave, in this way experiencing wave motion with their bodies. They embody the digital wave, in a way projecting themselves onto the technology as a cyborg (Hayles, 2005). The game also mediates the communication between players, at times literally prompting them to discuss certain topics. Further, this player collaboration design invokes an arcade-game-like feeling of "players versus the computer" where the two human players work together to try to "beat" the electronic game, cooperating in order to complete challenges presented by the game. Finally, digital literacy, which could include a variety of WBEG techniques required to even

101

know how to begin to play the game, is a reminder of just how entrenched in technology we already are. It is only in very recent history that the general structure, or grammar, of digital games has become thought of as common knowledge. For example, if a student who had never seen a video game of any type was asked to play *Waves*, she would probably have great difficulty. Digital literacy skills that the general population is assumed to have, such as understanding that projected items in the game can be manipulated by players' body movements, could require a great deal of time to explain to someone completely unfamiliar with the genre of video games.

SRL Support Features

The procedural rhetoric of *Waves* reveals several design features that support SRL. First, at the beginning of the level, instructions appear in the center of the game floor, disclosing the goal for level 2: "Make the entire middle wave glow green using DESTRUCTIVE INTERFERENCE." Goal setting is a major component of SRL as it enables learners to monitor their progress toward the goal and to know when they need to adapt their behavior to better accomplish it. Next, the task bar that lists three concrete actions that players need to complete to reach the level's goal encourages players to adopt those goals and helps guide them to a strategy for achieving the main goal of the level, which, in level 2, is a destructive wave. The task bar highlights the action that players need to complete at the current time while also displaying in a less emphasized shade, the other tasks to be completed. Again, this enables players to plan ahead. After a task is completed, it is checked off but also remains on display, encouraging players to reflect on the progress they are making.

Next, the feedback provided by the game in the form of wave motions promotes self-monitoring, a key SRL component. The players' waves respond to the individual motions of the players and the middle wave responds to the combination of the two player waves. This entails the size and speed of the blue wave and the yellow wave according to the motions of Player 1 and Player 2, respectively. It also includes the size, speed, and color of the middle wave: the middle wave changes from red to solid green to glowing green as players' waves correctly influence the middle wave (it also changes from green back to red as a result of the incorrect motions of the players' waves). Additionally, the scaffolding prompts support various stages of SRL. The initial prompt, "Could this level be too difficult for some people?" which appears on the game floor immediately following the level instructions, directs players' attention to the main goal for the level, and goal setting is integral to SRL. The prompts that appear later in the game, "Is the wave responding to your movements the way it should?" and "Is there anything different that could be tried here?" remind players to monitor the progress they are making (or to notice their lack of progress) toward the goal. These prompts encourage reflection on their current actions and perhaps attempting a new strategy. Monitoring progress toward a goal and utilizing cognitive strategies are both key components of SRL. These "middle" prompts also spur player conversation and collaboration, which are also important aspects of SRL; as players collaborate to better understand the game and their level of success, player discussion could include a range of SRL-promoting topics such as reflection on progress toward the goal, planning of future strategies, and social help-seeking, to name a few. Finally, the success stars and

message of "Congratulations! You used DESTRUCTIVE INTERFERENCE to create a winning wave!" all give the players the SRL-supporting feedback that they have successfully completed the level. This feedback, along with the reflection prompt, "How does this level work?" encourages players to reflect on the level and to verbalize the actions they executed in order to achieve success. This reflection on completed tasks is another hallmark of self-regulating learners.

To summarize, *Waves* reinforces player agency, thoughtful strategizing, and collaboration. SRL support features include the task bar, visual feedback, and pop-up prompting questions, which scaffold the SRL behaviors of goal setting, strategy planning, use of feedback, monitoring progress toward a goal, collaboration, and reflection on the completed task. The implications of these findings will be discussed in Chapter Four.

Procedural Rhetoric of *Color Mixer*

The procedural rhetoric of *Color Mixer* is detailed in Table 6 below, which contains four example player actions that could occur in level 2. As explained above, each row charts a distinct player action, and each column describes a specific aspect of the game's procedural rhetoric based on that player action. Again, *Color Mixer* requires three players to coordinate their arm motions in order to match different colors generated by the game. When players correctly match the target color, they hear three beeps and see the color they created around the edges of the color target. When players do not correctly match the prompted color, the black outer circle grows, indicating they will be given less time to match the next color, and no auditory feedback

is given. The level ends when the black outer circle has grown so large as to make it

impossible for players to continue matching the colors.

Table 5: Procedural rhetoric of *Color Mixer*: Level 2

	Player Action(s)	Computer Reaction(s)	Intended Denotation	Concept(s) Reinforced	Technique(s) Reinforced	SRL Support Feature(s)
E)	Red and Blue players raise wand, Green player keeps wand low in response to game target "magenta"	-Black outer circle becomes magenta; -Target color disappears; -Three-tone "correct" beeps play	Player actions are correct	Red and blue combine to create magenta	Collaboration: all three players must coordinate movements to achieve correct combination, often requiring much verbal communication -Agency: player movements effect change within the game	Positive visual and auditory feedback indicates successful color mixing
F)	Red and Blue players raise wands in response to game target "white;" Green player raises wand but not quickly enough	-Black outer circle grows -No sound plays -Next target color appears	Player actions are incorrect	Red and blue do not combine to create white	-Collaboration : all three players must coordinate movements to achieve correct combination, often requiring much verbal communication -Agency: player movements effect change within the game -Speed is important	Positive visual and auditory feedback indicates successful color mixing
G)	Blue and Green players raise wands in response to game target "yellow"	-Black outer circle grows -No sound plays -Next target color appears	Player actions are incorrect	Yellow is not made by the combination of blue and green	Collaboration : all three players must coordinate movements to achieve correct combination, often requiring much verbal communication -Agency: player movements effect change within the game	Negative visual feedback and lack of positive auditory feedback help players briefly reflect on incorrect actions
H)	All three players keep wands low in response to game target "red"	-Black outer circle grows -No sound plays -Next target color appears	Player actions are incorrect	Red is not made by the absence of red, blue, and green	Collaboration : all three players must coordinate movements to achieve correct combination, often requiring much verbal communication -Agency: player movements effect change within the game	Negative visual feedback and lack of positive auditory feedback help players briefly reflect on incorrect actions

The techniques that appear to be reinforced by the procedural rhetoric of *Color Mixer* are agency, collaboration, and speed. Player agency is communicated by the game through the positive or negative feedback of the outer circle and the beeps or absence of the beeps. If players make no movement, they cannot achieve success in the game. As discussed above, player agency is an important component of SRL and digital literacy, fostering learner confidence, self-efficacy, and motivation. Another technique promoted by *Color Mixer*'s procedural rhetoric is that of player collaboration. No level of the game can be completed with only one player. Each level requires the coordinated motions of three players, which inherently also necessitates communication between players. Again, collaborative, social learning is required for SRL and greatly augments digital literacy learning. Finally, *Color Mixer* also rewards player speed. Each color appears for just a few seconds, demanding quick responses from players. This implies that the game also rewards rote knowledge of color combinations: players have just a few seconds to 1) recognize the color they are being asked to create 2) recall the combination of red, blue, and green that creates that color 3) raise or lower their wands based on each player's assigned color. Players who do not have a strong command of color combinations will not fare well in this game, nor last very long until they have learned them. It can be assumed, however, that novice players will greatly improve from repeated playing of *Color Mixer*, as practice can improve memory and most skills. The facilitator, given his ability to pause the game with a remote control, could certainly also scaffold novice players by allowing them more time to recall the correct color combinations and to discuss options with the other players and the

106

facilitator. Rote knowledge is not usually sought after in the age of 21st century skills and instant Internet searches, so the inclusion of this technique in a WBEG such as *Color Mixer* is an interesting design choice. Perhaps this element was intended to increase player motivation and enjoyment.

Argument Made

The significance of agency, collaboration, and speed in *Color Mixer* seems to argue that, like in *Waves*, the players have control over certain aspects of the game. This again points to game feedback that teaches players the game's rules, goals, and content and encourages SRL-supporting and digital literacy-supporting motivation and confidence. *Color Mixer* also argues, by requiring player collaboration, that learning in groups is effective, which is also endorsed by SRL theories. All three players hold equal sway in the game. They must each make the correct motion; if one player decides not to participate, the others cannot be successful. Furthermore, all three players must act correctly within seconds of a color's appearance. This valuing of speed requires all three players to act quickly and therefore all players must have knowledge of a wide array of color combinations, creating the argument that rapid recall of the content knowledge is important in this WBEG.

SRL Support Features

Color Mixer, a WBEG, contains features that support SRL even though its creators do not overtly state their intent to include them, unlike *Waves*, which was modified with the task bar and pop-up prompts in an explicit effort to scaffold SRL. The

goal in *Color Mixer* is to match the rapidly changing center circle's color, so each new

color presents a new goal. Though brief and quickly changing within the game, this

presentation of a goal supports the goal-setting behavior of the self-regulated learner.

