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Game-Based Literacies and Learning: Towards a Transactional Theoretical Perspective

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Abstract

Current research suggests digital games can positively affect learning by motivating students in ways that traditional learning may not. Some argue that games possess similar elements to other signifying systems, including reading and writing. Employing a design-based research framework and drawing connections between gameplay and literacy, we explored how games may benefit from the literacy field's transactional theory to interpret the ways gameplayers' efferent and aesthetic stances affect gameplay and learning. Results indicated that (a) students with efferent stances may be better suited to game-based learning; and (b) games must be purposefully designed to manage the cognitive load required by the content and navigation features. Future research should focus on more in-depth analyses of in-game performance and its relationship to learning outcomes as well as further explore how transactional theory can be used to understand students' approach to gameplay using a combination of aesthetic and efferent stances.

Keywords: Game-Based Learning; Literacy; Transactional Theory; Cognitive Load; Design-Based Research

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Game-Based Literacies and Learning: Towards a Transactional Theoretical Perspective

Today's students are involved in a variety of literacy practices as they increasingly engage in digital gameplay on computers, hand-held devices and mobile phones, both in and out of school (Noonoo, 2019). Gee (2003) explains there are various ways of reading and writing and, each way is rooted in "a lived and historically changing set of discursive practices" (p. 21). In many ways gameplay is similar. Buckingham and Burn (2007) argue that there are numerous features that games share with other signifying or representational systems, including reading and writing. Games are almost always multimodal texts, where different communicative modes are combined, such as sound and music, speech and writing, and still and moving images. Spires (2015) notes, "Just as literacy practices are contextualized in social situations and relationships, game players establish shared language and understandings within a game; in essence they gain fluency in a specialized language" (p. 126). This assertion was also illustrated through a recent discussion by Lasley (2017).

Gee (2003) asserts that, "When people learn to play video games, they are learning a new literacy" (p. 13). He adds that in addition to the traditional idea of reading and writing, literacy is also tied to semiotics and social practices. Whether one fully agrees with Gee's definition of literacy or not, it is hard to ignore that there is a growing recognition of the transformative potential of video and online game-based learning in education.

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As numerous scholars have observed, a diverse range of students are poised to take advantage of educational games (Gee, 2007; Gibson, Aldrich, & Prensky, 2007). Educators and researchers are continuing to explore ways to appropriate the best features of game-based learning and bring them into the classroom. Generally, the research literature is divided into studies that focus on learning and studies that examine effects on motivation and engagement.

The studies that focus on learning do so in a variety of ways. For example, some research has shown that games can help students learn content in various subjects, such as science (Lester, Spires, Nietfeld, Minogue, Mott, & Lobeni, 2014), math (Castellar, All, de Marez, & Van Looy, 2015; McLaren, Adams, Mayer, & Forlizzi, 2017; Ninaus, Kiili, McMullen, & Moeller, 2017), English (Yip & Kwan, 2006; Pruden, Kerkhoff, Spires, & Lester, 2017), and foreign language (Johnson, 2010). Studies have also shown that games improve specific skills, such as problem solving (Chuang & Chen, 2009; Kolovou & Heuvel-Panhuizen, 2010; Liu, Cheng, & Huang, 2011; Spires, Rowe, Mott, & Lester 2011; Ya-Ting, 2012) and knowledge acquisition (Brom, Preuss, & Klement, 2011; Chuang & Chen, 2009; Huizenga, Admiraal, Akkerman, & Dam, 2009; Manfra & Spires, 2013; Papastergiou, 2009).

Research on games has evolved to the point that researchers have conducted meta-analyses to demonstrate the impact on learning. Recent meta-analyses have shown that games have an overall significant, positive impact on learning (e.g. Zhonggen, 2019; Lamb, Annetta, Firestone, & Etopia, 2018; Backlund & Hendrix, 2013; Clark, Tanner-Smith, & Killingsworth, 2016; Merchant, Goetz, Cifuentes, Kenney-Kennicutt, & Davis,

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2014; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013). The literature, however, is divided on the impact games may have on overall school-based academic achievement, which may be due to issues with measurement (Perrotta, Featherstone, Aston, & Houghton, 2013).

Many studies have also shown that games can improve students' engagement and motivation for learning (e.g., Papastergiou, 2009; McLaren et al., 2017; Sung, Hwang, Lin, & Hong, 2017; Sawyer, Smith, Rowe, Azevedo, and Lester, 2017). The meta-analysis conducted by Wouters et al. (2013), however, found that games did not differ from non-games with motivational outcomes. Nevertheless, Clark et al.'s (2016) more recent meta-analysis, which examined motivation along with other factors such as work ethic and intellectual openness as part of intrapersonal learning outcomes, found that games do support overall improvements in this area.

