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Interface Design of Educational Games for Middle School Students

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Interface Design of Educational Games
for Middle School Students

by

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Report

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Dedication

I would like to dedicate this report to my parents and sisters. Thank you for always encouraging me to pursue my goals. Without your support, it would have been much more difficult to complete my degree. Thank you for kindness, encouragement, selflessness, and love.

Acknowledgments

I would like to acknowledge Dr. Min Liu and Dr. Lucas Horton for their support during my time at the University of Texas at Austin. You both have enabled me to participate in professional experiences that developed my skills and knowledge of this field. Dr. Liu, thank you for your instruction, guidance, and the opportunity to participate in Alien Rescue. Dr. Horton, thank you for sharing your visual design aesthetic, interface advice, and usability expertise.

Abstract

Interface Design of Educational Games for Middle School Students

by

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The University of Texas at Austin, 2016

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The purpose of this report is to identify interface design elements in educational games for a middle school audience. The four games in this report were selected based on their availability to the general public and their reputable developers. The purpose in undertaking this research is to determine interface and interaction conventions in educational games for 11-14 year olds in order to make recommendations to designers and developers. This report identifies the ways each game approaches important features such as art direction, providing feedback, portraying significant events, indicating clickable items, and event timing. It discusses the games' techniques to guide gameplay. This report also addresses how interface design supports pedagogical goals.

Table of Contents

List of Tables

List of Illustrations

List of Screencasts

All screencasts are stored on a folder in UTBOX called Caroline Cancelosi MA Report Screencasts May 2016. Dr. Min Liu is co-owner of this folder. The are available to view and download without logging into UTBOX at https://utexas.box.com/v/carolinecancelosi .

Chapter One: Introduction

The rise of personal computers in the late twentieth century provided a new media for games. As designers transitioned from paper to pixels, digital media required consideration of how to best convey the affordances of a physical game given the constraints of a two dimensional screen. Simultaneously, the creation of educational games for personal computers provided parents and educators greater opportunities to engage students, facilitate learning, and increase motivation to interact with educational materials. Parents likely see educational games as a constructive pastime and way to improve academic success. Nearly 70% of "parents believe that playing games provides mental stimulation or education" and over 50% of parents think "that playing games helps children connect with their friends" (Erenli, 2013, p. 16). Educators use games, both digital and non-digital, to promote engagement and achieve learning outcomes by providing dynamic alternatives to traditional static course materials (Liao, Chen, Cheng, Chen, & Chan, 2011; Pinder, 2008; Plass et al., 2013).

The first two decades of the twenty-first century have seen the development and increased popularity of mobile devices such as tablets and smartphones (Arthur, 2012; Bonnington, 2015). Today, modern mobile devices possess the capacity to complete many daily computing activities without the aid of external equipment (Bonnington, 2015). Consumers now download applications, commonly known as "apps," to use on their mobile devices. Individuals and organizations with access to a mobile device and a download account can browse among hundreds of educationally-oriented games. While these games vary in pedagogical soundness and quality, they have changed the landscape of educational content creation.

Designers face multiple challenges when creating these apps; many of which can be categorized as relating to device size or interaction patterns. A significant device size challenge is how to best employ smaller screen sizes without compromising quality or usability. A notable aspect of this challenge is the screen size of a mobile phone versus that of a tablet, which may necessitate two separate designs. Clickable items need to be large enough for human fingers to accurately touch, but not so large that they distract from important educational content. In the case of interaction patterns, mobile devices employ physical gestures (e.g. swiping, pinching, tapping, extended pressing, and dragging movements) whereas laptops and desktops typically use separate devices such as trackpads, mice, and keyboards to manipulate interfaces. While a laptop or desktop can indicate interactivity through hover states, mobile devices do not have that same affordance. Furthermore, the use contexts between mobile and desktop devices may be different. Given the portable nature of mobile devices, users can interact with them while going about their daily activities. As such, mobile devices may be more likely to be used spontaneously and under multitasking conditions. This supposition is supported by the existence of Think with Google (Google's resource for digital marketers) and their identification of a "micro-moment" : the instant an individual uses a mobile device to discover information or complete a specific task (https://www.thinkwithgoogle.com/articles/being-there-micromoments-especially-mobile.html). In contrast, the dimensions of laptops and desktops require intentional use; one cannot easily walk around while using a laptop. As such, it may be reasonable for designers to assume that users sitting down at these surfaces may be more long-term goal oriented than mobile device users.

Digital user experience design and user interface design are still fledgling disciplines, especially given frequent technological advancements that change both the capabilities and challenges in the field. In addition to technical concerns, user experience and user interface (UX and UI) designers should create with educational goals in mind. They must consider how their learning environments impart skills and knowledge, offer an experience that balances predictable interactions and exploration, guides a user through a sequence, deals with incorrect user input, and not least, captivates users' attention.

Overview of the Problem

Several universities have created educational games for K-12 student use. The aim of these games is to create pedagogically sound educational content that instructors can confidently employ. In addition, the data collected from these games provides a rich source of research studies. For example, the University of Texas at Austin has published articles pertaining to research on perceptions of science education, student motivation, and the effectiveness of game-based learning from a single game (Kimmons, Liu, Kang, & Santana, 2012; Liu, Horton, Olmanson, & Toprac, 2011; Liu, Rosenblum, Horton, & Kang, 2014). In addition to the University of Texas at Austin, institutions that have conceptualized and/or developed online educational games include Rice University, the University Wisconsin-Madison, Massachusetts Institute of Technology, Harvard University, and Tufts University.

Alien Rescue, a 3D problem-based learning (PBL) environment created at the University of Texas at Austin, is an example of an educational game. While this report will address various scholars' interpretations of the word *game*, I believe that Alien Rescue qualifies as a game because it involves a challenge, requires players to make decisions that have consequences within the game, and has an element of mystery surrounding the conclusion; the player cannot say with certainty what will happen. Alien Rescue seeks to capture middle school students' imaginations through a science fiction inspired space station environment and aliens. Rather than simply showing content and testing students' knowledge, Alien Rescue presents students with the problem of finding homes for alien species in the Milky Way Galaxy. Students have access to tools that reinforce concepts (such as reference materials) and a probe design center which enables students to gather more information about planets. As such, students must analyze this information and use their judgment to find homes for the aliens.

Owing to technological advancements, the Alien Rescue team is converting from an outdated version that requires players to download software to use within a web browser (called a plugin) to a modern web-based game that does not require any downloads. As such, the Alien Rescue team views this transition as an opportunity to reimagine several design elements, including the interface and some interactions. This report is inspired by Alien Rescue's need to strike a balance between design trends and researchers' best practice suggestions.

The Purpose of this Report

The goals of this report are to: a) provide an overview of current best practices in user experience and user interface design, b) explore current games geared towards middle school students, and c) offer suggestions for the interface and user experience of an educational game. The intent of this report is to provide actionable advice that user experience and user interface designers can implement during the design of educational games for a middle school audience. Given that purpose, this report will focus on the following research questions:

1) How do interfaces encourage users to take action?
2) What techniques do educational game interfaces employ to provide feedback?
3) How are significant events or interactions presented in a way that convey their importance?

These research questions will be reviewed under the lens of social constructivism. By employing social constructivism as a framework, answers to the research questions must consider how the individual creates knowledge within social settings. While social settings traditionally refers to exchanges with other human beings, I contend that the high degree of interactivity within the games assumes a social role.

This report is organized into three chapters. The first chapter introduces the content – it contextualizes the subject matter and gives an overview of the problem. The second chapter consists of a literature review and an analysis of the games. The third chapter provides a discussion of the games and implications such as future research questions and considerations for educational game design.

Chapter Two: Literature Review and Analysis of Games

Literature Review

Literature that could apply to the field of educational games for middle school students spans the fields of interface and interaction design, human computer interaction, visual design, serious games, and motivation. Given this broad array of relevant topics, it is necessary to refine the scope. This literature will focus on interpretations of usability, the emotional component of design, learning theory, and aspects of games in an educational context.

Before delving into the literature it is necessary to say that design as a whole is affected by trends. A prominent trend in 2015 was "flat" design which originated circa 2011 (Meyer, 2015). This trend is characterized by simple illustrations rather than an attempt to ornately decorate interface items with intense shadows, reflections, gradients, and the like. While flat design simplifies interfaces, some usability experts such as the Nielsen Norman Group criticize the aesthetic's overly subtle signifiers of interactive elements (Meyer, 2015). Flat design's successor, Flat 2.0, features the judicious use of shadows and highlights; possibly offering a better way to provide visual cues while still embodying a sleek look (Meyer, 2015). The example of the shift to Flat 2.0 demonstrates the design field's evolving nature. While trends will always be an aspect of the aesthetic component of interface design, this literature review will attempt to review design conventions that transcend trends. These conventions are either supported by academic research or are promoted by industry experts.

Views of UX/UI usability. Blog posts and articles written by UX/UI practitioners abound; as of March 2016 the phrase “UX/UI principles” garnered over 380,000 results on Google. Content written by professionals often consists of recommendations to simplify the overall website design and create straightforward interactions (Dance, 2014; Hess, 2010). Both Dance (2014) and Hess (2010) stressed the importance of predictable interactions and respecting pre-existing design patterns. Academic researchers such as Park and Song (2015) and industry experts such as Mandel (1997) agreed that users should find interfaces non-intimidating. In order to design for usability, Mandel (1997) offered design principles that fall into three domains: enable users to confidently manage the interface, require as little memorization as possible, and create interface uniformity. According to Norman (2004): “[u]sability describes the ease with which the user of the product can understand how it works and how to get it to perform” (p. 37).

In contrast to popular advice, the scholars Blair-Early and Zender (2008) advocated carefully assessing the actual meaning of common terms used to describe design. Blair-Early and Zender (2008) criticized other scholars’ interpretations of good design as straightforward and “intuitive” (p. 86); arguing that these terms are too open to interpretation. Furthermore, Blair-Early and Zender (2008) contended that designers should have a grounding in principles which guide them, even as design trends inevitably shift and emerging devices propose new challenges. Some of their principles included: designing a clear beginning to the content, designing a clear end, “consistent logic” (p. 100), employing designs already known to the user, “feedback” (p. 101), “landmarks” (p.

101), which are identifiers of important actions a user can take, and designing to ensure harmony between the interface and information (Blair-Early & Zender, 2008).

In addition to interactions, usability includes aesthetic considerations as well. Bi, Fan, and Liu (2011) conducted a study to “develop a computational model of aesthetic ratings based on symmetry and the number of compositional elements to predict aesthetic ratings, which can be used to evaluate and support aesthetic design of interfaces” (p. 246). They found that images with high symmetry were ranked better than medium and low symmetry ones (Bi et al., 2011). This suggests that webpages should be composed of symmetrical images to please users. To observe the effect of taste among different cultural biases Bi et al. (2011) compared the data gathered from a Chinese group and an American one. They suggested their results gave “further evidence that in aesthetic research and design, the cultural and ethnic background of the users should be considered” (Bi et al., 2011, p. 258). This advice must be considered in relation to the impositions placed on the designer. It may not be possible to create different versions of an interface based on different cultures.