Feedback then enables players to self-monitor their success or failure to match the

color. Success is communicated by the black outer circle staying the same size but

changing to the same color as the center circle and by three auditory beeps. Failure is

indicated by the black outer circle increasing in size as well as the absence of any

sound effects.

Thus, the procedural rhetoric of *Color Mixer* seems to indicate that the game

places emphasis on player agency, collaboration, and speed. The features in this

WBEG that support SRL include goal setting and visual and auditory feedback. The

implications of these results will be discussed in Chapter Four.

Procedural Rhetoric of *Light and Mirrors*

Light and Mirrors is a two-player, one-facilitator WBEG where players use mirrors

to reflect light from a virtual laser around obstacles toward a target. Players achieve

success when the laser hits the bull's-eye of the target and the target reflects the

"sparks" of the laser. No auditory feedback is given, positive or negative, in this WBEG,

and players are made aware of failures simply by the lack of positive feedback. Levels

are not timed and can be adapted by the facilitator at any time during gameplay. Table

7 below charts the procedural rhetoric of *Light and Mirrors.* As with the other two tables

analyzing WBEG procedural rhetoric above, each row charts a distinct player action,

and each column describes a specific aspect of the game's procedural rhetoric based

on that player action.

Table 6: Procedural rhetoric of *Light and Mirrors*: Sample level

	Player Action(s)	Computer Reaction(s)	Intended Denotation	Concept(s) Reinforced	Technique(s) Reinforced	SRL Support Feature(s)
I)	Players 1 & 2 with wands bend down simultaneously to pick up mirror	-One mirror handle changes to blue -Other mirror handle changes to green	Mirror has been "grabbed" by both Player 1 (blue handle) and Player 2 (green handle)	Mirror can be manipulated by two players	Cooperation: moving mirror requires two players to coordinate their movements and communication	Positive visual feedback indicates mirror has been grabbed and can now be moved
J)	Player 1 stands up more quickly than Player 2 to move mirror	Blue mirror handle changes to black	Player 1 has lost her "grip" of mirror	Mirror must be manipulated uniformly by two players	Cooperation: moving mirror requires exact coordination of two players and some communication	Negative visual feedback indicates mirror can no longer be moved
K)	Players 1 & 2 simultaneously lift wands to same height above mirror and walk together	-One mirror handle changes to blue -Other mirror handle changes to green -Image of mirror moves in the direction of the players	Mirror is being manipulated by Players 1 & 2	Mirror must be manipulated uniformly by two players	-Agency: players can manipulate objects in the game -Cooperation: moving mirror requires exact coordination of two players and communication	Positive visual feedback shows mirror under players' control
L)	While holding wands at same level above mirror, Player 1 stands still while Player 2 steps slightly forward	-Mirror handles remain blue and green -Mirror pivots with Player 2's movement	Mirror is being angled by Player 2	Mirror can be angled by coordination of two players when their wands are at the same height	-Agency: players can manipulate objects in the game -Cooperation: moving mirror requires exact coordination of two players and communication	Positive visual feedback shows mirror under players' control
M)	Players 1 & 2 angle mirror so that laser strikes the center of the target	-Laser reflects in mirror onto target -"Sparks" emanate from bull's-eye of target -Three-tone "correct" beeps play	Players have successfully "hit" target with laser using the correct angle of the mirror	The angle of the mirror determines the angle of the laser's reflection	-Strategy use: thoughtful game playing yields success -Cooperation: moving mirror requires exact coordination of two players and communication	-Positive visual feedback shows laser under players' control -Positive visual and auditory feedback of "sparks" and beeps indicate completion of level

Techniques Reinforced

Light and Mirrors emphasizes player agency, collaboration, and strategy use. Player agency is supported via subtle visual cues from the game, such as the mirror handle's color changing when a player has effectively "grabbed" it and can now pivot the mirror (or, if the other player has also successfully "grabbed" the other handle, the color change indicates the players' ability move the mirror around the floor). As with the other WBEGs, feedback indicating player autonomy is common and important in these types of games to grow SRL- and digital literacy-supporting player confidence and to teach players about the game's limitations, objectives, and subject matter (e.g., Gee, 2003). *Light and Mirrors* also emphasizes collaboration between players. Limiting auditory feedback allows players to comfortably communicate with one another without having to compete with sound emitted from the game. *Light and Mirrors* is a two-player, one-facilitator WBEG. Both players are required in order to execute any action whatsoever in the game (such as moving mirrors). One player cannot move a mirror alone. Thus, each player must participate equally in the game in order to be successful. Collaboration is also encouraged by the unlimited amount of time given to players to complete a level. The slower pace of an untimed game promotes player discussion and collaboration much more effectively than a timed or fast-paced game. Again, collaboration is a component of SRL and can increase digital literacy skills. The collaborative and slow-paced nature of *Light and Mirrors* also fuels strategy use. Players have no need to rush and therefore no need to make wild guesses. Purposeful placement of mirrors, often preceded by inter-player discussion, is more likely to result

110

in success in this WBEG. Mindful, reflective behavior is indicative of SRL, and according to Selber (2004), digitally literate learners reflect on technology, how it is being used, and how it should be used.

Argument Made

Light and Mirrors supports the techniques of player agency, collaboration, and strategy use. Like the other WBEGs discussed here, *Light and Mirrors* argues that these game genres must alert the players in some way that their actions effect change within the game. The feedback given in *Light and Mirrors* is entirely visual and somewhat subtle, but it is absolutely necessary to impart upon players the rules of the game, the goals of the game, and the content of the game. *Light and Mirrors*, like the other two WBEGs above, reinforces collaboration between players and argues that learning with others is efficient learning. The final technique reinforced by the procedural rhetoric of *Light and Mirrors* is that of strategic playing. This emphasis again makes the argument that purposeful actions are preferable to thoughtless guesses.

SRL Support Features

Light and Mirrors is another WBEG where the game designers do not specifically claim to have embedded scaffolding for SRL, but these features are revealed by the procedural rhetoric nonetheless. In this game, there is one overarching goal: use the mirrors to direct the laser onto the target's bull's-eye. The slow pace of this game, created by the absence of a game clock or timer, encourages players to strategize, communicate, and constantly assess their progress toward the goal—all of which are

111

components of SRL. Visual feedback again helps players monitor their progress toward the goal. Mirror handles change colors when they have been "grabbed," and the mirror position changes in response to player motions. The laser also provides feedback, reflecting from the mirror across the game floor according to the angle it strikes the mirror. The target's "sparks" indicate the successful completion of a level. This feedback greatly supports SRL in providing evidence of performance that players can then compare to the performance necessary to reach the goal. These SRL-supporting features, as well as the techniques reinforced by the procedural rhetoric of these three WBEGs are discussed in the next chapter.

This chapter analyzed the procedural rhetoric of three similarly-structured WBEGs. Though the physical makeup of these games is very similar, their programming is strikingly different. While all of the games require players to perform specific physical actions much different from the actions necessary to play a traditional video game, player movement in these WBEGs ranges from standing still to stepping side-to-side to freely walking about on the game floor. Likewise, the playing techniques encouraged by these games were different, with the exception of player agency and collaboration, which are reinforced by all three WBEGs though in different ways. *Waves* and *Light and Mirrors* reward player strategy while *Color Mixer* requires speed and rote knowledge. They all scaffold SRL behavior in different ways, as well, providing players with goals and giving feedback that allows players to assess their progress. The next chapter addresses these findings and discusses their implications in more depth.

CHAPTER FOUR: DISCUSSION

The focused study of these three WBEGs is intended to investigate the implicit ideology of the games' designers. The last chapter used the tools of procedural rhetoric to expose the games' values and SRL-scaffolding features. This chapter discusses the implications of these reinforced techniques and skills in educational, sociocultural, and rhetorical contexts.