In recent years, there has been the emergence of theoretical and epistemological foundations for games (Gee, 2017; Aldrich, 2004; Prensky, 2006). As participants at the National Summit on Educational Games as far back as 2006 concluded, the key issue confronting the educational community is clearly articulating *why* and *how* games are effective. Although great strides have been made to meet this goal from 13 years ago, there are still not clear answers due to issues such as inconsistent measures of variables like learning, motivation, and academic achievement (Perrotta et al., 2013). Furthermore, researchers must strive to provide practical guidance for how and under what conditions games can be integrated into the classroom to maximize their learning potential. An essential question for educators is whether students can increase their school related

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content knowledge and academic achievement through a game experience (Perrotta et al., 2013).

The purpose of this article is twofold: First, we introduce the research and development process for CRYSTAL ISLAND, a narrative-centered learning environment, and propose this game as an exemplar that has the potential to affect school-based learning. Second, by drawing connections between gameplay and literacy, we explore how game research can benefit from theoretical perspectives from the literacy field, especially from transactional theory (Rosenblatt, 2004; McEneaney, 2003).

The Case of CRYSTAL ISLAND

CRYSTAL ISLAND is a narrative-centered learning environment that was created by Dr. James Lester, Director of the Center for Educational Informatics, and a multidisciplinary team at North Carolina State University (for a description of the multidisciplinary community, see Spires & Lester, 2016). Adopting Bruner's (1990, p. 35) assumption that "The system by which people organize their experience in, knowledge about, and transactions with the social world . . . is narrative rather than conceptual," CRYSTAL ISLAND designers embedded the science content within a strong narrative as a way to engage game players and help them better learn the content.

CRYSTAL ISLAND's science mystery was based on the NC Standard Course of Study for eighth-grade microbiology. Students work to uncover the identity and source of an infectious disease that plagues a research station. The story opens by introducing students to the island and members of the research team for which the protagonist's father serves as the lead scientist. Several of the team's members have fallen ill, and one of the team

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members accuses another of having poisoned the other researchers. Students must discover the outbreak's cause and source and either acquit or incriminate the accused team member.

Throughout the game, students explore the island and interact with other characters while generating hypotheses and collecting data to test their hypotheses. Students can pick up and manipulate objects, take notes, view posters, operate lab equipment, and talk with non-player characters to gather clues about the source of the disease. During the course of solving the mystery, students are minimally guided through a five-problem curriculum. The story and curriculum are interwoven throughout the student experience.

Theoretical Perspectives

The two theoretical underpinnings that guide this exploratory research are transactional theory (Rosenblatt, 1994; 2004) and cognitive load theory (Sweller, 2005). Both theories are discussed in conjunction with properties of game-based learning.

Gameplay and Transactional Theory

In addition to the discursive practices that are shared by both traditional and game-based literacies, it can be argued that both types of literacies can be explained by transactional theory (Rosenblatt, 1994; 2004). There are two core ideas related to transactional theory. The first core idea is that meaning is produced within a transaction between a reader and a text (Rosenblatt, 1978). For example, in contrast with more traditional models of reading, which typically "locate" meaning within the text and

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conceive of reading as the extraction of that meaning, transactional theory defines meaning as rooted in a reader's personal experience in reading, subject to personal reflection and self-awareness, and shaped by the reader's efforts to explain what is understood to others.

The second core idea is that the understanding a reader creates depends on stance, which refers to the orientation of the reader's attention—which may depend upon various factors, such as the type of text being read or purpose of the reader for engaging with the text, and may alter as the reader progresses through the text. Stance is defined as a continuum that moves from aesthetic to efferent points. Rosenblatt (2004) notes, "the efferent stance pays more attention to the cognitive, the referential, the factual, the analytic, the logical, the quantitative aspects of meaning" while "the aesthetic stance pays more attention to the sensuous, the affective, the emotive, the qualitative" (p. 1374). For example, when taking an aesthetic stance, readers might read for the pleasure they derive from the act of reading. According to Rosenblatt (1978), "in aesthetic reading, the reader's attention is centered directly on what he is living through during his relationship with that particular text" (p. 25). On the opposite end of the continuum is the efferent stance, in which a person reads to specifically learn more about the topic discussed in the book. As Rosenblatt (1978) states, with an efferent stance, "the reader's attention is primarily focused on what will remain as a residue after the reading — the information to be acquired, the logical solution to a problem, the actions to be carried out" (p. 23).