Barriers to usability. MacDorman, Whalen, Ho, and Patel (2011) asserted that an important impact on usability is how often users make mistakes. These mistakes might not consume much time during a usability test, but they impact usability and perceptions of the product (MacDorman et al., 2011). Overwhelming the user with too much stimuli is another barrier to usability (Nelson & Erlandson, 2008). In their study of a 3D educational game, Nelson and Erlandson (2008) found that students struggle when required to process visual and audio information simultaneously.

The emotional component to design. Norman's work *Emotional Design: Why We Love (or Hate) Everyday Things* focused on the profound positive impact of beautiful design. He delineated the "different levels of the brain: the automatic, prewired layer, called the *visceral level*; the part that contains the brain processes that control everyday behavior, known as the *behavioral level*; and the contemplative part of the brain, or the *reflective level"* (Norman, 2004, p. 21). Thus, enjoying design requires satisfaction of all three levels. Users must have a pleasant experience, which generates positive emotions, which in turn creates a positive impressions of the product (Norman, 2004). Conversely, a frustrating experience creates negative emotions and negative impressions of the product (Norman, 2004). MacDorman et al. (2011) confirmed that mistakes have an impact on users' overall feeling of a product. What these findings reveal for developers and designers of educational games is that they must be careful that their negative feedback devices (both in terms of faulty interface manipulation and incorrect pedagogical tasks) are not too jarring, otherwise they risk alienating and discouraging users.

Strategies for implementing emotional design. Desmet (2015) examined the differences between emotions and moods. According to previous research Desmet (2015) studied, emotions are fleeting, felt strongly, interject into our psyches, and inspire us to take action. By contrast, moods can last for part or all of a day(s), are felt moderately, effect our attitudes and actions, and provide situational awareness (Desmet, 2015). In order for people to negate negative moods and amplify positive ones, Desmet (2015) identified three genres of "mood-regulation strategies": "finding relief", "restoring balance", "building resilience" (p. 9). Therefore, designers must incorporate these mood regulation strategies into games.

Another emotional, human-based approach to design manifests through the application of a user persona during the design process. Idoughi, Seffah, and Kolski (2012) argued for the inclusion of user personae for adults; arguably this decision would be appropriate for children as well. While user personae typically account for factors such as demographic traits, source of motivation, and concerns, an emotionally aware take on personae would incorporate emotions and moods.

Learning theory. Similarly to adopting a user persona as a design strategy, personal motivation, attitudes, and feelings present an important role in constructivist and social constructivist learning theory. While the focus of this report is practice, rather than theory, a brief overview of significant concepts is necessary to contextualize design decisions made in today's games. Constructivism emerged during the 20th century. Two of its most important theoreticians are Piaget and Vygotsky, who proposed two different approaches to constructivism.

The main tenet of constructivism is that learners build ("construct") knowledge through their own internal processes; opportunities to build knowledge come from social and environmental interactions (Sjoberg, 2010). This can result in some understandings of the world that are intensely personal and other constructions that are shared among members of a group (Sjoberg, 2010). Instructors must be sensitive to their students' individual constructions rather than assume students are a blank slate ready for knowledge (Sjoberg, 2010). Given this foundation, Piaget focused on the intelligence aspect of constructivism, known as "cognitive constructivism" and Vygotsky centered on the interpersonal aspects known as "social constructivism" (Sjoberg, 2010, p. 485).

Piaget. Piaget's educational career was in evolutionary biology and he viewed development as a response to the environment. In addition to his unusual background, "[a] persistent and overriding interest in the area of *intelligence* is a salient feature distinguishing Piaget's work from that of most child psychologists" (Flavell, 1963, p. 16). One of Piaget's most famous theories is his stages of development. As cited in de Ribaupierre (2015), they consist of the sensorimotor stage (from birth until age 2), the preoperational stage (concluding around age 6), the concrete operational stage (age 7-12), and the formal operational stage which takes place during the teenage years.

Piaget identified different play behaviors that correspond to these stages. During the preoperational stage, children immerse themselves in playing through pretending; an activity which gives way to more realistic play involving rules during the concrete operational stage (Garwood, 1982). Piaget believed a child acted in response to his or her environment, a process known as "equilibration" (Muthivhi, 2015). Equilibration permits the child to construct categories for "his or her actions into schemas and structures, on the basis of which further construction of knowledge becomes progressively possible" (Muthivhi, 2015, p. 126). Thus, for Piaget, play helps build intelligence by enabling a child to take an active role in his/her development.

Vygotsky. Vygotsky also believed that children progress through stages, aided by play. However, Vygotsky's emphasis on the social aspect of constructivism created a different ideological focus. “For Vygotsky, imaginative play is a crucial component of normal development; game playing allows the development of language, cognition, emotion, social relationships, etc. For Piaget game playing was a symbolic conduct, along with language, drawing, and imitation” (Bonchis, 2013, p. 113). Vygotsky interpreted play strictly as children using their imaginations (Bodrova & Leong, 2015). “Sociodramatic or make-believe play, according to Vygotsky, has three features: children create an imaginary situation, take on and act out roles, and follow a set of rules as determined by those specific roles” (Bodrova & Leong, 2015, p. 374).

One of Vygotsky’s notable ideas is the Zone of Proximal Development (ZPD). “*It is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers*” (Vygotsky, 1978, p. 86). In other words, ZPD accounts for development by acknowledging how others push an individual towards growth (Vygotsky, 1978). Thus, ZPD is an inherently social theory. Bodrova and Leong (2015) suggested that in the instance of play, the communal knowledge of a group of playmates propels the individual towards greater comprehension, “even if individual children do not differ in their knowledge levels” (p. 376).

Zone of Proximal Development and usability. Given the benefit of collective intelligence provided by collaborative learning, Maier and Fadel (2009) expressed frustration with the then-current design process in their field of engineering design. They argued that design failed to incorporate a rapport between the designers and users.

Building on the discussion of affordances by Gibson and Norman, Maier and Fadel (2009) constructed their own understanding. "Affordances help to explain the entanglement between designers, users, and artifacts — relationships that are not currently handled by function based approaches to design" (Maier & Fadel, 2009, p. 13). Of particular interest to this report is Maier and Fadel's (2009) emphasis on the affordance relationship between the user and artifact.

> For example, the affordance of drivability of an automobile is one type of interaction, while the act of a person actually driving is a different type of interaction, but the two are related because the automobile must first afford driving (an affordance) before it can ever actually be driven (a behavior). (Maier & Fadel, 2009, p. 22)

Inspired by Maier and Fadel's Affordance-Based Design, Park and Song (2015) decided to revise e-learning material based on this design approach. The e-learning material Park and Song (2015) updated originally had navigation on both the left side and underneath the main content. Their revision included exclusive right side navigation so all the controls were in one place. As a result of these changes, there were higher levels of usability among the group using the Affordance-Based Design optimized version (Park & Song, 2015).

Critique of imagination's limits in constructivism. It is important to note research from Smith and Lillard (2012) that suggested social constructivism is not flawless. Smith and Lillard (2012) took issue with Piaget and Vyogtsky's beliefs that playing through pretending ceases when early childhood concludes. Various scholars have cited age six as the approximate year when pretend play ends and rule-based games emerge (Smith & Lillard, 2012). Smith and Lillard (2012) maintained that researchers may believe playing through pretending diminishes because they are ill-equipped to observe pretend situations; pretending may happen more subtly or fleetingly in middle childhood so its occurrence may not be readily apparent.

In order to better determine the rate of pretend play throughout childhood they asked 113 undergraduate students to recall their memories of this phenomenon (Smith & Lillard, 2012). They found that a meager 7 per cent ceased pretending before age 8, over 60 per cent of students stopped pretending between ages 8 and 13, and almost 20 per cent continued to pretend after age 13 (Smith & Lillard, 2012). Having younger brothers or sisters and living in a rural or suburban area were linked with play pretending during later childhood phases (Smith & Lillard, 2012). This research is important because it indicates that pretend playing is important. Playing a game like Alien Rescue requires a certain suspension of reality, and a willingness to accept "unreal" things without getting distracted by them. This research might possibly suggest that children who still pretend may get more out of educational games, especially games that incorporate fantasy.

Educational games. While the concepts of a game and play may seem self-evident, scholars disagree about semantics. Henriksen, Keenan, Mishra, and the Deep-Play Research Group (2015) asserted there are important differences between play and games. Games involve rules which constrain children by hampering what is possible (Henriksen et al., 2015). In contrast, play allows for "the pushing and subverting of boundaries" (Henriksen et al., 2015, p. 6).

> Watching children play reveals that much of the dialogue between children during play is about what is "permitted" and "not permitted." Play being unmoored from reality allows us to hypothetically explore the consequences of our actions, to test the boundaries of our influence. This is the fundamental difference between play and games. Though we play games, not all that we play can be called a game. Our notion of play is far wider than that of a game. Open-ended combinatorial creativity is what gives play its pedagogical power. (Henriksen et al., 2015, p. 6)

Based on a review of varying interpretations, Bonchis (2013) created two labels for the varying definitions of game: "emphasis on work or play" or "game as a mental function" (p. 106). The former definition seems to be influenced by Vygotsky, whereas the latter appears to be influenced by Piaget.

Perhaps a more fruitful approach is to attempt to define games by their characteristics, rather than their ideological underpinnings. Caillois's essential qualities of games (as cited in Erenli, 2013) were that they are "fun", "separate", "uncertain" (referring to what exactly will happen in the game), "non-productive", "governed by rules", and "fictitious" (p. 15). Clearly, as an educational researcher, Erenli (2013) found fault with the non-productive component of the definition.

In order to be engaging and pedagogically sound, an educational game must possess certain features, outlined by Engenfeldt-Nielsen (2011). While contextualizing components (such as characters, objects, and settings) create an environment, the actions within that environment are more important because they ultimately shape gameplay (Egenfeldt-Nielsen, 2011). In other words, the scope of actions within a game is determined by the game's rules (Egenfeldt-Nielsen, 2011). To create effective educational games, mastery of the educational content must be essential to success in the game (Egenfeldt-Nielsen, 2011). In addition, the game should have a symbiotic relationship between environment and game events (meaning that the environment's affordances should relate to actions that move gameplay along) and motivate students through interesting content and just enough difficulty to keep students engaged (Egenfeldt-Nielsen, 2011).

Games as motivators. Several researchers have examined the motivating effect of games used in educational situations. Students had more content knowledge after playing Alien Rescue than before; there was also a slight implication students were motivated to put forth a stronger effort (Liu et al., 2011). While the game MinecraftEdu was not found to drastically alter academic outcomes in one study, the researchers observed that the majority of children in the study believed it "enhances creativity", "improves learning", "enables discovery", and "facilitates learning of historical content" (Sáez-López, Miller, Vázquez-Cano, & Domínguez-Garrido, 2014, p. 125). Thus, perhaps the mere prospect of playing a game motivates students to increase their academic efforts.

To assess the relationship between academic motivation and enjoyment of a commercial handheld digital device, Liao et al. (2011) provided students with a My-Mini-Pet. The My-Mini-Pet device encourages children to care for a digital animal in exchange for the animal's increased well-being. Liao et al. (2011) added mathematics questions to the My-Mini-Pet game by incentivizing better pet rewards in exchange for correctly answering mathematics questions (Liao et al., 2011). Based on these results, Liao et al. (2011) contend that the "feature of long-term management will help learning to promote the adoptability of students and to integrate current learning tools" (p.86).