Educational Context of Reinforced Techniques

Waves, *Color Mixer*, and *Light and Mirrors* all emphasize player agency and collaboration. *Color Mixer* rewards players for speed and rote knowledge, while *Waves* and *Light and Mirrors* emphasize player strategy. All three games emphasize player agency in slightly different ways. *Waves* requires players to move their feet and therefore their entire bodies in order to effect change within the game. *Color Mixer* players raise and lower wands, and *Light and Mirrors* players must pair up and move their wands in unison to manipulate objects in the game. Learner agency manifests itself in many forms, and it is a key component of student-centered instruction, which is endorsed by the two types of learning theories discussed above, constructivism and socioculturalism. The requiring of players to physically move their bodies reinforces the idea of agency; players' physical actions result in visible changes in each game. This physical component provides the additional benefits of embodied learning discussed previously. Collaboration, too, is a technique embedded within all three games. Once again, it is done differently in each game. *Waves* gives each player control over

individual waves, and players must coordinate their separate waves in order to effect change on a third wave. *Color Mixer* requires each player to move each of their wands individually, and the combination of all three players' movements results in a success or a failure within the game. In *Light and Mirrors*, players must discuss their strategy and exactly coordinate their movements with their wands to manipulate game objects. Thus, collaboration can occur in a variety of forms and games. Constructive and sociocultural educational theories both endorse collaboration, as well. Constructivists encourage learners to interact with the world and with others to improve their understanding of concepts. Sociocultural theory views learning as a social series of intentional activities that students perform together to build collaborative knowledge. *Color Mixer* alone seems to reward speed and rote knowledge.   Although it is likely that this element of the game was added in order to better engage players with the game and its content, it stands out in its connection to the educational theory of behaviorism. Behaviorism as a learning theory has generally fallen out of favor, though many of its practices remain in traditional education. Classrooms adhering to the beliefs of behaviorism rely on lectures by teachers, rote memorization by students who are assigned tasks that are primarily the repetitive practice of lower-level thinking skills. *Color Mixer* could be considered such a task, as players repeatedly practice making additive color combinations.

The emphasis of strategy use found in *Waves* and *Light and Mirrors* encourages players to engage in the three key phases of SRL. When players strategize, they plan, monitor their progress, adjust their strategies as a result of the game's feedback, and

reflect on the game's challenges. These are the key aspects of SRL. Planning and choosing a goal encompass Zimmerman's (1998) *forethought phase* of SRL. Monitoring their progress throughout the game constitutes his *performance phase*, and the act of reflecting on the game comprises Zimmerman's (1998) *self-reflection phase* (p. 278). *Color Mixer*, too, provides its players with goals. All three WBEGs also present rich feedback to players, enabling players to assess their progress toward the goals. *Waves* offers additional SRL support features in the form of the task bar and prompting questions. The task bar supplies mini-goals that also give visual indication of checkmarks to indicate player progress toward the larger level goal. The prompts encourage players to monitor and reflect on their performance throughout the level. *Waves* also possesses the additional SRL feature of a reflection prompt at the end of each level; this question is intended to induce player reflection on the entire level and specifically the actions they performed to achieve success.

Sophisticated digital literacy skills are required in order to play any of these three WBEGs. Players must understand the general game mechanics and symbols of each game; they must also be able to correctly interpret game feedback. This digital literacy is not innate, though it is often assumed of WBEG players just as, for example, film literacy is assumed of audiences. In the 1920s, a British doctor named William Sellers created educational films for native populations in Africa and, based on the natives' reactions while watching the films, Sellers created a series of guidelines for future instructional films (Parsons, 2004). These guidelines were based his observations that the natives focused on the "wrong" things (such as a chicken in the corner of the screen

rather than the main characters in the center), got confused by flashy camera work such as close-ups, were easily confused by images of unfamiliar things, and laughed at "inappropriate" moments. What Sellers mistook for a lack of intelligence in these audiences was simply a lack of film literacy. These populations had never seen a film and therefore did not "read" the film in the same way that film literate populations did. The same is true for novice video game players. Those who have never seen or played video games must acquire the digital literacy skills necessary to understand the meaning behind game images, which are often simplified using visual, culturally-dictated shorthand. WBEGs are designed to teach players many of these things as they play. Players effectively practice and improve their digital literacy skills while playing a WBEG, increasing their abilities to learn within that game and others. Many video games as well as the three WBEGs in this study afford players opportunities in early levels to acquire knowledge and skills that are required in later levels. This scaffolding ensures more efficient learning and allows players to improve their abilities to apply newly acquired knowledge to new situations and contexts.

Sociocultural Context of Reinforced Techniques

The prominence of player agency and collaboration in all three games leads to the conclusion that the designers of these WBEGs are biased toward the more contemporary learning theories of student-centered instruction, though the designers of *Color Mixer* also emphasize rote knowledge characteristic of behaviorism and teacher-centered instruction. These designers also have a bias toward a specific kind of knowledge, science content knowledge. Players entering these games with prior

knowledge of wave behavior, additive color, reflection, and angles will have an advantage over players who lack this knowledge. These games also recognize only this type of intelligence and not, say, musical intelligence or any of Gardner's (1983) other multiple intelligences. Additionally, due to the nature of game programming, these games possess a bias toward specific, single solutions within these specialized knowledge bases. *Waves* players must produce a certain wavelength in the center wave. *Color Mixer* only accepts additive color combinations, which are different from more commonly known subtractive color combinations (those achieved by mixing primary paint colors). *Light and Mirrors* deals solely with reflection of lasers rather than other, more common light sources. Finally, these games each differently bias specific body movements. In *Waves,* players are only recognized as participating in the game if they are tall enough to be sensed by the motion-tracking equipment secured to the ceiling above the game floor. *Waves* players are also expected to step from side to side while remaining facing to the front; this is not the most intuitive way to form a virtual wave. Many study participants initially attempted jumping, sliding their feet from side to side, moving their arms from side to side while keeping their feet still, turning their whole bodies to take a few steps and then turning the whole way around to step in the other direction, etc. *Color Mixer* expects players to move very differently. Players of this game must stand in one place and only raise and lower the arm holding the wand. Other motions, such as moving their feet or raising their other arm, are not detected by the game because they do not change the wand's position. The motions of both of these WBEGs are fairly arbitrary, suggesting that game designers are not concerned

117

with matching virtual motions to non-virtual ones, although this could also be a result of constraints specific to the types of programming and equipment used. Only *Light and Mirrors* requires players to move in ways closely connected to the ways they would move the physical objects digitally represented in the game. To move a mirror in *Light and Mirrors*, players need to bend down, virtually grasp its handles (one player on each side), and lift, move, and lower it in unison, just as they would move a large, non-virtual mirror.

As mentioned above, digital literacy is required in order to play these three WBEGs. Visual symbols are present in each game and need to be correctly interpreted. Players of *Waves* must understand that the differently colored lines on the floor represent generic waves (e.g., light waves, sound waves, water waves, etc.). *Color Mixer* players must discern that the circle of color on which they stand represents the color that the raising and lowering of their wand contributes to the combined color that appears in the center circle. In *Light and Mirrors,* players read the symbols of a red-and-white circle signifying a target, a red line representing a laser, a rectangle with lines on each side denotes a mirror with two handles, and a rectangle with a brick pattern symbolizing a wall. The designers of these WBEGs made the assumptions that players could either immediately understand these symbols or quickly discern their meaning in the contexts of the games. Players unfamiliar with the items depicted by these symbols or the conventions used to represent them will be at a disadvantage in these games. Players inexperienced with game representations in general may have

118

difficulty comprehending the idea that these icons are intended to be representative of anything.

Rhetorical Context of Reinforced Techniques

The above analyses of these three WBEGs reveal the assumptions of the game designers as they relate to education and sociocultural biases. Placing the games' reinforced techniques and SRL scaffolding in a rhetorical context takes this analysis a step further. The study of rhetoric is the study of communication and generally includes communication intended to both express as well as to persuade. Traditional studies of rhetoric deal with verbal and written communication. Subfields of traditional rhetorical studies have emerged over time to include visual rhetoric, the study of communication through images, like the scholarship of Barthes (1977) and digital rhetoric, which studies communication as it is mediated through digital technology (defined in Bogost, 2007). The subfield of procedural rhetoric, the focus of this dissertation, is the study of communication as mediated through processes (Bogost, 2008). The rules of each WBEG, respectively, are expressions of specific perspectives of the world. The term WBEG itself can be broken down into perspectives. First, these games utilize motion-sensing technology to allow player participation to involve the *whole body*, taking the perspective of embodiment. Players make rather large motions with their bodies in order to play the games, and this movement engages parts of their brains not often utilized when playing traditional console games. Next, these games are *educational*, intended to teach the concepts of waves, additive color, and light reflection, respectively. This is done in a way that is comparable to simulations; concepts are

simplified and represented in two-dimensional worlds by somewhat abstract images. This educational perspective necessitates scaffolding and feedback, which are also common features of videogames. Feedback is crucial for SRL, which is a series of processes that result in effective learning. The three WBEG environments are also conducive to constructing knowledge through purposefully designed interactions with virtual objects as well as non-virtual players. Additionally, the WBEGs are of course *games.* Players are given performance goals and the evaluative feedback of winning or losing (albeit usually in the form of level completion/incompletion). The WBEGs' encoded rules influence player behavior to help them construct their own understandings of the educational concepts through simulation-like manipulation of virtual objects. As discussed above, digital literacy is required to play these WBEGs and to understand the explicit and implicit arguments they make.