Historically, transactional theory assumes that the reader naturally takes a stance during reading (McEneaney, Li, Allen, & Guzniczak, 2009) or more likely, moves up and

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down a continuum from aesthetic to efferent while reading in order to accomplish a reading goal (Spires & Donley, 1998). However, McEneaney et al. (2009) found that when using expository hypertext, the researchers were able to influence readers' stances through reading prompts. They also found that aesthetic readers exhibited a higher understanding of the text. This finding was surprising, as the researchers anticipated that efferent readers would better understand nonliterary text, since previous research had shown that aesthetic readers better understand literary texts (Many, 1990; 1991).

There is a wealth of research and theory that demonstrates how digital environments affect the ways in which readers process information (e.g., Wolf, 2018; Leu, Kinzer, Coiro, & Cammack, 2004). However, using a transactional theoretical lens to interpret readers' processes is still under-explored. McEneaney et al. (2009) were among the first to explore transactional theory in digital environments, specifically with hypertext. The exploration of transactional theory within game-based learning environments is a natural progression since games are multimodal texts.

Just as good readers adopt a particular stance to accomplish their reading goals, game players may also utilize a stance, such as those in the efferent/aesthetic continuum, to "read" and play the game. However, which stance or combination of stances is more effective for gameplay or learning has yet to be demonstrated. This study is designed to take the first step in exploring players' stances and their relationship to gameplay and learning outcomes.

Gameplay and Cognitive Load Theory

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In designing CRYSTAL ISLAND, we considered Sweller's (2005) cognitive load theory, which holds that schemata are the structures that form a person's knowledge base. There are three sources of cognitive load: intrinsic, extraneous, and germane (Sweller, van Merrienboer, & Paas, 1998). The intrinsic cognitive load deals with the cognitive load required to learn the content of the subject matter being presented, which, in CRYSTAL ISLAND, is microbiology. The extraneous cognitive load refers to the unnecessary cognitive load required by the instructional design elements of the game. For example, if a game is poorly designed, a student may experience more cognitive demand when attempting to understand how to play the game. Ideally, game designers should work to keep the extraneous cognitive demand low or nonexistent and work to optimize the germane cognitive load, in which the game works to aid the player in processing and understanding the content more deeply.

To stimulate learners to use the appropriate cognitive processing, we kept in mind that it is the total cognitive load of the game that matters most; the game must be within learners' working memory limits. With a narrative-centered learning environment such as CRYSTAL ISLAND, the balance between narrative structures and content is tenuous. If the appropriate balance is not achieved, learners' working memory may be overloaded which may negatively impact learning (Kiili, 2004). As Kiili (2004) notes, "cognitive load should be optimized in games by cutting down irrelevant multimedia elements, applying modality effect, providing usable user interface and challenges that support knowledge construction" (p. 21-22).

Study 1

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This exploratory research investigated the effects of the CRYSTAL ISLAND environment on student science learning, interest, and reading stance (Rosenblatt, 1994) using a design-based research methodology (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). Design-based research was appropriate since the team was using student data to create new iterations of the game. We hypothesized that students who participated in the CRYSTAL ISLAND conditions would perform better both on science learning and a problem-solving task than students in a control condition.

Methods

Participants. A total of 151 eighth grade students participated in the study (males = 78). Approximately 55% of participants were European American, 26% were African American, 6% were Asian, 5% were Hispanic or Latino, and 8% identified as other. Participants' ages ranged from 12 to 15 (M = 13.26, SD = 0.523). The students completed the state-mandated standard course of study microbiology curriculum before receiving the instruments, interventions, and tests of this experiment.

Students were randomly assigned to one of three experimental conditions: CRYSTAL ISLAND Narrative (n = 60), CRYSTAL ISLAND Narrative-Light (n = 55), and Content Control (n = 36). Uneven numbers across conditions was due to missing data on either pre or post-test, as the two tests were conducted a week apart. The difference between the Narrative and Narrative-Light is that the Narrative condition had more storyline details included.

Materials and procedures. The materials and procedures as part of the methods include CRYSTAL ISLAND curricular development, CRYSTAL ISLAND environment

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development, and detailed procedures in order to conduct the research.