Pedagogical considerations. In addition to UX/UI concerns, designers and developers of educational games must account for pedagogical considerations. "[E]ducational goals for the twenty-first century are very different from the goals of earlier times" (Bransford, Brown, Cocking, & the National Research Council (U.S.), 2000, p. 131). Creators of educational games need to determine how to best employ technology in the context of modern approaches to learning. Bransford et al. (2000) identified three kinds of learning environments: "learner centered" (p. 133), "knowledge centered" (p. 136), and "assessment centered" (p. 139). Learner centered assessments have a holistic focus; this includes being aware of students' cultural practices and their experiences outside of the school (Bransford et al., 2000).

This holistic approach shares theoretical similarities to situated learning. Situated learning involves getting from one mental model to another; a process that occurs by the learner first understanding what he or she knows, then learning another's model, and finally reconciling the two (Goel, Johnson, Junglas, & Ives, 2010). Of course, situated learning itself ties back to social constructivism (Goel et al., 2010).

Problem-based learning. In an effort to make education more comparable to real life, problem-based learning emerged. Rather than demanding students solve an unrealistic and abstract problem, some educators began to favor approaching a "meaningful, but ill-structured problem solving activity" (Marra, Jonassen, Palmer, & Luft, 2014, p. 221). Jonassen (2011) stated that the revolutionary aspect of problem-based learning is that it does not wait for students to become experts before attempting the problem. Jonassen (2011) acknowledged the scaffolding required for students who are new to problem-based learning, especially since it "represents a significant shift in learning" (p. 96). Jonassen (2011) offered a contextual grounding of PBLs through Problem Based Environments (PBLEs). "PBLE is a generic term to describe the instructional components necessary for supporting students learning to solve different kinds of problems in PBL setting. PBLEs may define different approaches to PBL" (Jonassen, 2011, p. 99-100).

Game Selection

This report endeavors to explore educational games that are available to members of the public, such as middle school teachers or parents. Some educational games, such as Alien Rescue, require access codes in order to maintain the integrity of game data which will later be used for research purposes. For the sake of easy access, the games used in this report do not require approval from developers and are freely available online. All games were found via Internet search.

Selection criteria. The games in this report had to meet several criteria for inclusion. All the games were identified as appropriate for middle school students by the developers. In order to be included, the game had to provide feedback on user input. In addition, the game had to be developed by an entity with expertise in education, such as a university or a private company in the educational field. Lastly, the games had to be available for free. Unstructured, creativity-based games were not included. Games from "edutainment" providers (e.g. the History Channel) were not qualified.

BrainPOP is an online content provider for K-12 educators. It is a platform that curates content from a variety of sources. BrainPOP features lesson plans, educational films, activities, quizzes, and games that are searchable by age group and subject area. BrainPOP allows users to search for content that aligns with Canadian and American educational standards. According to their site:

> BrainPOP can be used in traditional, blended, and "flipped" learning settings, supporting individual, team, and whole-class learning. At school and in more informal learning environments, our characters help introduce new topics and illustrate complex concepts. BrainPOP is also an ideal fit for mobile learning and BYOD classrooms: our BrainPOP site is optimized for mobile browsers, and our educational apps - available on all major platforms - have been downloaded millions of times, and lauded in countless reviews. (BrainPOP, n.d., 3rd para.)

Given the fact that BrainPOP is free, does not require an account, and can be played immediately without special instructions, it was selected as the provider of several games. Although BrainPOP has an app, the app did not contain mobile versions of games as of the writing of this report in February 2016.

In addition to BrainPOP, Apple's App Store was also used as a game provider. This resource was selected for two reasons: 1) to have the research experience of playing games optimized for mobile devices and 2) the supposition that it may be more natural for a parent or child to search the App Store for educational content rather than conducting an Internet search. To maintain parity with the BrainPOP games, the iPad selection was also free.

Selected games. Based on the above criteria, the games examined in this report are: Citizen Science, After the Storm: Day One, Cool Science Careers: Imagine Yourself, and World's Worst Pet: Vocabulary (hereafter referred to as World's Worst Pet: Vocab). Citizen Science is available on BrainPOP and created by the Games Learning Society (GLS). The goal of GLS is to create products of a high quality both aesthetically and pedagogically (http://glsstudios.com/index.html). After the Storm: Day One is an abbreviated version of a longer game called After the Storm. Available through BrainPOP, After the Storm: Day One was created by Classroom, Inc. Cool Science Careers: Imagine Yourself is also available on BrainPOP and was designed by the Rice University Center for Technology in Teaching and Learning. World's Worst Pet: Vocab is an iPad game created by i-Ready which belongs to the company Curriculum Associates. There are six levels of World's Worst Pet that are aligned for third through eighth grade respectively. The game is intended to align with the Common Core.

Table 1

Background Information of Selected Games

	Citizen Science	After the Storm: Day One	Cool Science Careers: Imagine Yourself	World's Worst Pet: Vocab
Subject Area(s)	Language Arts (argument building) Science	Language Arts (journalism) Decision Making	Science Career Awareness	Language Arts (vocabulary)
Developer	GLS	Classroom, Inc.	Rice University	Curriculum Associates
Accessible Through	BrainPOP	BrainPOP	BrainPOP	Apple's App Store

In order to access the games used in the report, follow the links and instructions below.

Citizen Science: https://www.brainpop.com/games/citizenscience/

After the Storm: Day One: https://www.brainpop.com/games/afterthestormdayone/

Cool Science Careers: Imagine Yourself:
https://www.brainpop.com/games/coolsciencecareersimagineyourself/

World's Worst Pet: Search for World's Worst Pet in the App Store, then download the app.

Game Analysis

The game analysis occurs within the framework of social constructivism because games inherently demand participation from their users. Especially since these games are single player, one must absolutely engage with the content and construct meanings. In the absence of an instructor, the interface acts as a guide, reinforcing the student-led inquiry of social constructivism. While students do not play these games in groups, interacting with onscreen characters provides a social component. The interface of each game enables some form of mobility and thus choice in deciding how to approach the game. Finally, students approach these games with different preconceived notions and levels of knowledge. As a result, no two students experience the same game identically.

The criteria for analysis reflects the research questions. All games had to share common elements in order to facilitate comparison. Each game was analyzed based on art direction, techniques to guide gameplay, the way the game provided feedback based on user actions, event timing, the styling of progress and resource identifiers, design decisions regarding significant events, and differences in the mobile version (if available). Research question 1 (How do interfaces encourage users to take action?) corresponds to art direction, techniques to guide gameplay, the way the game provided feedback based on user actions, event timing, and differences in the mobile version (if available). Research question 2 (What techniques do educational game interfaces employ to provide feedback) pertains to the way the game provided feedback based on user actions, the styling of progress and resource identifiers, design decisions regarding significant events, and differences in the mobile version (if available). Research question 3 (How are significant events or interactions presented in a way that convey their importance?) aligns with event timing, the styling of progress and resource identifiers, and design decisions regarding significant events.

In order to visually communicate the games' interactions, this report is accompanied by several screencasts. These screencasts are stored in a folder in UTBOX called "Caroline Cancelosi MA Report Screencasts May 2016" and do not require an access code. One can view and download the screencasts at https://utexas.app.box.com/v/carolinecancelosi . This report refers to screencasts by their titles with the understanding that the reader can reference them by visiting the above web address.

Citizen Science.

Overview. Citizen Science is a single player game in which the player selects an avatar. The plot consists of traveling through time to initially prevent and later remediate the eutrophication of Lake Mendota in Wisconsin. Citizen Science combines science and language arts content by requiring players to create arguments using science facts they ascertain throughout the game. It is a problem-based learning environment.

Art direction. Citizen Science employs a cartoon-like aesthetic. The game environment uses bright colors with especially saturated chroma for characters. While the game takes place in settings that exist in the physical world (such as the dock of a lake, a ship's deck, a neighborhood sidewalk, etc.) these environments are depicted in a highly stylized way. These deliberately unrealistic aesthetic decisions lend an otherworldly fictional element to the game.

Techniques to guide gameplay. Citizen Science commences with players selecting an avatar. The player can choose between a male or a female, but cannot select other physical attributes. Once that selection is complete, the game launches into a tutorial that situates the game context and explains how to interact with other characters. There are only two screens to click through. Character interaction drives the game plot, so ensuring that players understand how to "speak" with other characters is essential. Once the tutorial launches, a transparent black overlay appears on the screen. The first screen consists of white, adolescent-like handwriting that briefly explains the game context. All other interface elements are inactive. While there is no next button, clicking the screen advances the tutorial. The second screen of the tutorial features circles and arrows to indicate the player's avatar and the representation of another character. Through this short tutorial, the player is given essential information and can jump into the game. Please refer to the video titled "CS Tutorial".

Once the player is moving around the game environment, there are several visual clues that provide guidance on what to do next. One of these clues is a blue bubble shaped icon with a white exclamation point. These blue icons appear above characters' heads to signify that a character has something to say. A drawback of the bubbles being blue is that they occasionally do not provide enough contrast with the other blue tones in the environment. However, the white exclamation point works to draw attention.

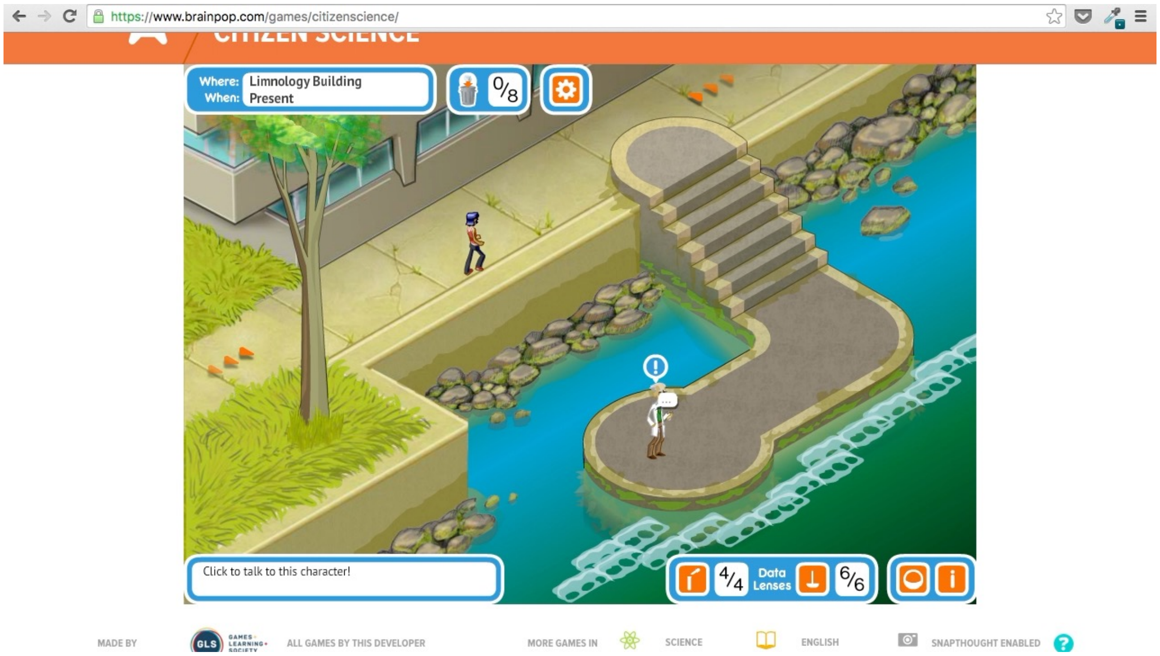

Illustration 1. Screen guiding gameplay in Citizen Science.