Many of the behaviors of digital literacy are analogous to those of SRL. Digitally literate learners are able to understand, critique, and ultimately improve technology (Selber, 2004). Digital literacy and SRL both influence academic achievement and both are sets of skills that can be learned, practiced, and improved. Self-regulated learners understand a task's goals, monitor their progress, and reflect on the completed task. Returning to Zimmerman's (1998) definition of SRL, "the self-directive process through which learners transform their mental abilities into academic skills," it can also be said that digitally literate learners must be self-directed and able to use technology to leverage their knowledge for academic success (p. 2). Self-regulated learners have the ability to learn efficiently; the digitally literate can learn efficiently in a digital

120

environment. Like self-regulated learners, digitally literate learners are characteristically active learners, using cognitive and metacognitive strategies to accomplish tasks, monitoring their understanding, seeking and knowing how to obtain additional resources as needed. Even hyper-reading, Hayles's (2012) term for the combination of self-monitoring and self-regulating understanding of information presented in nonlinear formats such as Internet searches, involves SRL skills. Finally, most digital technology, like games, empowers users to learn on their own and to leverage their mental abilities into digital literacy skills.

Digital literacy, specifically the rhetorical literacy component championed by Selber (2004), includes the reflection on the construction of digital environments, the evaluation of these environments, and the alteration of the technology that created said environments. This dissertation reflects and evaluates three WBEGs in an effort to influence future iterations of these digital environments. Because technology influences humans and humans influence technology in a continuing feedback loop of technogenesis (Hayles, 2012), it can be assumed that the reinforced techniques, SRL scaffolding, and perspectives in these three WBEGs have been influenced by both humans (and therefore educational traditions and theories, sociocultural biases, etc.) and preexisting technology (videogames and other media). All four of the techniques of agency, collaboration, strategy use, and speed/recall that are reinforced by one or more of the WBEGs, are also fairly common to console video games. They are also commonly reinforced by non-digital games, suggesting a trail of influence reaching back centuries rather than mere decades.

Values of WBEG Designers

The three WBEGs, *Waves, Color Mixer,* and *Light and Mirrors* all reinforce a number of values that are also emphasized by American education. Most of these values also make up components of SRL and digital literacy skills. Many of these values are also core values of our culture. They are: accuracy, collaboration, problem-solving, learner autonomy, and the scaffolding of learning.

Pedagogical Values

Accuracy is one value that all three WBEGs seem to have in common; each problem within each game has only one correct solution. In *Waves* and *Color Mixer* especially, players must coordinate their efforts to achieve an exact solution to each given challenge—a specific wavelength and a precise combination of colors. *Light and Mirrors*, because of its open-ended nature, does *allow* players the freedom to solve the challenges laid forth by the teacher-player in more than one way. The game is structured to indicate success, however, when the challenge is solved the first time. In other words, *Light and Mirrors* also encourages one correct solution. These games give the player a sense of completion and finality when one correct solution is found; *Waves* and *Light and Mirrors* end each level when players solve the problem once. *Color Mixer* does this a bit differently, but still values one correct answer. A level in *Color Mixer* will continue as long as players can produce correct answers quickly enough and ends when players fail to achieve correct solutions within the allotted timeframe. Just as students can visually see the completion of a worksheet after they fill in all of the blanks,

it is very clear to players of all three games when one level ends. This idea that

learning is an exercise in producing a series of single, correct answers seems like it is

another artifact of behaviorist beliefs about education. It may also be the mark of

single-answer assessments that continue to pervade this country. The descriptions of

SRL, too, are riddled with the idea of learning tasks that need to be completed only

once, the correct way. Interestingly, digital literacy diverges from the single-solution

model, encouraging exploration, multiple solutions, and lifelong learning. Digitally

literate learners are "reflective producers of technology" (Selber, 2004, p.182), who work

to improve the digital realm. There is room within SRL models for multiple solutions; in

fact, encouraging learners to look for more than one correct solution to a given problem

would be an ideal way to scaffold self-reflection. In assessing a problem for additional

solutions, learners are compelled to reflect on the results of their previous solutions.

Collaboration is another value that these games and education have in common.

As discussed above, each game requires the physical participation of all players in

order for the team to succeed. Players will succeed more quickly when collaborating

with one another, in Waves and in Color Mixer; in Light and Mirrors, it is impossible for

players to succeed without orchestrating their physical motions, something that requires

and encourages much collaboration. Another marker of constructivist and sociocultural

educational theory, collaborative learning activities are thought to increase student

understanding and retention of new knowledge (Steinkuehler, 2005; National Education

Association, 2015) as well as critical thinking skills (Vygotsky, 1978; Gokhale, 1995;

Johnson & Johnson, 1999). The reproduction of this pedagogical style in these WBEGs

indicates the constructivist and sociocultural beliefs of the designers that learning is social. This belief encourages SRL, as well, because of its external, social component. When learners collaborate to complete a task, they give each other feedback and aid the other's self-monitoring process. The ability to collaborate with others to solve problems is also a skill required by the "real world." Society simply cannot function without collaboration between people of all types to solve all sorts of necessary problems. Technology, as it facilitates long-distance communication, is demanding stronger collaborative skills from those who use it. Digitally literate learners must become clear communicators to a variety of audiences. This value resonates across our culture, and it is not surprising to see it manifested within these WBEGs.

Problem-solving is another pedagogical value that has gained the endorsement of contemporary educators who continue to push away from the behaviorist teaching practices that focus on learning as memorization. One modern pedagogical teaching model is termed problem-based learning. This style follows the constructivist theory of education. In problem-based learning, students are presented with authentic problems to solve, and activities are student centered, self-directed, self-reflective, and facilitated by instructors (Hung, Jonassen, & Liu, 2008). *Waves, Color Mixer,* and *Light and Mirrors* could be considered to be problem-based learning activities. They present players with realistic challenges to solve in groups and are also player-centered, self-directed, self-reflective, and facilitated by instructors. The skills required of the student in a problem-based learning environment are also SRL skills: planning, monitoring, and reflecting. Problem-based learning requires learners to plan and self-direct, collaborate

to solve problems while self-monitoring, and reflect on their learning. Project-based learning and SRL can both be scaffolded by instructors or technology. Digital literacy also requires problem-solving skills. Selber's (2004) definition of digital literacy includes several problem-solving skills, such as competent use of technology, intelligent critique of technology, and the ability to reflectively produce technological improvements. These are without a doubt difficult, real-world problems. Problem-solving skills are important cultural values because the very existence of society rests on the problem-solving abilities of the people who exist within it.

Autonomy is another pedagogical value reinforced by these WBEGs; learners must be active agents in their own education. None of the games permit players to play without engaging at least physically in the game. Players who wish to remain passive observers will actually prevent their two- or three-player team from achieving the goal in any of the three WBEGs. This is a view of education that has gained traction in contemporary, formal education settings; learners must be responsible for their education and take an active role in learning activities. The interactive nature requiring player participation also happens to be one of the motivating factors for playing video games. Again, this constructivist or sociocultural concept of a learner being an active participant in education contrasts with the more traditional, behaviorist model of a learner as a passive recipient of knowledge. The idea of player agency within a video game also contrasts with more traditional forms of entertainment such as television or films where the audience consists solely of passive observers. Modern education embraces the learner who participates and self-regulates. SRL encompasses a variety

125

of activities requiring the learner to be autonomous. Digital literacy, too, requires active

participation and independence to effectively navigate technology. Our culture values

freedom and autonomy as well as participation and hard work over inaction and

laziness. An autonomous leaner in this context is not one who is free from the need for

any assistance, but one who can navigate well enough to locate additional help and

resources as needed.

Scaffolding of learning is another pedagogical value shared with games and

American education. The idea of providing scaffolding, or support, for students to

enable them to accomplish learning tasks just out of reach is a common pedagogical

theme. Scaffolding places more difficult activities within a student's zone of proximal

development (Vygotsky, 1978) and helps guide their learning. These WBEGs could be

said to have two facilitators, the WBEG itself and the human teacher/facilitator who

played the game with them (or, in the case of Waves, stood to the side). The WBEGs

here are examples of technology scaffolding learning. Color Mixer and Waves have

three levels of increasing difficulty, where the earlier levels give payers opportunities to

hone the skills they will need for the later levels. Light and Mirrors is entirely controlled

by the teacher-player who will likely scaffold the playing in a similar way, because

starting with an easier task and progressing to more difficult tasks is a common feature

of learning in our culture. In Waves, the facilitator scaffolds player learning and player

SRL by reiterating or clarifying the prompts embedded within the game. The Color

Mixer teacher-player is able to pause the game to scaffold player learning, perhaps

choosing to give players hints, allow them more time to collaborate, or adding higher-

order thinking questions to the game. In all three WBEGs, the human facilitators are able to provide additional scaffolding as the players need it. While giving students assistance on learning tasks as needed is common in nearly all models of education, the role of the teacher as a facilitator of learning (rather than the provider of knowledge) is a key feature of constructivist and sociocultural learning theories (Jonassen & Land, 2000). Self-regulated learners view their teachers as one resource at their disposal and seek facilitation as they need it. Digitally literate learners, too, are able to capitalize on the scaffolding provided by a variety of technology, leveraging it to access assistance as necessary. The value of scaffolding, of facilitated yet self-directed learning pervades society. Children explore the world safely under the guidance of their parents, for example, discovering things on their own and asking for answers to the whats and whys of the earth and beyond.