***Crystal Island* curricular development.** Crystal Island was designed around five curricular goals. The first goal of the learning environment was to identify that the inhabitants of Crystal Island have fallen ill due to a pathogen. This required users to learn about what a pathogen is and is not. They also had to apply this information to the narrative story. The second curricular goal of Crystal Island required users to learn more about viral, bacterial, and fungal pathogens. Users had to learn about the microbiological structure of these pathogens individually, including the size, shape, and components, in order to complete this goal. The third curricular goal built upon the second by requiring users to integrate their knowledge about the microbiological structures in order to make comparisons across pathogens' size, shape, and components. The fourth curricular goal of Crystal Island required users to create and test hypotheses about what types of pathogen was causing the Crystal Island illness and its origin. In order to complete this goal, users had to learn about and apply the scientific method, while integrating their knowledge about pathogens. The fifth and final curricular goal was to learn about how one would treat and/or prevent various pathogenic illnesses. The development of the curriculum was aligned with the NC Standard Course of Study for eighth grade microbiology content.

***Crystal Island* environment development.** Key features in the first iteration of the Crystal Island learning environment included:

1. Character interactions were fully text-based and menu-based.
2. Students could take notes, but not while simultaneously talking to a character,

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reading a book or poster, or working with the factsheet.

3. Students answered a total of 26 True/False questions posed to them by characters at the end of conversations. They were given the chance to answer a question only once before moving on.
4. The narrative was largely linear. Students needed to complete one goal (talking to a character) before being permitted to proceed to the next. If spoken to, every character would prompt the student to go speak with the current goal's target character.

Procedures. Pre-intervention assessments for each participant were completed one week prior to the intervention. These materials consisted of a researcher-generated CRYSTAL ISLAND microbiology content test and demographic survey.

Participants in the two CRYSTAL ISLAND conditions (Narrative and Narrative-Light) were directed to examine CRYSTAL ISLAND instructional materials, which consisted of a description of the backstory, the task, and the characters. Participants also received a map of the island and a control sheet. Participants in the two conditions had 50 minutes to solve the mystery. During this time, students needed to accomplish various goals, including learning about pathogens; recording the symptoms of the sickened researchers; noting features of hypothesized diseases causing the CRYSTAL ISLAND illness; testing possible sources; and reporting the solution to the camp nurse to develop a treatment plan.

Content from the curriculum used to develop CRYSTAL ISLAND was translated into PowerPoint format to serve as a Content Control condition. Each slide covered a segment

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of the curriculum and was designed to replicate a classroom PowerPoint presentation. The presentation consisted of slides with the same verbiage and images that were included in the CRYSTAL ISLAND experience. The PowerPoint did not include the narrative and plot central to CRYSTAL ISLAND. Participants were instructed to go through the PowerPoint at their own paces. At two points during the PowerPoint students were prompted to take a quiz; the same quiz questions used in the CRYSTAL ISLAND quizzes were used in the PowerPoint.

After the designated amount of time had lapsed (50 minutes), all participants were instructed to move on to the post-intervention phase. All students completed assessments that included multiple-choice content questions and the Perceived Interest Questionnaire. The intervention procedures were implemented as intended. For the two CRYSTAL ISLAND conditions, not all students completed all elements of intervention by the end of the designated 50 minutes, while all students in the PowerPoint condition finished. Evaluation of the intervention was based on the intervention as delivered.

Measures

Research measures for the first study included multiple-choice content questions, the Perceived Interest Questionnaire (PIC), and think-aloud protocols (TAPs).

Multiple-choice content questions. The pre- and post-intervention content test consisted of 23 questions designed by an interdisciplinary team of researchers and curriculum specialists. Two eighth-grade science teachers critiqued the content test to establish content validity. Based on examination of parallel analysis, results from an exploratory factor analysis (promax oblique rotation), of the 23-item multiple choice

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items at post-test reduced to form five factors of questions: 1) 5 items focused on information concerning all pathogens in general, 2) 3 items about the size and shape of pathogens, 3) 5 items concerning illness or diseases caused by pathogens, 4) 7 items specifically about viruses, and 5) 3 items specifically about bacteria. Structure coefficients between factor and their corresponding questions ranged from .32 to .98 and correlations among factors ranged from .06 (illness and bacterial specific questions) to .25 (illness and all pathogen general questions). Internal consistency estimates between questions for within each factor were: general pathogen (α = .84), size and shape (α = .81), illness and disease (α = .73), virus (α = .87), and bacteria (α = .75).