Physical navigation within the interface is achieved through orange triangles that provide directional guidance to paths that will lead to character interactions or task-oriented activities. A text box in the lower left corner provides hints on what to do or where to go next.

In addition to the introductory tutorial, Citizen Science provides ad hoc on-screen guidance when the player encounters a novel situation. These instructions take the form of brief, just-in-time tutorials, hover states for novel objects, and a mouse change from an arrow to another shape when the mouse approaches a novel object. For example, when the player must interact with the surface of the lake to take water clarity measurements, the mouse transforms into a Secchi disc when the player is close to the hot spot that will trigger the screen depicting the water measurement sequence. Please refer to the video titled “CS Novel Environment, Task Performance, and Interactive Feedback”.

Feedback. Depending on the player’s actions, the game will provide positive or negative feedback. *Citizen Science* allows players to make mistakes. However, they are not penalized for these mistakes; meaning the player can repeat an action as often as necessary (i.e. constructing an argument or taking a pH reading) until the correct action is achieved. This interaction choice encourages students to keep trying, rather than penalizing them for failing. An important design decision is immediate feedback. This means that the ambiguity players may feel occurs only while making decisions, it does not persist after the decision has been made because immediate feedback is available.

This feedback consists of written messages and visual cues. The written messages are in a large font. Positive feedback congratulates the user on successfully completing the task and provides instructions for the next challenge. Negative feedback indicates an incorrect action, but the detail of feedback varies with task. For simple tasks such as taking a pH reading or dropping a Secchi disk, the negative feedback indicates a specific problem to remediate, such as the Secchi disk being too deep to gain an accurate reading.

For the more complex interaction of constructing an argument, the player visually sees which components of the argument are incorrect. The player constructs an argument by dragging Inventory items on the left (facts acquired throughout the game) to the Argument Builder on the right. Each argument component is represented by a diamond that fits into a larger diamond shape. When a component of an argument is correct, the diamond is green. When a component is incorrect, it is red.

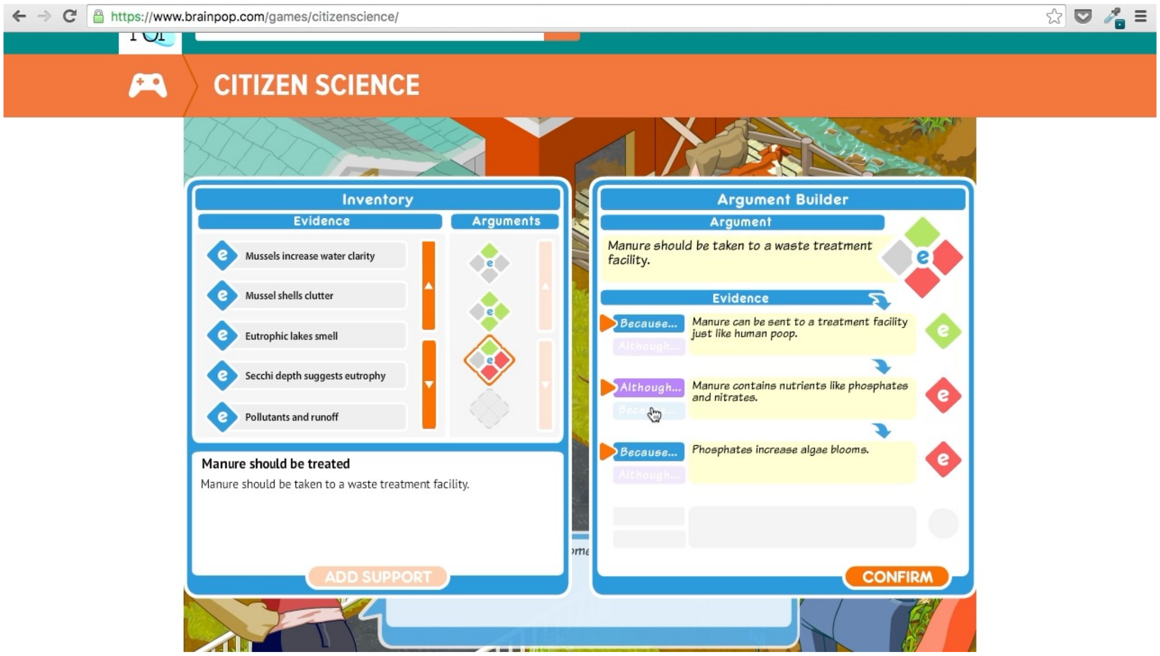

Illustration 2. Correct and incorrect argument components.

If a user submits an incorrect argument, the other character in the discussion informs the player that he/she is not convinced. However, there are no critiques of the specific argument. There is no explanation or hint why the argument is incorrect. Therefore, the player must use logic to determine why the argument is fallacious. Thus, the interface supports the educational goal of critical thinking and supports student persistence. Since the game builds on winning arguments, the student must keep trying to advance.

Event timing. Citizen Science does not impose time restrictions on players for progressing through conversations or arguments (arguments are used to convince other characters to take actions that promote a healthy lake, saving it from eutrophication). To progress the conversation, the player must click "continue." This permits players to absorb the written content at their own pace. If the conversation results in a new piece of information, called “new item” in the game, the player is immediately notified by an icon appearing on the screen. The icon is dropped into the orange i icon at the bottom of the screen. Thus the information is “placed” into a repository for later reference. Please refer to the video titled “CS Conversation and Information Acquisition”.

Progress and resource identifiers. As the player acquires data that will help construct an argument, the player is notified via flashing animation. Citizen Science also employs conventional video game design items such as progress markers to show how close one is to achieving a task. These progress markers are showed as fractions for the tasks that involve physical simulations. Notably, these tasks are small numbers (less than six) so they do not overwhelm the user.

The same approach is used for the argument builder tool. When a user first begins to build arguments, the interface does not show all the arguments the player will have to solve. Rather, a set of four argument diamonds are visible. The only active diamond is the first one, the others are greyed out. Similarly, the down arrows are greyed out as well. While the player may not consciously notice this design, it prevents the user from seeing too much information which can be overwhelming (Nelson & Erlandson, 2008).

Significant events. In an inactive or low activity state, the environment is portrayed from above at a slight angle. This enables the player to see the avatar in the context of the game environment. However, the interface changes during important interactions which can be categorized into three styles. The first style governs conversations with other characters. During these interactions, the bird’s eye view present during inactive or low activity states of the game is still visible but the player’s avatar and the character he/she is speaking with appear in large illustration at the bottom of the screen. This draws the player's attention to the foreground.

The second style determines how research and argument building functions work. The Globe and Argument Builder do not have their own backgrounds. They are overlaid against the current page the user happens to be viewing. However, the current page is darkened by a transparent black filter. This design decision was unexpected given the concentration required to determine this content.

Illustration 3. Globe interface demonstrating the second style of significant event interfaces.

The third interface style for significant events is a screen dedicated completely to primarily conveying the information associated with a particular event. The examples of this in gameplay are taking pH measurements and dropping Secchi disks.

Differences in mobile version. Citizen Science requires Flash. Since Flash is not supported on the iPad, it is not available in a mobile version for Apple users. This report was researched and completed on an Apple device.

After the Storm: Day One.

Overview. After the Storm: Day One is a single player game that progresses through the daily decisions of a newspaper editor after a hurricane. The game features an online newspaper called *The Daily Byte*. After the Storm: Day One combines leadership, literacy skills, and decision making.

Art direction. After the Storm: Day One has a sophisticated aesthetic that likely appeals to middle school students accustomed to the high quality graphics in commercial games. During the introductory sequence, the game presents text and images in a format similar to a graphic novel. The overall effect is a highly stylized version of animated depiction of reality.

Illustration 4. Screenshot from the introduction of After the Storm: Day One.

The game employs a wide variety of colors but does not have the same vividness as Citizen Science. Its palette uses muted yellow and green tones with the exception of the brightly colored characters who stand out against the background.

Techniques to guide gameplay. After the Storm: Day One employs a tutorial to introduce characters and the game environment. In contrast to Citizen Science's approach, After the Storm: Day One employs a character to guide the player through the interface. (Citizen Science employs a ghost character to orient the player on the Lake's history and the player's mission, but the ghost does not provide an interface orientation.) The magazine's intern, Ernie, introduces the player to clickable items on the interface. This is achieved through a similar technique to Citizen Science – circling items of importance. In addition, Ernie gives an overview of an important tool – the player's onscreen smartphone. The smartphone is employed to measure progress towards the game's tasks and receive important communication. Ernie reassures the player that he is available should the player hesitate where to go next. Thus, he acts as a constant guide. Forward and back buttons on the tutorial screens indicate that it is self-paced and affords users the opportunity to review past content.

Interactive items in the interface are indicated by a special hover state. The item will turn phosphorescent green when rolled over. Upon clicking the item the screen will change from a view of the environment to a detailed image of that item. This focuses user attention to the task at hand, rather than the distractions of the highly interactive environment. Please view the video "ATS Interactive Objects".

A key element that guides gameplay in After the Storm: Day One is conversation between characters. While Citizen Science also includes an important conversational element, After the Storm: Day One selectively provides players with the opportunity to choose between two things to say at certain points during conversations.

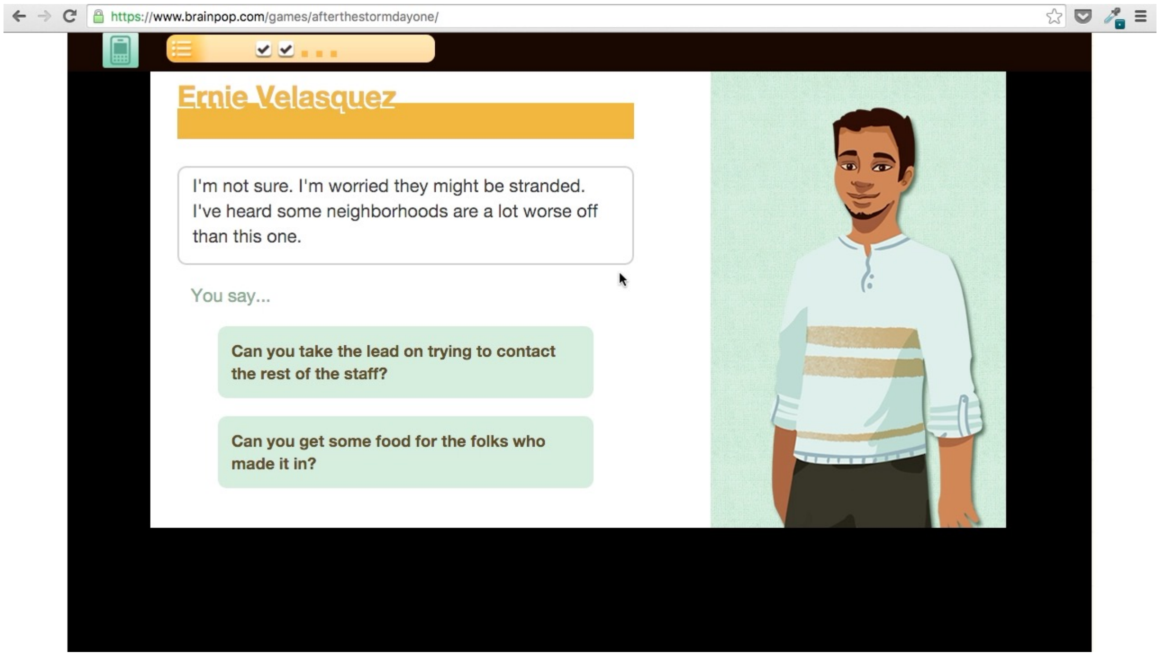

Illustration 5. The player is presented with a choice during a conversation with Ernie.