Waves, Color Mixer, and *Light and Mirrors* all reinforce several pedagogical values that are woven into the fabric of education in this culture: accuracy, collaboration, problem-solving, learner autonomy, and the scaffolding of learning. These pedagogical values can be found in a majority of formal and informal learning sites. They are also cultural values. The way we think about the learner reflects the way we think about ourselves. We enjoy being right. We are social. We like a challenge. We appreciate our freedom. And we reach out to one another for help when we need it. These cultural and pedagogical values are detectable within these WBEGs because of the above analysis of their procedural rhetoric. The design choices of these games reveal the assumptions their creators have about learning, learners, and society.

Research Questions Revisited

This dissertation focuses on a main research question and two sub-questions:

How can the procedural rhetoric of three whole-body educational games improve the understanding of self-regulated learning with digital technology?

1) *How effective are elements designed to support SRL in a WBEG?*

2) *What does the procedural rhetoric of three WBEGs reveal about the underlying assumptions of the designers of these types of games?*

The primary question is best answered only after exploring the answers of the two sub-questions. The hypothesis attempting to answer the first sub-question reads: *a WBEG can effectively support SRL through design features that prompt players to plan; monitor their actions, cognition, and strategies within the game; and reflect on their performance at the end of each level.* All three WBEGs in this study provided players with clear goals and feedback to aid self-monitoring, but only *Waves* specifically prompted players to monitor and reflect within the game. The quantitative study of *Waves* seems to point toward the acceptance of this hypothesis, with players' scores on the SRQ questions increasing slightly and their post-test scores demonstrating that they had increased their knowledge of wave movement and interaction. In the case study, however, it appears that the game itself may not be doing the effective prompting. Players responded more vocally to the facilitator's questions than to the written prompts. The players in the case study almost appeared to be ignoring the written prompts within *Waves* and instead responded to the prompting of the facilitator, though players did act as though they were reading and reacting to the three tasks in the task bar. This leads to the suggestion that

SRL behavior could be prompted by a WBEG itself in the absence (or silence) of a facilitator, a claim ripe for future research. Additionally, the number of SRL behaviors performed by the two players in the case study exactly matched the number of prompts that appeared to these players during this level of gameplay. This indicates that the quantity of prompts programmed into *Waves* was appropriate, which is important information for future game designs including scaffolding of SRL.

The hypothesized answer to this second sub-question focusing this dissertation reads: *The procedural rhetoric of three WBEGs reveals that these games privilege and rely on SRL-supporting elements to increase player familiarity with and understanding of science concepts.* The techniques reinforced by one or more of the three WBEGs revealed by this study are player agency, player collaboration, use of strategy, and rote knowledge. The problem-based learning tasks of these WBEGs encourage critical thinking by presenting players with real-world (though often simplified) problems to solve together. Many SRL behaviors are also reinforced. All three WBEGs present players with a goal, provide feedback, and encourage collaboration. *Waves* and *Light and Mirrors* both facilitate strategy planning, though in different ways. *Waves* prompts players to make purposeful movements and to monitor the success of their strategies while *Light and Mirrors* affords players all of the time that they need to plan and coordinate strategies. Only *Waves* specifically prompts its players to stop and reflect on a completed level. It should be noted, however, that additional SRL behavior could easily be prompted and scaffolded by the facilitator of each game.

Through the exploration of one WBEG using a quantitative study, a case study and the analysis of three WBEGs using the tools of procedural rhetoric to investigate the values they reinforce as well as the SRL elements they support, this dissertation strives to test the hypothesis: *the procedural rhetoric of three WBEGs can inform the understanding of SRL with digital technology by dissecting their design features and the elements that support SRL, enabling informed analysis and providing a rich description of the three games.* The discussion of the SRL-supporting elements that this study's analysis of procedural rhetoric reveals certainly informs the understanding of these elements and how they operate in these WBEGs. This game-specific information can then cautiously be generalized to other WBEGs, other video games, and also to other technology. The inclusion of scaffolds for goal setting, feedback, collaboration, strategy planning, progress monitoring, and reflection can all be incorporated into other technology. The fact that all three games did not include all of these scaffolds as well as the knowledge that different games supported the elements of SRL in very different ways also informs the understanding of SRL in digital technology. Scaffolding elements of SRL can exist in many different forms in digital technology. This dissertation also investigated the techniques reinforced by these three WBEGs, furthering the understanding of digital literacy in educational and sociocultural contexts. The final chapter discusses this dissertation's conclusions and implications for future research.

CHAPTER FIVE: CONCLUSIONS AND FUTURE RESEARCH

Conclusions

The above exploration of three WBEGs applies procedural rhetoric to deepen the understanding of the connection among these types of games, SRL, and digital literacy. Digital literacy and SRL skills are both important for learners to develop and improve in order to keep up with the 21st century's fast pace of technological change, and WBEGs present one platform capable of teaching these skills. The three WBEGs in this study teach players the digital literacy skills required to play them and provide opportunities to practice those skills through leveled play. Two examples of digital literacy skills required for these games include the specific physical motions that operate the games and the concept knowledge that the games are intended to teach. *Waves* requires players to move their whole bodies by stepping side-to-side to create a wave; *Color Mixer* is operated by vertical gestures of the players' handheld wands, and player movements in *Light and Mirrors* simulate the actions required for bending, lifting, and moving non-virtual furniture. Embodied experiences have been cited as the most effective way to learn (Gee, 2003). Scholarship on embodiment suggests that all of these motions and especially those in *Light and Mirrors* (because they closely resemble motions that the player would perform in non-virtual environments) enhance player learning by stimulating additional parts of the brain (Lindgren & Johnson-Glenberg, 2013). Language is riddled with physical terms denoting abstract concepts. For example, a learner could be described as "picking up a new skill." Although skills are

131

not acquired by literally lifting them from the ground, the figurative term "picking up" is still commonly used to describe the mastery of a new ability. Many figurative terms remain linked to the parts of the brain that control the physical movements they literally describe, suggesting a deeper connection between language and the body than many suppose (Boulenger, Hauk, & Pulvermüller, 2009). Embodied learning capitalizes on this connection between language and bodily movement to help make learning more efficient. This digital representation of human action also presents an interesting combination that can be considered a cyborg (e.g., Hayles, 2012; Haraway, 2006). The creation of the human-technology cyborg to accomplish learning mediated through technology requires digital literacy. Cognition "extends beyond the body's boundaries in ways that challenge our ability to say where or even if cognitive networks end" (Hayles, 2012, p. 17); thus, the digitally literate learner must navigate technology as an extension of herself. The digital literacy to wield technology in this way is obtained through practice, which is what these three WBEGs give players: practice being cyborgs, using technology as extensions of themselves. Additionally, *Waves, Color Mixer,* and *Light and Mirrors* provide players the opportunity to manipulate virtual objects to provide them with content-knowledge enhancing experience with wave motion and interaction, additive color, and light reflection, respectively. Content knowledge is presented to learners in a game format, and research suggests that video games teach well and employ exceptional motivating techniques (e.g., Eichenbaum, 2014; Granic et al., 2004). Given the results of this dissertation and the existing scholarship on these

132

topics, it can be concluded that WBEGs effectively provide players with opportunities to enhance their digital literacy skills and content knowledge.

Complementing the teaching of the digital literacy skills required for playing the game, WBEGs often embed elements that scaffold SRL. *Waves* was intentionally altered to include these elements; *Color Mixer* and *Light and Mirrors* were not, and yet they also provide players with features that scaffold SRL behavior. *Color Mixer* scaffolds SRL by valuing player agency, providing immediate feedback, and promoting player collaboration. In *Light and Mirrors*, players are also given agency, feedback, and collaborative opportunities; additionally, they are encouraged to strategize. These are elements that support SRL (e.g., Zimmerman, 1998). These components of SRL scaffolding help players acquire the digital literacy skills and content knowledge required of the games. Features such as these can also commonly be found in all types of games, so it is logical to conclude that WBEGs can and often do scaffold player SRL.

The analysis of procedural rhetoric proved to be an effective method to use when studying WBEGs. The use of this technique in this study allows for each game's featured techniques and SRL-scaffolding features to be cataloged, examined, and critiqued. By charting player actions, game reactions, and the SRL-supporting elements of each WBEG, the specific ways these games scaffold SRL becomes clear. The case study of *Waves* provides additional information as to how and why these elements are effective, augmenting and validating the results of the procedural rhetoric analysis. Bogost's (2007) method of reading and interpreting the design structure of these games proves to be an effective technique. The lens of digital literacy provides an additional

133

layer of interpretation to Bogost's methods and opens the door for more thorough critique. Methods critiquing technology such as those proposed by Selber (2004) allow for further exploration of procedural rhetoric using educational, sociocultural, and rhetorical perspectives. Thus, the procedural rhetoric of WBEGs can be effectively studied and can be augmented by the inclusion of other types of research methods.