Perceived interest questionnaire (PIQ). The PIQ was adapted from measures used by Schraw (1997) to examine within-subject relationships with learning outcomes. The measure consists of ten Likert items measuring students' situational interest related to CRYSTAL ISLAND and Content Control interaction. To illustrate the scale, example items include the following: "I got absorbed with CRYSTAL ISLAND without trying to," and "CRYSTAL ISLAND really grabbed my attention." The PIQ for the Content Control condition was identical to the CRYSTAL ISLAND version except "The PowerPoint" was substituted for "CRYSTAL ISLAND." Internal consistency among the 10 items was high at α = .94.

Think-aloud protocols. In order to understand more fully what aspects of the gameplay students were focusing on, we conducted think-aloud protocols (TAPs) with a small sample of 7 students (male = 4). Four participants were European American, 2 were African American, and 1 was Latino. We asked for teacher recommendations for students

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who would be able to articulate their game playing process.

Early work by Ericsson and Simon (1980) suggested that TAPs "interpreted with full understanding of the circumstances under which they were obtained, are a valuable and thoroughly reliable source of information about cognitive processes" (p. 247). Researchers have used TAPs to evaluate student engagement with multimedia or online environments across many academic disciplines (Coiro & Dobler, 2007; Damico & Baildon, 2007; Pressley & Afflerbach, 1995). During an individual 1-hour session, the researcher asked a student to think aloud while playing CRYSTAL ISLAND. If the student went three minutes without talking, the researcher prompted the student by saying, "Please, think aloud as you play the game" (Hilden & Pressley, 2011). The students' verbalizations were digitally recorded and transcribed verbatim. The transcriptions were analyzed in verbal units, which in this case were verbalized sentences, using Rosenblatt's (2004) transactional theory as a lens for analysis. Three of the seven student transcripts (42.8 % of the transcripts which included 44.8 % of the total verbal sentences) were randomly selected for coding in order for the researchers to establish inter-rater agreement, Cohen's Kappa = .914, $p < .001$. Specifically, two researchers independently coded sentences in one of three categories: (a) logistical, (b) aesthetic, or (c) efferent. A logistical response related to the student trying to figure out how to navigate the game (e.g., "I don't understand how to move to the Infirmary"). An aesthetic response focused more on emoting with the text (e.g., "I don't like this character because he seems sinister"). An efferent response focused on analyzing the factual content of the game (e.g., I think salmonella is causing people to get sick on the island"). In addition to the

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two transactional categories of aesthetic and efferent, the logistical category referred to the logistics of getting around within the game—and did not relate to an aesthetic or efferent stance.

Results

Science content learning across experimental conditions. A preliminary analysis was conducted to ensure that there were no differences among the condition's (Narrative, Narrative-Light, Content Control) pre-intervention science curriculum test scores. An analysis of variance (ANOVA) indicated that as would be anticipated due to random assignment, there were no significant differences among conditions, $F(2, 146) = 2.734$, $p = .068$, $\eta^2 = .036$.

To examine the effect of the intervention on students' science content learning, a RM-ANOVA was conducted with the within-subjects variables of occasion (pre- and post-intervention), multiple-choice question type (general pathogen, size and shape, illness and disease, virus, and bacteria question types) and the between-subjects factor of condition (Narrative, Narrative-Light, Control). Analysis indicated that there was a main effect for occasion, $F(1, 146) = 44.696$, $p < .001$, $\eta^2 = .234$, such that collapsed across condition, students experienced a significant gain in performance from the pre- to the post-test assessment. Students answered on average 1.776 ($SD = 3.3$) more questions correctly on the post-intervention test than on the pre-pre-intervention test. Moreover, there was a significant occasion by condition interaction, $F(2,146) = 9.905$, $p < .001$, $\eta^2 = .119$, indicating that learning gains differed by condition. As seen in Figure 1, the largest learning gains occurred in the Content Control condition ($M = 3.51$ items, $SD = 3.61$),

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followed by the Narrative-Light condition (*M* = 1.25, *SD* = 3.26), with the lowest learning gains occurring in the Narrative condition (*M* = 0.56, *SD* = 2.76). Bonferroni post-hoc comparisons revealed that there were significant learning gains for both the Content Control ($p < .001$) and Narrative-Light conditions ($p = .006$); however, the learning gains in the Narrative condition were non-significant. Post-hoc comparisons indicated that the learning gains for the Content Control were significantly greater than gains experienced by both the Narrative ($p < .001$) and Narrative-Light ($p = .004$) conditions' learning gains. Lastly, the results indicated that there was not a significant three-way interaction between occasion, question type, and condition, $F(8,288) = 1.32$, $p = .232$, $\eta^2 = .035$. Therefore, the relation between occasion and condition did not differ as a function of question type.