This design choice demands that players make decisions that require judgment on interpersonal matters. As shown above, the player can either ask Ernie to find missing team members or care for the ones immediately present.

The player's smartphone serves an essential role in the game as well. The smartphone is always accessible as a resource and a communication source. It contains a dictionary, a notes section, a to do list, and a text messages section. Once a player completes a task, the smartphone's to-do list will pop up, communicating the most recent achievement.

Feedback. The game permits players to submit incorrect feedback, but also communicates when they are wrong or make a less than desirable choice. A game task is analyzing a press release to determine which pieces of information must be released immediately, in the near future, and not at all. The user indicates his/her choices by highlighting the press release text in different colored highlighters. The interface allows users to click a box on the right side of the text to select the highlighter color. Underneath this box is a number indicating how many phrases belong to the color's category and how many the user has already selected. The text section of this interface allows users to click chunks of phrases (usually a sentence or two). This action highlights the text in the selected color. The user only discovers the answers are incorrect or correct after submission. For reference, please view the video "ATS News Report".

Another one of the game's major tasks is selecting missing words to complete an article. The player fills in all the "blanks" of incomplete words and can only view the correctness of the choices after submission. The correct words have a green checkmark and the incorrect words have a red checkmark. However, it is not possible to click on the correct or incorrect icons for more information. Rather, the user is told that he/she will revisit the task to try it again when he/she has better information.

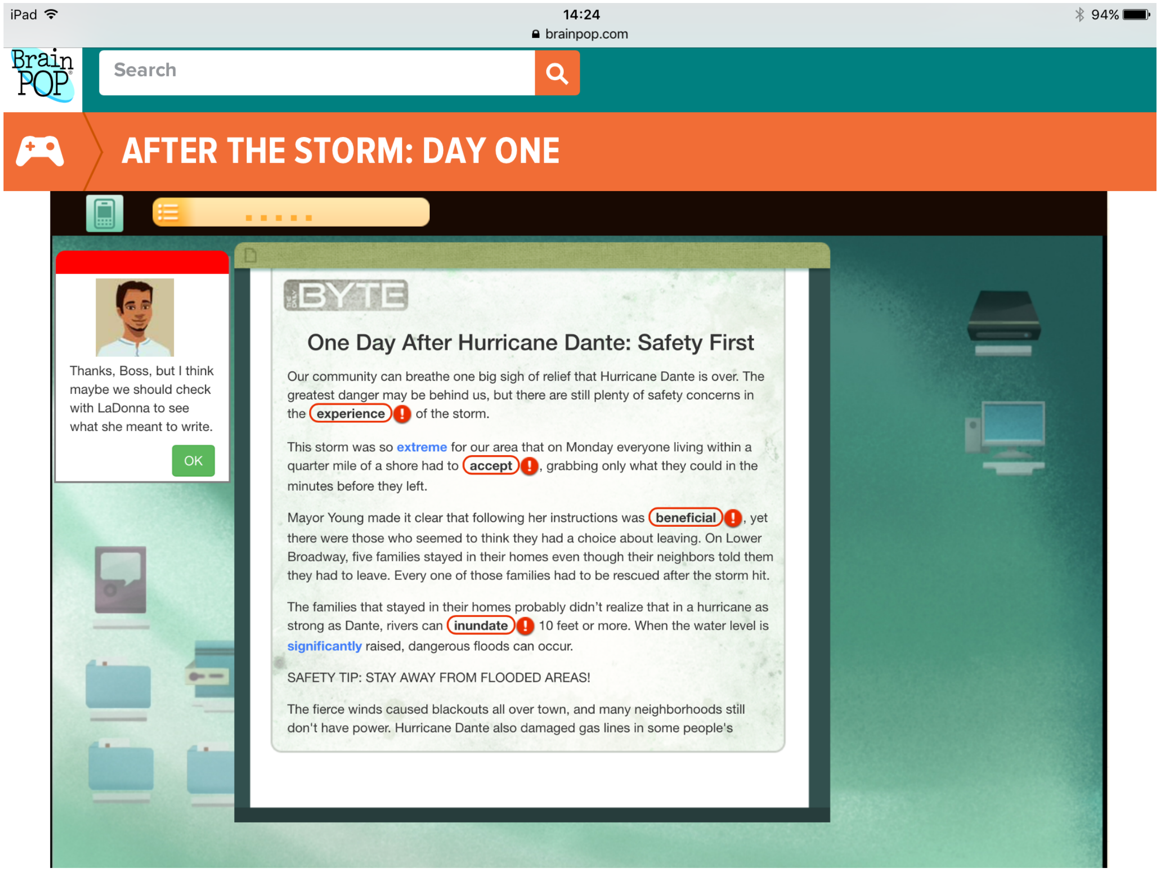

Illustration 6. Indication of incorrect choices selected during a fill in the blank exercise.

An alternative game session in which incorrect answers were purposely given revealed a challenge in creating the game interface. While this may not hold true for the main version, in the light version of the game (Day One) the user can finish the game session with incorrect, yet complete tasks. Thus, users know their work is incorrect but are not given a reason why.

Feedback is essential when players must make a choice in conversation between saying the "correct" option (finding a way around a problem) and "incorrect" option (resignation to the challenge being too difficult). When a user selects the correct option, the discussion mentions a strengthened resolve to solve a problem. When a user selects the incorrect option, the character will remind the user not to give up, citing responsibility to disseminate information. The character's response to the incorrect answer steers the player towards the correct answer. Thus, feedback is used to reinforce desirable behavior.

Event timing. Users click through the tutorial, respond to conversations, and complete tasks at their leisure. While the interface does not permit a user to exit an activity, he/she is permitted to change his/her response multiple times before submission. Once the user finishes a discussion/task, the user is booted out of the previous screen and is immersed into the background screen with the smartphone in the foreground, informing the user of another task completed.

Progress and resource identifiers. The smartphone is a major progress identifier in terms of the overall game. The To Do list keeps track of what the user has done and what needs to be completed. It also contains the player's resources in a compact fashion. Progress throughout individual game tasks is indicated by a blank item being filled in or a section of text being highlighted and the corresponding highlighter count moving up. While in a task, the user has the liberty of moving about the assignment, answering out of order.

Significant events. Significant events are given new screens. In the instance of character interaction, the interface only shows a simple background that consists of the image of the character the player is speaking with and the dialogue text boxes. Once the conversation is over, the previous screen appears. In the case of game tasks, the text body appears on the left and the options for word or highlighter placement are on the right. These events do not allow the user to exit without completing the interaction.

Differences in mobile version. Using an iPad to play After the Storm: Day One presents the challenge of a lack of hover states. As such, the player does not have visual clues about what to explore next. This can result in longer game play and possibly increase user frustration.

Cool Science Careers: Imagine Yourself.

Overview. In addition to teaching science knowledge, Cool Science Careers: Imagine Yourself (hereafter referred to as Imagine Yourself) game also helps students discover if they are well suited towards a variety of scientific careers. Players complete simulated experiments and at the conclusion of each experiment there is information on who may enjoy the career related to the particular experiment and the necessary educational attainments. This game is immersive and task oriented. It encourages self-reflection from the players.

Art direction. Imagine Yourself has the most photorealistic interface of all the games considered. Rather than appealing to fantasy, it represents an actual science lab. Through this art direction, the game attempts to be immersive and simulate the actions a lab worker would take. All action happens from a first person perspective. While the player does not see his/her hands, he/she can manipulate objects. Imagine Yourself mostly employs bright colors during interface screens that depict experiments. The art direction follows this path because the game is intended to educate students about career options in the sciences.

Techniques to guide gameplay. Imagine Yourself consists of students exploring four different science careers. There is a “home screen” with links to a module for each career. Players can progress through the careers at will, probably to allow them to “experience” the career that intrigues them most first. Each module follows a general pattern of immersing the student in a lab environment.

Pulsing green florescent light over a particular object (similar to After the Storm: Day One) invites students to explore and indicates where they should go next. Clicking on this object triggers an experiment which allows players to learn by doing. To see this in action, please view “IY Flashing Object and Smartphone Interaction”. The players receive information about the topic as the experiment progresses. Thus, the interface acts as a guide, rather than a passive lesson followed by questions.

The manipulation of physical objects during the experiments is key – it simulates the physical steps a scientist takes during an experiment. Furthermore, it builds students’ familiarity with lab equipment and following a specific process to obtain scientific results. Text provides written instructions that are reinforced by the module’s animations of physical actions. For further reference, please view “IY Lab Experiment”.

Feedback. During the experiments/research, the player receives immediate feedback that clearly indicates whether the answer is correct or incorrect. This not only applies to a final answer but an answer that is used to build an equation. The user must try again until the correct answer is obtained. The interface design employs the traditional color associations of red for incorrect and green for correct.