This dissertation takes the position that four important areas of research, WBEGs, digital literacy, SRL, and procedural rhetoric, are intertwined. Scholarship from each of these areas informs and improves the others. This was illustrated and explained by Figure 1 and Table 1 above. WBEGs require and teach digital literacy while also scaffolding SRL; this can all be examined using Bogost's (e.g., 2007) method of analyzing each game's procedural rhetoric, which is in essence a way to read the games, and the method itself requires digital literacy.

The results of the multi-method investigations in this study contribute to the understanding of WBEGs, digital literacy, SRL, and procedural rhetoric. *Waves, Color Mixer,* and *Light and Mirrors* were found to teach digital literacy and science concepts by providing players with the opportunity to practice manipulating digital technology that represented the physical world. These games also scaffold SRL skills by facilitating player planning, progress monitoring, and reflection. At the programming level, the procedural rhetoric of three WBEGs appear to reinforce the values of accuracy, collaboration, problem-solving, learner autonomy, and scaffolding. Game designers must ask themselves if these are the values they want future games to perpetuate. Teachers wishing to utilize WBEGs with their students should be aware of these values

in the games and use that information to select the games that reinforce the values that they deem most appropriate. Finally, scholars should verify the results of this study and conduct additional research to extend it, critiquing the procedural rhetoric of other games and even other cultural institutions, as Bogost (2007) briefly mentions, describing some of the scholarship written about the "hidden curriculum" of traditional American schooling (p. 264).

Future Research

As with most research studies, this study has many limitations and challenges. In-depth studies could not be conducted to investigate specific player behavior or learning with *Color Mixer* or *Light and Mirrors*. The studies of *Waves* were exceedingly short-term, and therefore no claims can be made about WBEGs and long-term recall. The single-intervention style, too, of the *Waves* studies is also limiting. An additional study that follows up with players weeks or years after they play the game would be beneficial. Another possible extension of this study could investigate the claim that these WBEGs provide players with spaces to practice their digital literacy skills and concept knowledge—if so, it is likely that additional opportunities to play the game could enhance digital literacy and learning. Furthermore, the three WBEGs studied here are all designed for multiple players, which prevent the conclusions from extending to single-player WBEGs. Future study could provide insight as to the ways single-player WBEGs might leverage other features to scaffold the social aspects of SRL and digital literacy. Likewise, this study focused solely on WBEGs designed with the game projected onto the floor. It would be interesting to see the effect on players if the game

135

were also projected in other areas, perhaps on a wall in front of them or several walls surrounding them.

One challenge this study posed was the combination of approaches from very different fields. The use of a quantitative study, a case study, and an analysis of procedural rhetoric created a difficult (though worthwhile) task of coordinating and integrating information. Another challenge was the inability to see or play the two SMALLab games, *Color Mixer* and *Light and Mirrors* in person. This study relied solely on the video explanations and written descriptions of these games that appear on the lab's website. Few WBEGs structured similarly to *Waves* that this author can physically access exist, limiting the scope of games in this study.

This dissertation generates many additional questions for future investigation. The SRL scaffolding elements in *Waves* were revealed by the case study to rely heavily on a human facilitator reading or rephrasing the prompts, although the quantitative study suggested that the prompts were effective. Future study is needed to investigate the efficacy of the SRL scaffolds embedded within the game and how to best format them (e.g., by augmenting or replacing the textual prompts with audio prompts, pauses in gameplay until players answer a prompted question, etc.) to fully engage the players in the absence or silence of a facilitator. While the case study results suggest that the number of prompts is appropriate for supporting SRL, further investigation can verify this and also reveal which types of scaffolding measures (e.g. pop-up prompts, task bars, types of feedback) are most effective. Additional study is also needed to discover how much time spent playing SRL-scaffolding games results in significantly improved

136

SRL skills for the player. Furthermore, study is required to verify just how transferrable the SRL and digital literacy skills taught by WBEGs are to other digital and non-digital contexts.

The next steps this author would take if given the time and resources include designing and testing a WBEG that encourages or requires players to devise multiple solutions to the same challenge. Creativity and critical thinking are required to solve the same problem in multiple ways, and they are vital 21st century learning skills. Another step would be to compare the learning that takes place when playing a WBEG and when playing the same game on a console. Finally, the design of this new WBEG that leverages the findings of this research would provide players with an authentic, real-world problem with multiple solutions, requiring players to use motions that replicate the exact motions required of its real-world equivalent and actions that specifically map abstract concepts, and scaffold SRL and digital literacy skills. While the value of accuracy may need to be reconsidered in favor of creativity to solve a problem in different ways, the values of collaboration, problem-solving, autonomy, and scaffolding are worth perpetuating.

APPENDIX A: IRB APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Eileen M. Smith** and Co-PIs: **Charles E. Hughes, Shaun Gallagher**

Date: **July 09, 2014**

Dear Researcher:

On 7/3/2014, the IRB approved the following human participant research until 07/02/2015 inclusive:

Type of Review:	IRB Continuing Review Application Form
Project Title:	Full Study: Metaphor-Based Learning Through Whole-Body Interaction in a Mixed Reality Science Center Experience
Investigator:	Eileen M Smith
IRB Number:	SBE-11-07772
Funding Agency:	National Science Foundation
Grant Title:	
Research ID:	1051278

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 07/02/2015, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Joanne Muratori

IRB Coordinator

Page 1 of 1

APPENDIX B: QUANTITATIVE STUDY PRETEST

Waves Pretest (Summer Study)

The simulation game you are about to play is all about waves. There are many types of waves in the world including sound waves, light waves, and waves made by water, just to name a few. The simulation is designed to help you experience how most waves behave and interact with each other. Because we would like to see how much the game teaches, we need to find out how much you know about waves already. Please answer the questions below as best as you can. It is okay if you don't know the answer!