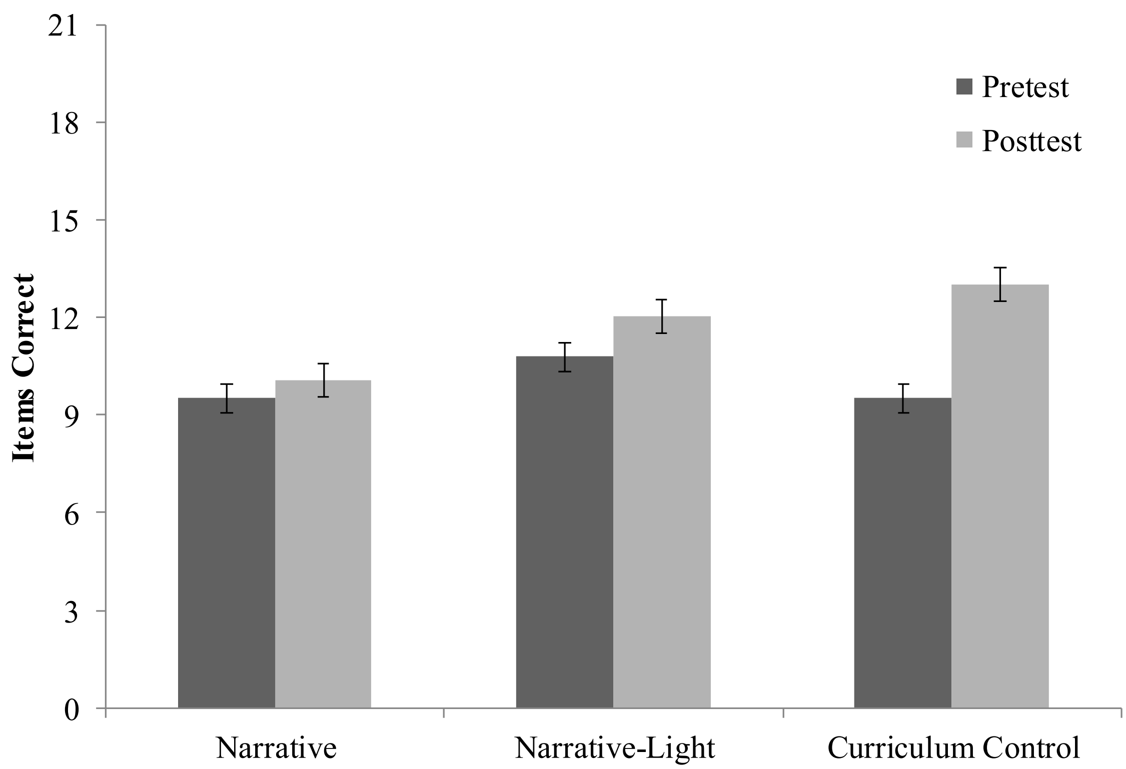

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Figure 1. Pretest and posttest means for microbiology contest test by experimental condition in Study 1. Standard errors represented in the figure by the error bars attached to each column.

Engagement ratings across experimental conditions. To examine if students reported differential levels of engagement across the experimental conditions, an analysis of variance was conducted (ANOVA) with the between-subjects variable of condition (Narrative, Narrative-Light, Control) and the dependent variable of PIQ score. Results indicated that there was a significant effect of condition, $F(2,146) = 3.328$, $p = .042$, $\eta^2 = .042$. Bonferroni post-hoc comparisons revealed that students in the Narrative-Light condition ($M = 3.53$, $SD = 0.92$) reported a significantly higher rating of engagement compared to their peers in the Content Control condition ($M = 3.02$, $SD = 0.97$), $p = .038$. Students in the Narrative condition did not report engagement ratings that were significantly different than their peers, *p*s > .443.

Think aloud protocols. The results showed that out of a total of 791 verbal units, 286 (36%) were deemed to be of a logistical nature, 319 (40%) were of an aesthetic nature, and 186 (23%) were of an efferent nature (see Table 1). Noting the relatively low percentage of efferent verbal units (23.51%) relative to logistical and aesthetic units (76.49%) and the variation in use of efferent units (range = 14.29% to 34.55%), we used these results to inform our next iteration of the game in hopes of scaffolding students' focus on the efferent or instructional elements of CRYSTAL ISLAND.