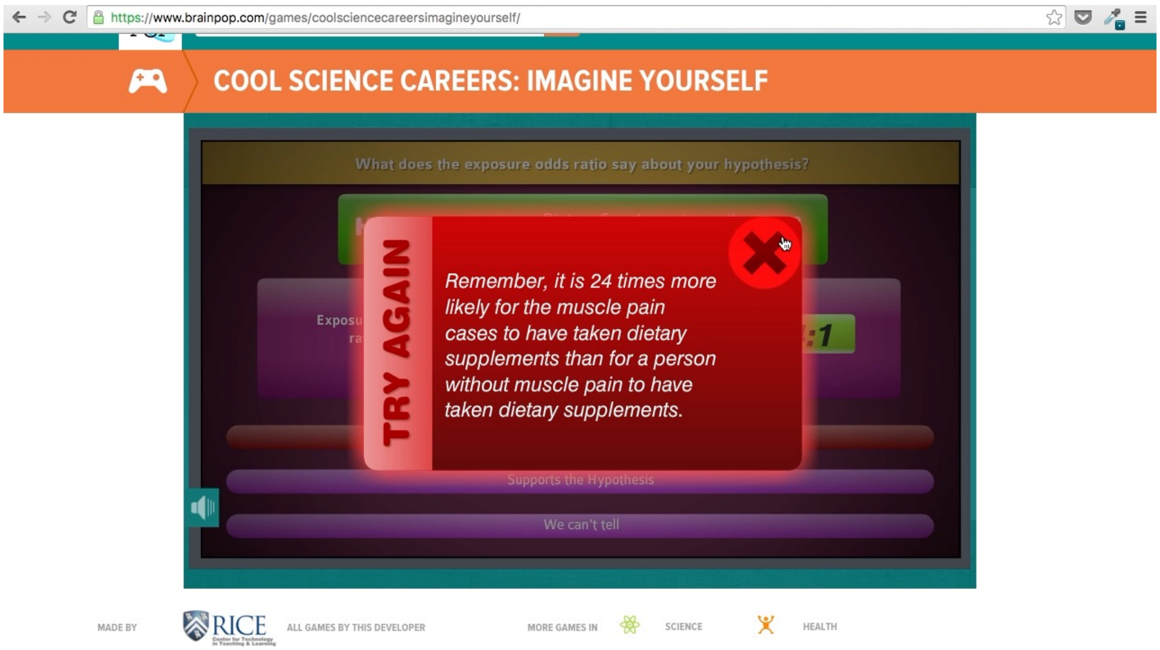

Illustration 7. Depiction of an incorrect answer during a critical thinking exercise in a lab simulation.

As shown above, the feedback takes visual command of the screen. The rest of the interface is greyed out and the user must interact with the notification to progress, even though this interaction can be as cursory as quickly hitting exit. Unlike other correct/incorrect feedback messages, Imagine Yourself provides some related information that could help a player rethink a problem. In this way, the interface mimics an instructor who could provide clarification on the problem. The correct notifications provide a brief summary of why the answer was right.

A negative and perhaps unintended form of feedback is the precision required to manipulate pipettes and other similar objects. The user must execute a grasp and drag motion that is not entirely natural after simply clicking on computer screens to access the experiment part of a module. Upon the successful completion of a module, there is a certificate of completion the player can print out.

Event timing. Players can progress at their own pace through the experiments. However, once in an experiment, players are locked both in that sequence and on that page. Progressing to the next page requires a correct answer. When an experiment is complete, the user is returned to the laboratory. A bulletin board in the lab lights up to encourage the user to click. This bulletin board contains practical information about how to get to that particular career.

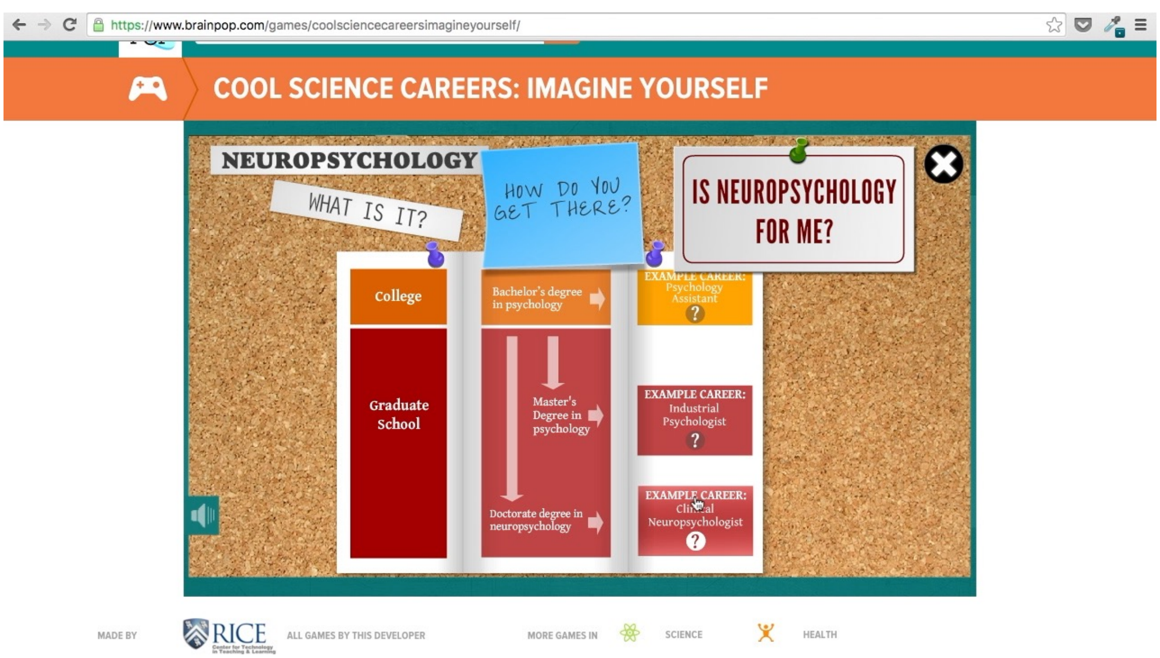

Illustration 8. A stylistically bulletin board that has clickable elements.

The bulletin board pictured above is interactive. Clicking on a particular heading will display that specific content. This process mimics the steps in searching for information. It also reinforces content while extending knowledge.

Progress and resource identifiers. While subtle, progress bars appear on the "main page" of each module. Their presence indicates to the player that the module is not yet over. However, the flashing objects convey a continuation of the module more obviously than the progress bar. Once inside an experiment sequence, the progress bar disappears.

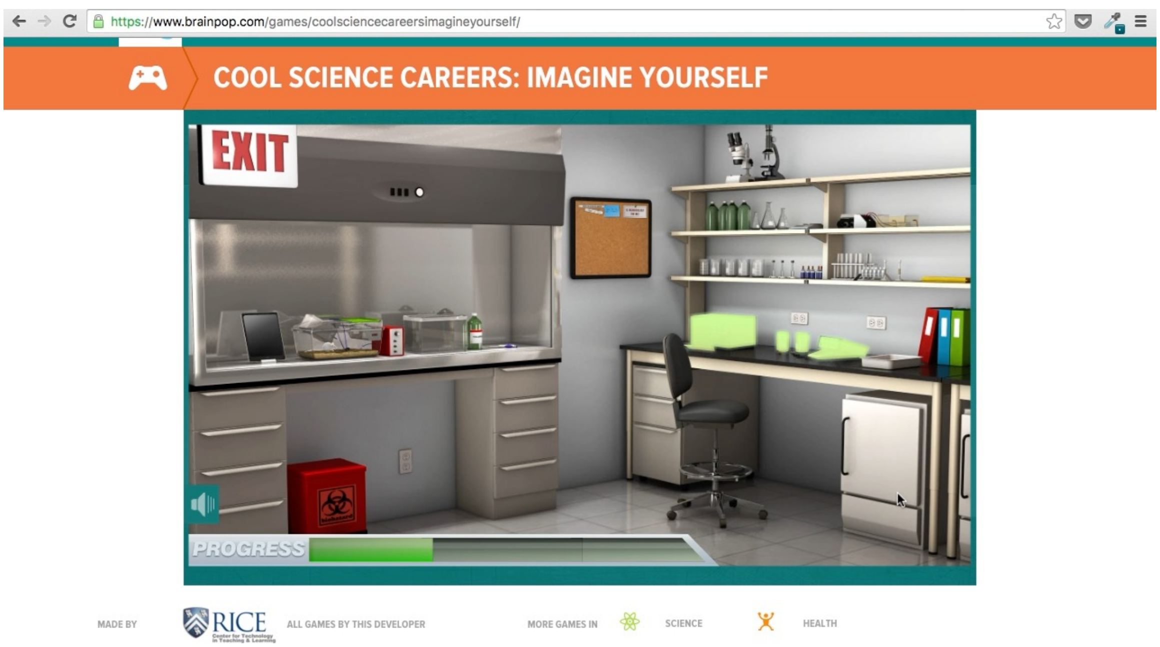

Illustration 9. Progress bar and green lab objects to indicate where to click next.

In contrast to the progress bar within the home screen, there are no visible progress or next/back buttons within the tasks of an experiment. Presumably, this is to prevent student anxiety over how many steps remain. Please view “IY Progress Within Experiment”.

Significant events. Whenever the interface goes from a home screen into an experiment, the interface looks completely different. There are two general aesthetics for significant event/process interfaces. The first aesthetic is for experiments that require manipulation of physical materials. In this setting, the user sees an up-close view of the experimental materials. The second aesthetic concerns mathematical calculations, graph comparisons, or similar information. These interfaces vary but they tend to be a solid color background to draw focus to the data and accompanying question. Please view “IY Progress Within Experiment”.

Differences in mobile version. Cool Science Careers: Imagine Yourself requires Flash. Since Flash is not supported on the iPad, it is not available in a mobile version for Apple users.

World’s Worst Pet: Vocab.

Overview. World’s Worst Pet is a single player game that is focused on progressing through game levels and acquiring badges. The game starts when a young male narrator tells the audience he found an otherworldly pet. The plot consists of the pet, named Snargg, getting into dangerous situations. The player must answer vocabulary questions to get Snargg out of trouble. World’s Worst Pet differs from the previous three games because it is embodies a drill format rather than a problem based learning environment.

Art direction. The overall look of this game is playful. Given its premise of rescuing a fictitious pet, it does not attempt to be serious or realistic. The aesthetic effect is nonthreatening and friendly. Given the wide age range of students who may use this app (8 – 13 years old), the illustration needs to be appeal to a broad group. While this aesthetic is not as sophisticated as others, it suits content material that is independent of a game environment.

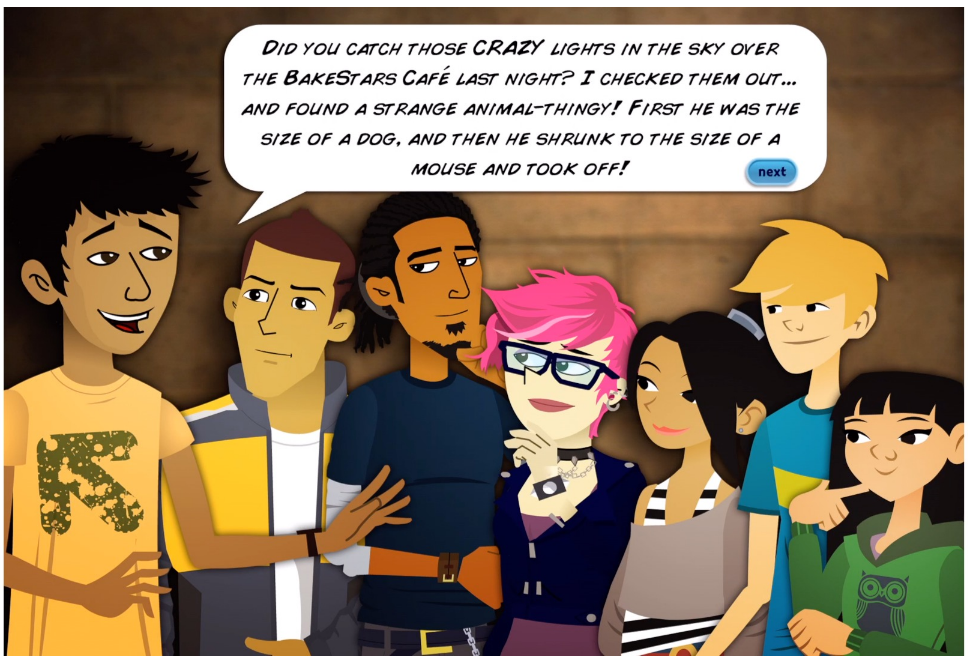

Illustration 10. Illustration style in World's Worst Pet: Vocab with Sweet T talking.