1. What are the parts of a wave? List as many as you can.

2. What is constructive interference?

3. What is destructive interference?

4. What is a standing wave?

5. In the diagram below, there are two waves in the same medium that are influencing one another. Draw a wave in the middle to represent what would occur when their forces **combine**.
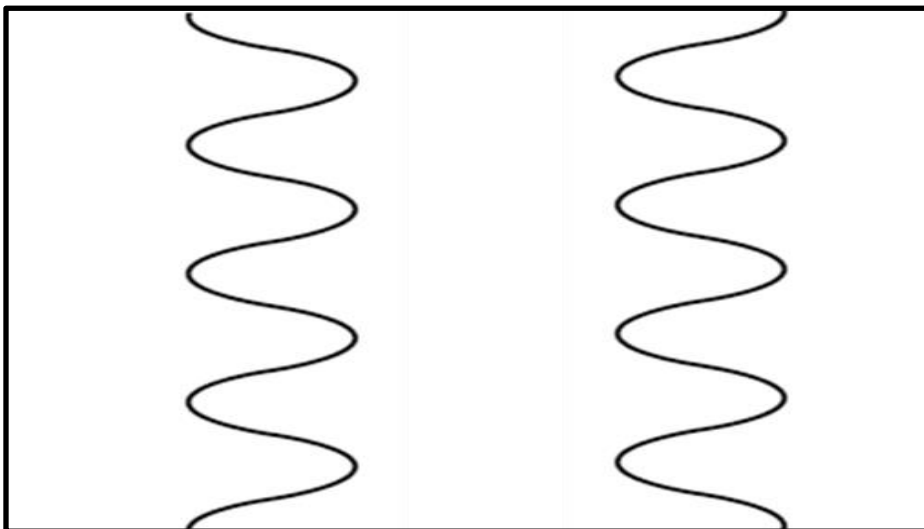
6. In the diagram below, there are two waves in the same medium that are influencing one another. Draw a wave in the middle to represent what would occur when their forces **combine**.
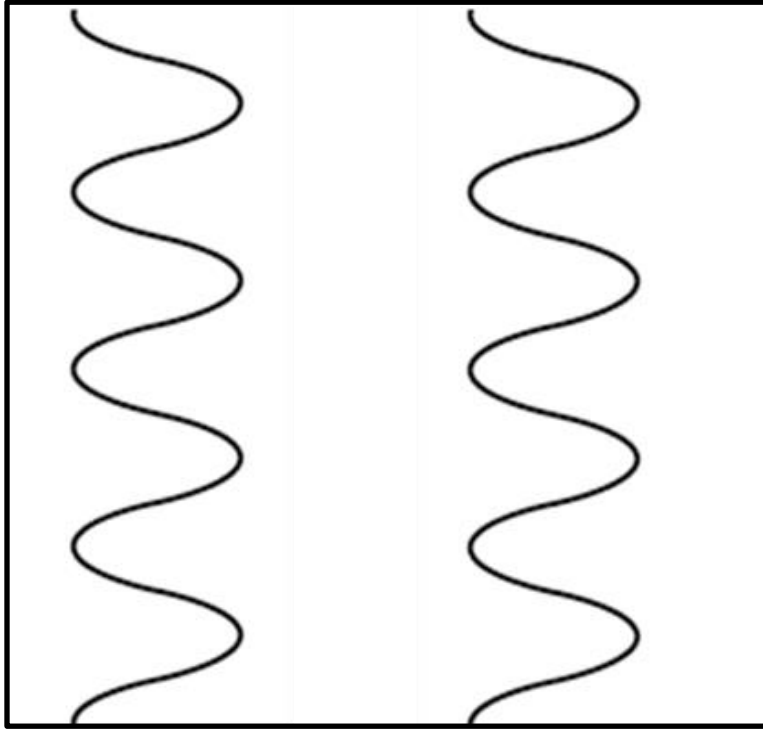
7. Beside the wave below, sketch what it would it look like if this wave suddenly got *significantly* **slower**.
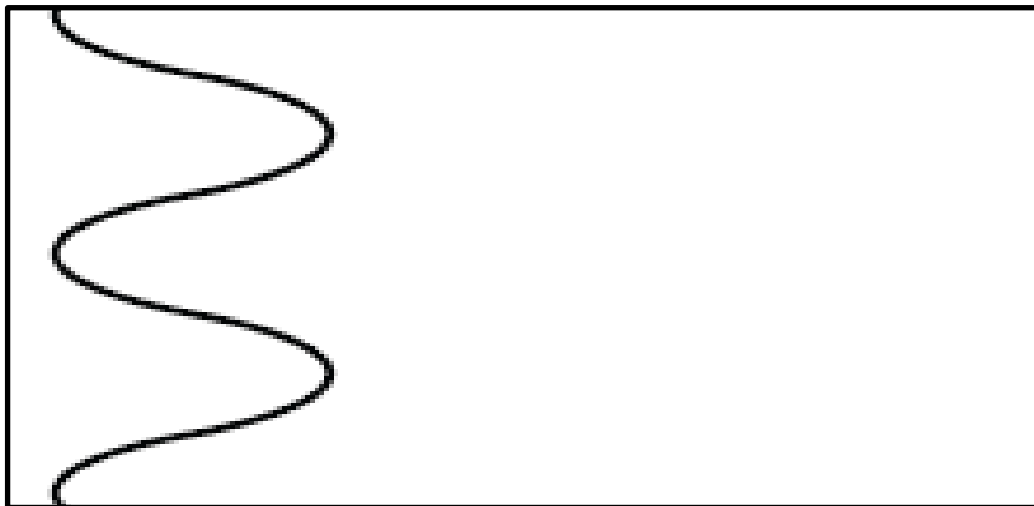
For the following questions, circle one number to show how much you agree or disagree with the statement, with 1 meaning you strongly disagree and 5 meaning you strongly agree.

8. I usually keep track of my progress toward my goals.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

9. I have trouble making up my mind about things.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

10. I reward myself for progress toward my goals.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

11. I don't notice the effects of my actions until it's too late.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

12. My behavior is similar to that of my friends.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

13. It's hard for me to see anything helpful about changing my ways.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

14. I am able to accomplish goals I set for myself.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

15. I have so many plans that it's hard for me to focus on any one of them.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

16. I change the way I do things when I see a problem with how things are going.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

17. I think a lot about what other people think of me.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

18. I am willing to consider other ways of doing things.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

19. If I wanted to change, I am confident that I could do it.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

20. When it comes to deciding about a change, I feel overwhelmed by the choices.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

21. I have trouble following through with things once I've made up my mind to do something.

    Strongly Disagree   1   2   3   4   5   Strongly Agree

APPENDIX C: QUANTITATIVE STUDY POSTTEST

The questions below deal with the "pop-ups," (the words that appeared at various times during the simulation) and the task bar. We would like to improve these parts of the simulation, so please answer them below honestly to help us make the simulation better. Circle one number to show how much you agree or disagree with the statement, with 1 meaning you strongly disagree and 5 meaning you strongly agree.

1. The pop-ups are a useful part of the simulation.

   Strongly Disagree   1   2   3   4   5   Strongly Agree

2. The pop-ups interrupted me while I was playing.

   Strongly Disagree   1   2   3   4   5   Strongly Agree

3. The pop-ups were unnecessary because I was already asking myself similar questions while I played.

   Strongly Disagree   1   2   3   4   5   Strongly Agree

4. The pop-ups were helpful and reminded me to think about my strategy in the simulation.

   Strongly Disagree   1   2   3   4   5   Strongly Agree

5. The pop-ups were distracting.

   Strongly Disagree   1   2   3   4   5   Strongly Agree

6. I read all of the pop-ups.

   Strongly Disagree   1   2   3   4   5   Strongly Agree

7. The pop-ups helped me focus on what I was doing.

   Strongly Disagree   1   2   3   4   5   Strongly Agree

8. The task bar (checklist) helped me figure out what I was supposed to do.

   Strongly Disagree   1   2   3   4   5   Strongly Agree

9. The task bar was helpful.
   Strongly Disagree   1   2   3   4   5   Strongly Agree

10. The task bar was distracting.

Strongly Disagree   1   2   3   4   5   Strongly Agree

11. I read all of the things in the task bar checklist for all of the levels.

Strongly Disagree   1   2   3   4   5   Strongly Agree

12. Little problems or distractions throw me off course.

Strongly Disagree   1   2   3   4   5   Strongly Agree

13. I feel bad when I don't meet my goals.

Strongly Disagree   1   2   3   4   5   Strongly Agree

14. I learn from my mistakes.

Strongly Disagree   1   2   3   4   5   Strongly Agree

15. I think a lot about how I'm doing.

Strongly Disagree   1   2   3   4   5   Strongly Agree

16. It bothers me when things aren't the way I want them.

Strongly Disagree   1   2   3   4   5   Strongly Agree

17. I call in others for help when I need it.

Strongly Disagree   1   2   3   4   5   Strongly Agree

18. Before making a decision, I consider what is likely to happen if I do one thing or another.

Strongly Disagree   1   2   3   4   5   Strongly Agree

19. Please share any suggestions or comments you have about the pop-ups or the task bar (checklist) in the simulation:

➔ Almost done! One more section to go!! ➔

Now, we would like to find out how much the simulation actually teaches about waves. Please answer the questions below as best you can.

20. What is constructive interference?

21. What is destructive interference?

22. What is a standing wave?

23. What are the parts of a wave? List as many as you can.
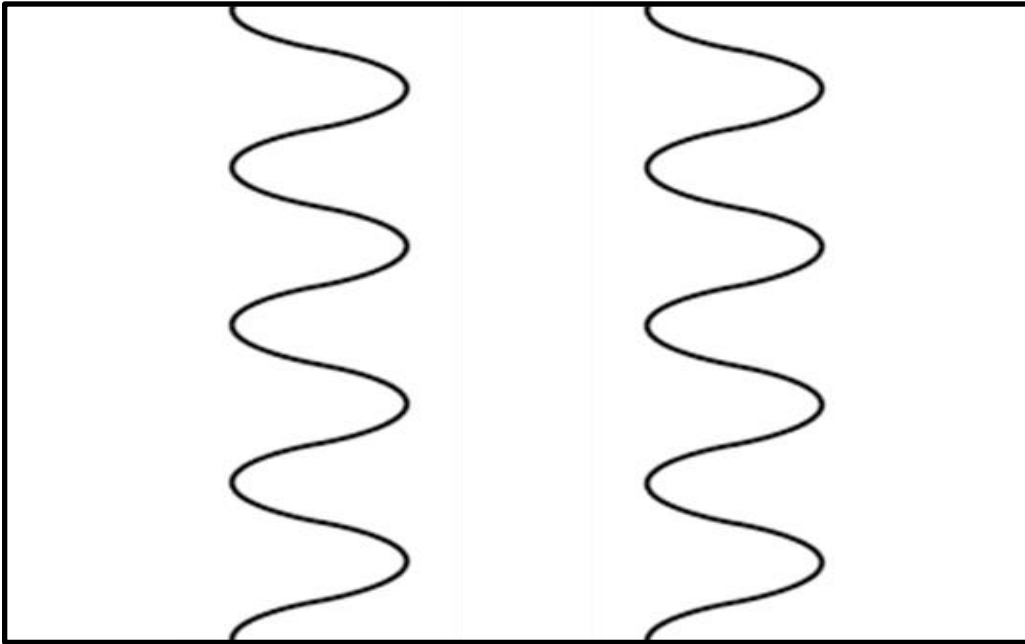
In the three diagrams below, there are two waves in the same medium that are influencing one another. Draw a wave in the middle to represent what would occur when their forces combine.