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Table 1

Study 1 Think Aloud Verbal Unit Distribution

Source	Logistical	Aesthetic	Efferent	Total Verbal Units
Student 1	84 (57.93%)	38 (26.21%)	23 (15.86%)	145
Student 2	34 (34.34%)	38 (38.38%)	27 (27.27%)	99
Student 3	26 (23.64%)	46 (41.82%)	38 (34.55%)	110
Student 4	91 (47.15%)	50 (25.91%)	52 (26.94%)	193
Student 5	9 (16.36%)	34 (61.82%)	12 (21.82%)	55
Student 6	30 (28.57%)	60 (57.14%)	15 (14.29%)	105
Student 7	12 (14.29%)	53 (63.10%)	19 (22.62%)	84
Total	286 (36.16%)	319 (40.33%)	186 (23.51%)	791

Discussion for Study 1

Our hypothesis that students participating in the CRYSTAL ISLAND conditions would perform better on a science content measure than students in the control condition was not supported. While students in all three conditions increased their science content knowledge, students who were exposed to the content in a direct fashion through a self-paced PowerPoint presentation scored higher than students who participated in the CRYSTAL ISLAND game. There are several factors that could contribute to these results. First, in our attempt to control for time on task, we did not provide enough time for all

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students to complete the game. This, of course, limited potential test performance for students in the CRYSTAL ISLAND conditions since all students were not exposed to the microbiology content. Second, the intelligent version of the software provided customized scaffolding for students as they progressed through the game; it is possible that the amount of scaffolding was not adequate to provide support for all students to successfully navigate the game in the allotted time. Third, while CRYSTAL ISLAND provides substantial motivational benefits with regard to self-efficacy, presence, and perception of control, it appears that student learning gains are less when compared to a PowerPoint control. It is possible that both the game actions and the narrative storyline could have provided extraneous cognitive load, serving only as a distraction from the science content to be learned.

Previous research has demonstrated the power of games to engage and motivate students as discussed earlier. Based on our results here, it appears that in order to facilitate significant learning gains, students must be given ample time to complete the game as well as customized scaffolding support. Since one unique aspect of a game is that students approach the environment and task idiosyncratically, it is important to capitalize on this phenomenon within the game experience. Based on our results, it appears that the narrative storyline served as a distraction and added extraneous cognitive load for students.

Based on the analysis of the TAP data, we made improvements to the logistics of the game and in the next iteration included instructional scaffolds that encouraged the students to focus on the science content and therefore a more factual, analytic, and

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therefore efferent stance. In essence, the scaffolds positioned the content more to the forefront of the game experience to optimize germane cognitive load, which we hypothesized would cause students to adopt an efferent stance more often. With these modifications in place, we conducted a second study to see what, if any, effects there would be on science learning as a result of playing the game. Specifically, we hypothesized that scaffolding that increased students' efferent stances while playing the game would help students focus more on the science content, which would be evident on measures of content knowledge.

Study 2

The purpose of the second study was to explore how transactional theory (Rosenblatt, 1978; McEneaney, 2006) might serve as an interpretive lens for narrative-centered game-based learning. Transactional theory was leveraged in the present study in several ways, with the second core idea—that a reader's understanding of a text depends on their stance—being the main focus of the investigation. First, transactional theory was used to inform the creation of content scaffolds within the game in order to provide a game or "text" that might evoke efferent responses. These content scaffolds were intended to perform in conjunction with the narrative aspects of the game in order to achieve an optimal cognitive load balance between efferent and aesthetic game-player stances. The effectiveness of the scaffolds was examined. Second, transactional theory was also used to explore if individual differences in stance predict effectiveness in gameplay as indicated by learning gains and completion of in-game goals. Complementing this goal, the relation between in-game performance (i.e., goal

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completed) and learning outcomes was also examined. Lastly, we explored if students' stances influenced how they interacted with the learning environment, which in turn influenced how much they learn (i.e., does in-game performance mediate the relation between stance and learning gains?).

Methods

Participants. A total of 100 eighth grade students participated in Study 2 (males = 51). Approximately 48% of participants were European American, 35% were African American, 12% were Hispanic or Latino, 2% were Asian, and 3% were of other races. Participants ranged in age from 12 to 15 (M = 13.38 SD = 0.51). The students had not completed the microbiology curriculum mandated by the state standard course of study before receiving the instruments, tests, and interventions of this experiment.

Participants were randomly assigned to one of three conditions: CRYSTAL ISLAND with the efferent content scaffolding (Scaffolding, n = 28), CRYSTAL ISLAND without efferent content scaffolding (Non-Scaffolding, n = 37), or Content Control (n = 35). A total of four sessions were held over two days. Students who did not complete all four sessions were excluded from the analysis, which resulted in uneven numbers across conditions. The Scaffolding condition was identical to the Non-Scaffolding condition except for in the Scaffolding condition the addition of prompts received via the game's personal digital assistant (PDA), which helped students address some perceived shortcoming in their microbiology knowledge, or otherwise aid them in solving the mystery. The selection of which prompt was presented to a student was based on a Bayesian student model. Prompts were presented every three minutes; however, students

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could also request prompts via the PDA.