In the case of World's Worst Pet: Vocab, the content is vocabulary questions. While this app requires critical thinking and judgment skills, there are drill aspects to the app. As such, the illustration does not need to be elaborate because the learning environment is not a complex, problem-based learning scenario.

Techniques to guide gameplay. World's Worst Pet: Vocab makes use of a brief introduction to situate players in the game context. Its most important techniques are the use of interface/interaction tutorials and the omnipresence of a guide in the upper right corner should a user get stuck. The interaction tutorials are mandatory and they fall into two genres. The first genre shows users around the vocabulary introduction section. It is here that the guide, the main character named Sweet T, explains how the game works and assures the user he will be available for reference should the user get stuck. To see this in action, view "WWP Vocabulary Introduction" .

The second genre consists of three steps to point out where items are and a demonstration of the manual gesture to move a vocabulary word into the selection bin. The user cannot progress forward to actual gameplay until this tutorial has concluded. However, the next button appears soon after. For a visual reference see "WWP Interface Tutorial".

Feedback. The interface provides feedback by preventing players from dropping an incorrect word choice to the bin. It is possible to drag an incorrect word over to the bin, but when a student gets close to placing it, the word pulls back to its original spot. This physical notification takes the place of a verbal message. When a student places a correct word in the bin, the word lights up gold. As more words are dropped into the bin, the rope holding it up frays. Eventually, when the bin is full, the rope holding it up glows gold and the student can swipe across the rope to tear it down.

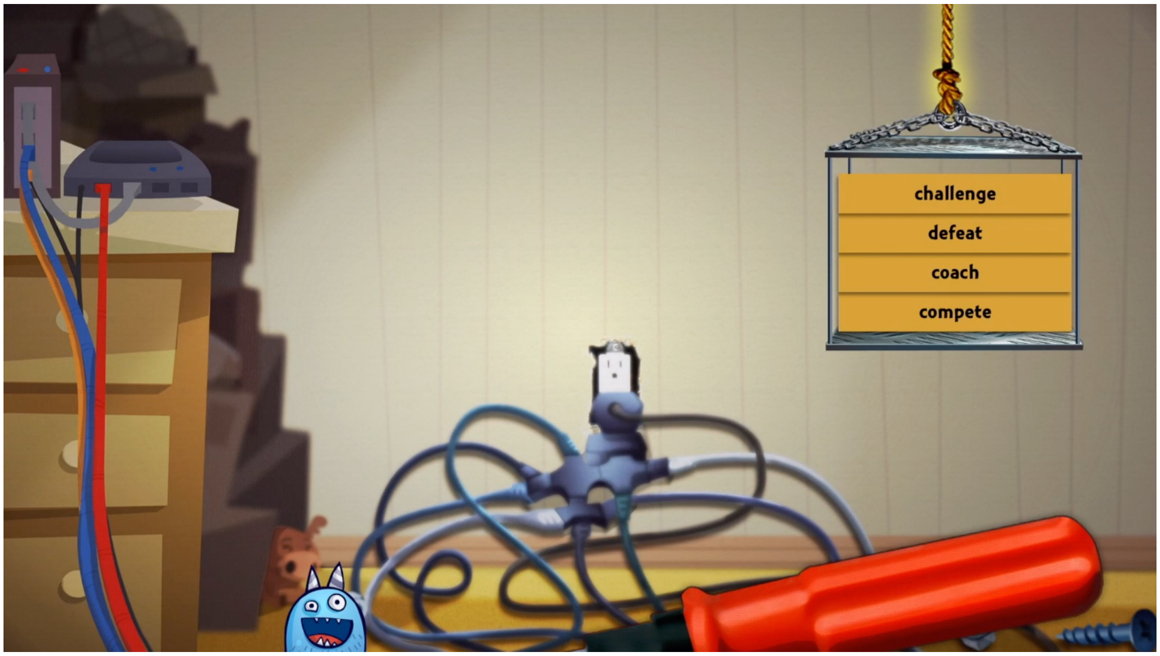

Illustration 11. Snargg featured on the bottom left and bin ready to drop.

Perhaps because the focus of the game is so verbal, the interface feedback was purposely designed to be visual in nature to the lessen cognitive load on one domain area.

Event timing. There is no timer, but after a student completes several sessions within a sublevel, the next game qualifies for winning a badge. This game is time stamped along with a congratulatory notification. The meaning of this time stamp is not entirely clear. The instructions do not emphasize completing tasks in a certain amount of time. The game also allows students to change word sets, levels, and log out at any time. The game continues automatically until a student completes a set. Then the student must decide what to do next.

Progress and resource identifiers. While the game's open structure of permitting users to play a level at-will provides freedom, it also prevents a clear hierarchy of progressing through the game. Although a student may be motivated by the prospect of earning badges to complete each sublevel, students are not required to go in any particular order. He/she may click sublevel set 1, exit that session, and enter sublevel section 7. This layout enables students to play to their level, but may not necessarily force them to face academic challenges. Partnered with the fact that students can never submit a wrong answer, the game does not promote facing the possibility of failure.

An alternative way to examine this structure is that this openness enables students to play a level below their actual grade level without feeling embarrassed. Similarly, advanced students can play above their technical grade levels. Thus, the app can be used for remediation and knowledge advancement.

The main resource is Sweet T, depicted by an illustration of his head in the upper right corner. Sometimes other characters appear in Sweet T's place. Apart from this guide, the game does not have other resources because the player does not need to keep track of complicated or detailed information. The game asks the player to focus on the task at hand without the distraction of a complex plot.

Significant events. A significant event would be considered a badge. Since the game follows a repetitive drill structure, it does not have complex interactions.

Chapter Three: Discussion and Implications

Discussion

The discussion section will address the research questions raised in Chapter Two. In addition, it will cover the similarities and differences among the games.

Answers to research questions. Research question 1 posed: How do interfaces encourage users to take action? From an art direction perspective, bright colors indicated interactive objects, especially characters. The designers employed several techniques to nudge users towards taking action such as controlling when buttons appear, using highly visible markers (such as lines or flashing lights) showing where to "walk" or click next, changing the mouse shape during the hover state over a clickable object to demonstrate its interactivity, and zooming to focus attention. Feedback encouraged action through hover states. The event timing encouraged action by freezing players within a sequence, preventing them from moving on until an action occurred. Visual indications of resources appeared on an as-needed basis. Mobile differences encourage action by educating users about available actions through a tutorial.

Research question 2 asked: What techniques do educational game interfaces employ to provide feedback? Designers used a variety of techniques such as immediately providing feedback on the correctness or incorrectness of the answer, allowing the player to make an error and move on, or requiring the user to try again until the correct answer was achieved. Resources were used to provide feedback by immediately sliding on the screen so the player would be required to engage. To indicate a significant event, the visual perspective would change. Designers used the techniques of pop-ups, zooming, or showing a new screen with reduced or no visual clutter. Mobile devices present a different feedback schema because they do not have hover states. World's Worst Pet: Vocab mitigated this issue by having incorrect answers slide away.

Research question 3 inquired: How are significant events or interactions presented in a way that convey their importance? Interface designers used event timing to eject players out of screens once the sequence was complete or goal achieved. To present the importance of significant events, a visual component of the typical landscape would be altered – either a character would become larger or a separate screen would appear. Progress towards completing a task and resource identifiers would appear to visually fill up (in other words, parts of the whole would be added). If movement to another part of the game environment was required, a flashing light or mobile phone reminder would appear.

Similarities and differences among the games. Citizen Science, After the Storm: Day One, and Imagine Yourself are high caliber games both in terms of content complexity and game environment. These three games consist of mandatory movement around an interface, interaction with items within that interface, and completing multiple challenges to achieve a larger goal. It would not make sense to compare the quality of World's Worst Pet: Vocab to these previous three because its intent is much simpler. However, World's Worst Pet: Vocab has the merit of an intuitive interface and a visually-oriented design, complementing the game's focus on text.

Shared themes. There were several common themes among the educational games in this study. One of these was the incorporation of a guide. After the Storm: Day

One and World's Worst Pet: Vocab include a human character the player could consult. In these games Ernie (After the Storm: Day One) and a character in the upper right corner of the screen (World's Worst Pet: Vocab) are clearly identified as a resource to consult should the player get stuck. While Citizen Science also employs guides through revealing conversations, there is not a consistent individual to consult.

Another shared theme is the incorporation of technological devices into the interface. After the Storm: Day One and Imagine Yourself contain devices such as desktop computers, tablets, and smartphones. In addition, these devices help drive game play by providing communication regarding tasks.

Illustration 12. Smartphone use in context After the Storm: Day One.

The smartphone in After the Storm: Day One mimics the multi-functionality of an actual device; displaying content according to the constraints of an actual handheld device. In addition, the player can consult the phone whenever he/she desires, just like in real life.

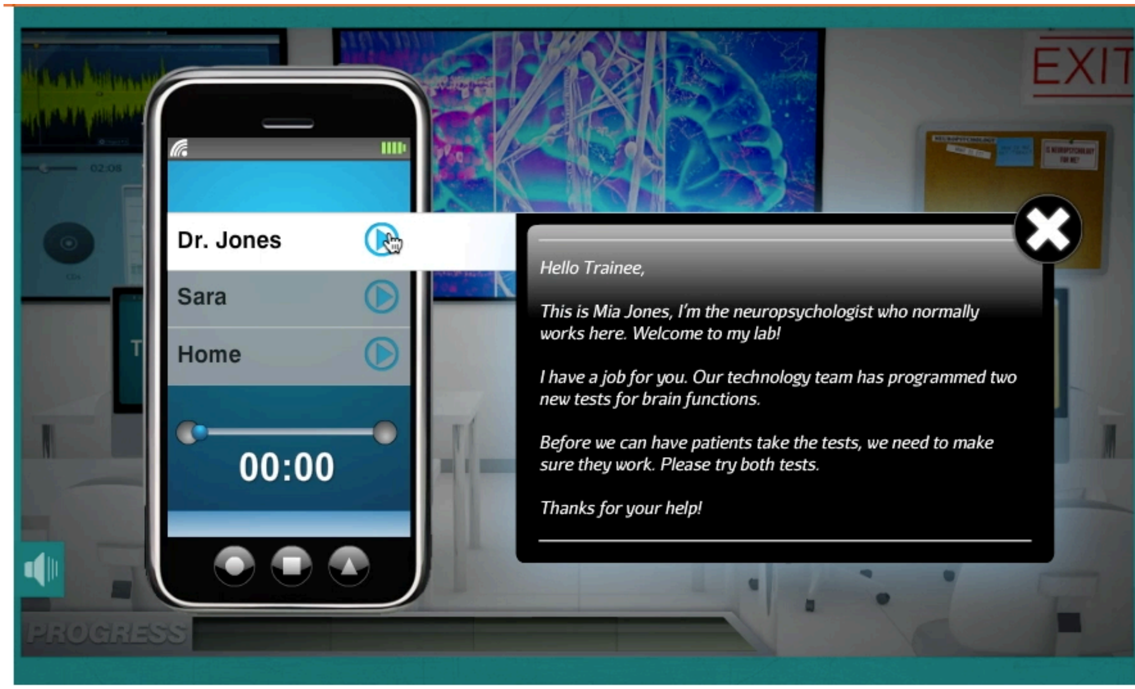

Illustration 13. Smartphone use in context in Imagine Yourself.