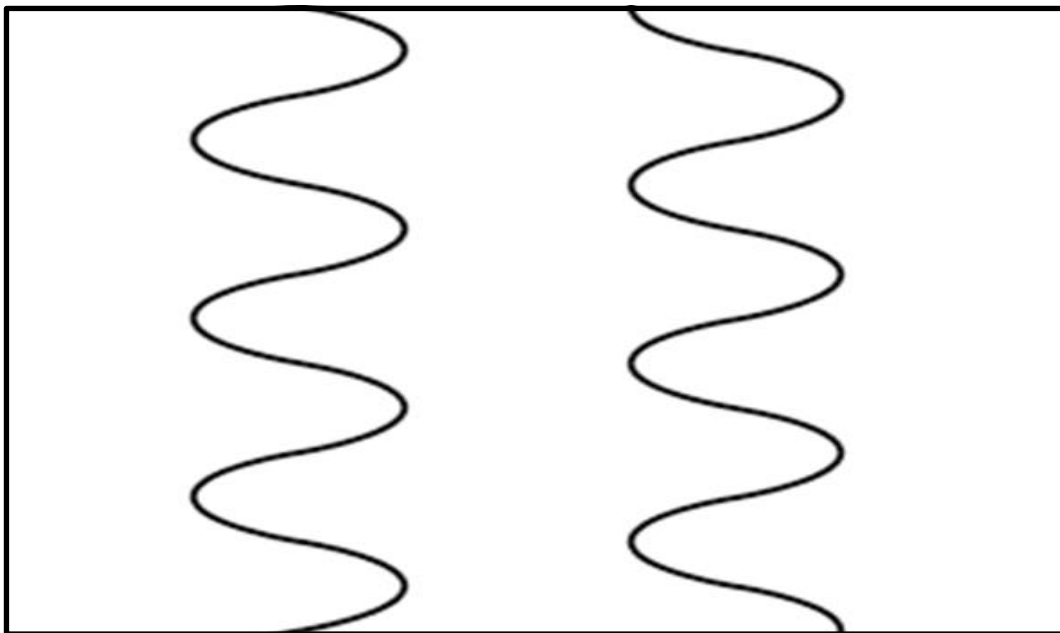4. *Draw a wave in the middle to represent what would occur when their forces combine.*
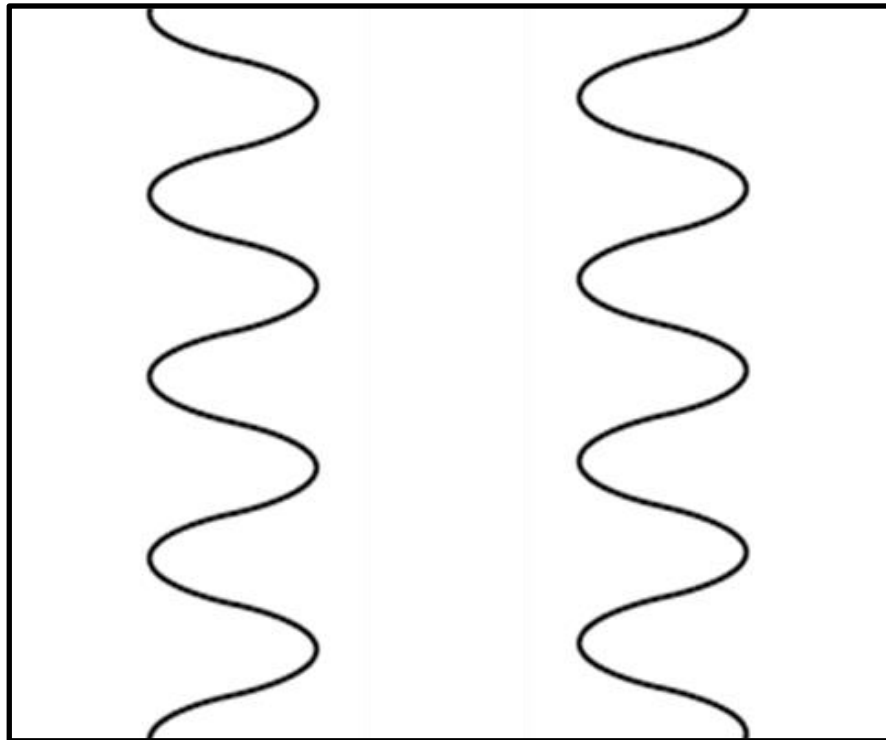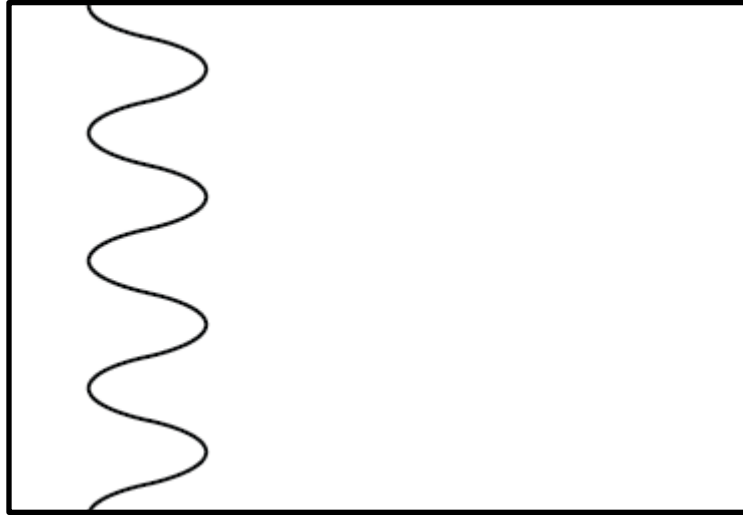
25.

Draw a wave in the middle to represent what would occur when their forces combine.

26.

27. Beside the wave below, sketch what it would it look like if this wave suddenly got *significantly* **faster**.

***Optional* questions to help inform our research:** *(You **don't** have to answer these if you don't want to)* ☺

28. What is your age? _____

29. What is your gender?
  ☐ Male
  ☐ Female
  ☐ I prefer not to respond

30. What is your racial or ethnic identification? (Select only one.)
  ☐ American Indian or Other Native American
  ☐ Asian, Asian American or Pacific Islander
  ☐ Black or African American
  ☐ White (Non Hispanic)
  ☐ Hispanic or Latino
  ☐ Multiracial
  ☐ Other
  ☐ I prefer not to respond

☺ **Thank you so much for helping us with this project!** ☺

APPENDIX D: CASE STUDY TRANSCRIPT OF *WAVES* LEVEL 2

Case Study Transcript: Level Two of *Waves*

Spoken by a player
Spoken by the facilitator
Written prompt within game: P=prompt; TB=task bar item (numbered 1-3)

GS	*TB1: Stand next to each other. – immediately checked off*
GS	*P: Make the middle wave glow green using DESTRUCTIVE INTERFERENCE*
GS	*TB2: Turn the middle wave green using destructive interference.*
FS	Destructive…
GS	*P: Could this level be too difficult for some people?*
FS	So what do you think that means?
GS	*TB2: Turn the middle wave green using destructive interference—checked off*
GS	*TB3: Make a small middle wave glow green using large destructive movements.*
R-PP	**I think it means just going crazy**
GS	*P: Is the wave responding to your movements the way it should?*
	Haha, leave it to middle school boys to define 'destructive'…
FS	But let's put it in the context of 'constructive'
R-PP	**Um, like, not big?**
GS	*P: Could a different motion change the wave pattern?*
FS	Ok so try that now. Make it not big. It's not big now, is that working?
R-PM	**um.. [thinking]**
FS	What do your directions say?
R-PR	**[TB3] "Make a small middle wave glow green using large destructive movements."**
R-PR	**So, opposite.**
	Ooh.
	inaudible
GS	*P: Can your partner do anything different to help get the wave closer to the goal?*
PM	**Crash. Oooh.**
FS	What are you doing when it's [the middle wave] green vs. when it's red?
R-PM	**um we're making it kind of stay still…**
GS	*P: Is there anything different that could be tried here?*
PE	**Come ON…**
FS	…But in relationship to each other? What are you doing when it's green?

152

	Huh?
	Never mind. Keep going.
GS	*P: Could a different motion change the wave pattern?*
PP	**it's like a … OK you go to the left and I'll go to the right.**
PM	**Ah HAAAAAA….**
GS	*P: Can your partner do anything different to help get the wave closer to the goal?*
GS	*[success stars indicate level is completed]*
R-PM	**Yay!**
FS	Awesome! Ok so what's destructive [mean]?
R-PE	**-standing really still. [may have been referring to the screen where all the waves are currently frozen]**
GS	*P: How does this level work?*
FS	Ok real quick, how did that level work? What did you have to do?
R-PE	**We had to do the opposite thing from each other**
FS	To…?
R-PE	**To make it win.**
	Okay.

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