The smartphone employed in Imagine Yourself serves a more basic function and cannot be retrieved whenever the player wishes. Furthermore, the interface does not mimic a real smartphone because the message appears to be a voicemail but displays as text in a window outside of the phone's physical borders. Imagine Yourself employs the smartphone as an afterthought, rather than a vital interface component.

All four games made use of chunking to divide content into accessible parts. None of the games required players to race against the clock, valuing accuracy over speed.

Another pattern was "locking" players in an interface until the task was complete. Finally, all game interfaces had an emphasis on quality graphics, regardless of aesthetic style.

Significant game features. There are several high level design features in the games that shape the overall experience. One of these is mobility within the environment; mobility being defined here as autonomous change of location initiated by the user. Citizen Science and After the Storm: Day One both afford a great degree of physical mobility. Citizen Science takes place in an outdoor setting and requires the player to physically move his/her avatar to the next location in order to acquire necessary information. Due to this feature, it is the most physically active game. The mobility in After the Storm: Day One is more passive. The player clicks on a location to enter that space. For instance, the player would click on the door of the photo room to enter. Once a player clicks a desired location, he/she sees the scenery of that place.

In contrast, Imagine Yourself and World's Worst Pet: Vocab do not have backgrounds that permit exploration. Imagine Yourself offers freedom in permitting users to determine which lab to explore first. Once inside a lab, it offers multiple interfaces within the same space (e.g. a research screen versus a panorama of the lab) but does not require the user to move to another part of the lab or another building to complete the sequence. Any change of location is completed for the user. Similarly, World's Worst Pet: Vocab offers different background imagery but the user has no control over this environment.

The pronounced mobility featured in Citizen Science may be because it is the only game that features an avatar. In After the Storm: Day One, the player is aware that he/she is a newspaper editor and therefore a different person in the game than in real life. However, since there is no physical representation of that alter ego in the game, it does not employ an avatar. In Imagine Yourself the player is clearly him/herself and World's Worst Pet: Vocab focuses on engaging the player in task-focused drills rather than creating an identity.

The aesthetic environments within the game influence the overall feel. Citizen Science and After the Storm: Day One both use stylized environments to different effect. Although both are obviously animated, Citizen Science has a more youthful, cartoonish feel whereas After the Storm: Day One is more sophisticated and less childish. Due to its visual styling, it conveys a more adult feel which makes sense because the player's character and his/her office "colleagues" are adults. In contrast, the Citizen Science avatar appears to be a tween or a young teen. The environment of World's Worst Pet: Vocab could be considered a fantasy one because of the fictitious Snargg and the series of random backgrounds that do not fit together. Even though Citizen Science employs some fantasy elements such as time travel and otherworldly characters (a ghost and a monster), the environment is more realistic than fantasy because of the context of collecting scientific facts to solve a real world problem.

Citizen Science, After the Storm: Day One, and Imagine Yourself all feature problem-based learning elements. Citizen Science and After the Storm: Day One have open, navigable interfaces that support the ambiguous nature of problem-based learning.

Unlike Alien Rescue, there are interface clues that indicate which actions to take next. However, they still demand independent thinking and decision-making from players. Imagine Yourself incorporates problem-based learning elements, but given its more structured environment, it could not be considered an optimal example. All the games except Imagine Yourself offer an interface tutorial before gameplay. However, Imagine Yourself mitigates this need by providing immediate visual cues via flashing objects. Once a player interacts with an object, the game follows a rigid set of interactions to prevent the player from getting off task. As needed tutorials are provided during experiments with equipment manipulations.

Table 2

Significant Game Features

	Citizen Science	After the Storm: Day One	Imagine Yourself: Cool Science Careers	World's Worst Pet: Vocab
Mobility within Environment	✔	✔	-	-
Use of Avatar	✔	-	-	-
Realistic Environment	-	-	✔	-
Fantasy Environment	-	-	-	✔
Stylized Environment	✔	✔	-	-
Fantasy Character(s)	✔	-	-	✔
Problem-Based Learning Environment	✔	✔	✔	-
Interface Tutorial Before Gameplay	✔	✔	-	✔
Ad-Hoc Interface Tutorial(s)	✔	-	✔	-

Indications of clickable items. Both After the Storm: Day One and Imagine Yourself utilize green lighting to indicate an interactive item. However, they have different techniques. After the Storm: Day One requires players to discover what is clickable by casting a green light over an interactive item during a hover state. In contrast, Imagine Yourself uses a flashing green light on an object to an encourage a user to click an object, such as a computer or a phone, to receive information about the task. Hovering on various lab objects will show inactivity with the exception of the bulletin board and the next sequential object to click. This design choice reveals the game's priorities. By enabling a player to quickly access information about the career path and requisite academic steps, the player can avoid the discovery experience. This choice indicates that the developers do not want to deny students information, even if it is possibly at the risk of not intriguing them via the research sequence.

Citizen Science takes the approach of using objects as markers. Two examples include speech bubbles over characters' heads to indicate conversation capacities or signs over places to take water samples and readings. This approach is much more direct than After the Storm: Day One, but given Citizen Science's vast physical environment and the need to traverse it, this design decision makes sense.

Since World's Worst Pet: Vocab is an app and does not have hover states, it mitigates potential user confusion with an initial interface tutorial. The only interactive items are the word choices, the guide, the rope when the problem set is complete, and navigation elements that permit the player to exit.

Differences in feedback styles. Citizen Science, After the Storm: Day One, and Imagine Yourself all permit players to submit incorrect answers. However, Imagine Yourself is the only game that provides hints on why an answer is incorrect. If the user guesses an incorrect answer, it is possible to keep on selecting answers until he or she submits the correct one. Imagine Yourself uses a color scheme of red and green to indicate incorrect and correct respectively. Similarly, After the Storm: Day One and Citizen Science have red and green color cues. World's Worst Pet: Vocab does not use color to indicate an incorrect answer. Rather, the word choice slides back to the word bank and Snargg makes an anxious vocal sound. Interestingly, the only color change is one from light gold to dark gold once a correct answer is placed into the word bin. In light of Norman's (2004) work on emotional design, the absence of major negative feedback indicators (e.g. a popup or other significant interface change) is likely an intentional choice. Since World's Worst Pet: Vocab consists of a drill format, rather than critical thinking exercises mixed with occasional fact recollection, constant negative feedback may have resulted in persistent unpleasant emotions. Therefore, the designers and developers may have elected to use a more subtle reinforcement.

Implications

After the literature review, individual game analysis, and game comparison I had a more informed and nuanced perspective on educational games. In this section I will share my thoughts on the topic. During my search for mobile-based educational games, I encountered free products on the App Store with varying levels of educational rigor. The educational aspect was often an afterthought, although the interfaces were usually beautiful and engaging. A future direction of interface research can compare the features of educational games to “edutainment” games produced by large media companies. The researchers can propose which qualities to borrow from games with a more commercial focus while also suggesting techniques for the edutainment games to be more pedagogically vigorous. Another research project could consist of examining apps marked as educational for a specific audience and content area (i.e. middle school language arts) that are available from the App Store or Google Play. The intent of this research would be to identify a continuum of educational soundness in order to devise a ranking scheme that would help parents and educators select products with confidence.

Unexpectedly, my research and observations left me with more questions. Before completing my literature review, I anticipated finding multiple articles on interface design for educational games created for a middle school audience. In actuality, I was confronted with a paucity of literature; the only search that directly matched my criteria was the Nelson and Erlandson (2008) article which is not recent considering the advancements in computing since that time. Therefore I suggest that more research is required in this domain.

As I observed my selected games, the queries that emerged were more specific than my original research questions. Thus, they are the next steps in the research process, either for me (should I continue this research) or another researcher.

1) What tools can a UX/UI designer consciously employ to guide gameplay?
2) How will an interface differ depending on educational goals?

3) How does an interface support player decision-making?

Based on my experience playing educational games, I have devised some potential answers. I am aware that academic research involving a middle school audience is likely necessary to support the following conjectures.

Conjecture for Question 1

Guidance techniques adopted by the games included a "guide" to ask for advice, a tutorial, and a plethora of visual cues on what to explore next in order to gain more information. Techniques for visual cues included an obvious hover state and an icon on the interactive area.

Conjecture for Question 2

The interface of a problem-based learning environment will allow greater mobility within the game. Based on the games selected, the player can physically move from different locations but once the player has entered a challenge, he/she is locked in it until that challenge is complete. Another technique used in problem based learning games is indicating that information is incorrect without explicitly saying why. Further research is needed, but this may encourage users to think through why an answer is incorrect. If an educational game is drill-based, such as World's Worst Pet, the interface does not need to have an elaborate environment.

Conjecture for Question 3

A well-crafted educational game can support both content knowledge and promote decision-making skills. An excellent example of this is After the Storm: Day

One. Building these decision-making abilities could be essential as middle school students enter adolescence and face challenges such as peer pressure.

Miscellaneous observations. Both Citizen Science and After the Storm: Day One employ relevant issues in their storylines. Players in Citizen Science must manage the effects of human pollution on the environment and After the Storm: Day One participants must cope with the aftermath of a natural disaster. Both of these problems affect large groups of people and require the coordination of multiple groups for resolution. Both games have interfaces that require movement around the game environment and discussion with other characters. Due to these characteristics, their interfaces support information seeking and taking initiative. Given this similarity, freedom of movement and a plethora of interactive objects may be essential interface features for games that promote critical thinking and unraveling complex problems.

Imagine Yourself could have employed fellow lab mates to communicate information and serve as mentors during experiments. Instead of using the smartphone, a lab mate could walk into the frame and reveal relevant information. If the game designers were worried about the interface feeling crowded with another character taking up space, then the experiments could remain as-is. Especially in contrast with the other games which feature other characters and interactions, the mood of Imagine Yourself felt isolated.

Recommendations for educational games based on this report. Based upon this report's analysis, below are recommendations for educational game designers and developers to consider.

- Include as-needed information. Rather than employing a tutorial to cover all the interfaces a user will see, use several mini tutorials to briefly teach the information as it is encountered.
- Consider a way to include information or a hint if a user gets stuck. This scaffolding technique could be providing a "bonus" fact or providing a parallel example.
- If possible, find a way to explain incorrect answers for players. This may be especially important for students who play independently of instructor guidance.
- Design a "mask" a player can apply over an interface to determine which items are clickable. This will compensate for a lack of a hover state in mobile devices. It could also provide increased accessibility.

Educational games can provide an engaging and constructive experience for middle school students. Designing games that are equally as effective on desktops and mobile versions is challenge that UX/UI designers will increasingly face. The learning goals of the educational game should determine the design.

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