Materials and procedures. Materials and procedures included ***CRYSTAL ISLAND*** curricular development, ***CRYSTAL ISLAND*** environment development, and detailed procedures in order to conduct Study 2.

CRYSTAL ISLAND curricular development. The curriculum was refined from Study 1. In particular, there was a reduced focus on fungi and parasites resulting in the removal of purposeful exposure to information on these two topics.

CRYSTAL ISLAND environment development. The CRYSTAL ISLAND environment was also refined from Study 1 in order to increase the effectiveness of the intervention. Changes included:

1. Multimodal Communication: Character interactions included voice-acted spoken dialog, which was lip-synced and included gesture, facial expression, and eye contact.
2. Narrative Minimization: The poisoning/character conflict elements of the storyline were removed. The conflict element was removed based on the Study 1 finding that the narrative element did not enhance students' science learning.
3. Learning Tool Enhancements: A communicator device (aka PDA), which was used to take and view notes, consult a microbiology field manual, take quiz questions, and request hints, was added. PDA afforded students the opportunity to take notes at any point in the game. Refinements were also made to the Study 1 fact sheet in order to enhance students' ability to draw conclusions to solve the science mystery. Specifically, the new diagnosis worksheet was organized into

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subcomponents (patient symptoms, laboratory test findings, estimates of predictive likelihood of particular causes, final solution) that highlighted what types of information would be necessary to know for solving the mystery.

4. In-game Assessment Refinement: Quiz questions were multiple-choice with four possible answers each instead of true/false.

Procedures. In the CRYSTAL ISLAND conditions (Scaffolding and Non-Scaffolding), students were first provided general information about the CRYSTAL ISLAND narrative and game controls during an introductory presentation by a researcher. Following the instructions, students completed the pre-intervention multiple-choice content questions. Students had 60 minutes to solve the CRYSTAL ISLAND mystery. Solving the mystery consisted of learning about pathogens, viruses, and bacteria; developing a list of the symptoms of the sick researchers; recording notes about diseases possibly afflicting team members; testing possible sources for the disease; and finally, reporting the disease, as well as its source, cause, and treatment, to the camp nurse. After the time had lapsed (increased from Study 1 to 60 minutes) or the participants had completed their interaction, students were instructed to continue to the post-intervention phase where students completed assessments that included multiple-choice content questions, two application-level constructed responses, a measure of stance, and the Perceived Interest Questionnaire.

As in Study 1, content from the curriculum used to develop CRYSTAL ISLAND was translated into a PowerPoint format to serve as the Content Control condition. Participants were instructed to go through the PowerPoint at their own paces. At two

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points during the PowerPoint, students were prompted to take a quiz; the same quiz questions that were used in the CRYSTAL ISLAND quizzes were used in the PowerPoint. Following the instructions on how to use the PowerPoint and quizzes, students completed the pre-intervention multiple-choice content questions. After the completion of the Content Control interaction, participants were instructed to move on to the post-intervention phase. As with the CRYSTAL ISLAND condition, students completed assessments that included multiple-choice content questions two application-level constructed responses, and the Perceived Interest Questionnaire.

The intervention procedures were implemented as intended. For the two CRYSTAL ISLAND conditions, not all students completed all elements of intervention by the end of the designated 60 minutes, while all students in the PowerPoint condition did. To account for variation in the degree to which students completed the CRYSTAL ISLAND intervention, information on in-game performance was collected in Study 2. Evaluation of the intervention was based on the intervention as delivered.

Measures

Research measures for the second study included multiple-choice content questions, application-level constructed responses, the Perceived Interest Questionnaire (PIC), measure of stance, and in-game performance.

Multiple-choice content questions. The pre- and post-intervention content test consisted of 16 questions designed by an interdisciplinary team of researchers and curriculum specialists. Two eighth-grade science teachers critiqued the content test to establish content validity. The assessment was a modification from the version given in

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Study 1. In particular, this test was reduced to 16 questions to reflect the reduction of content presented in the CRYSTAL ISLAND interaction. Questions were also reworded to result in 8 factual-level questions that were designed to be direct and literal in nature and 8 application-level questions that were designed to require an application of knowledge to a situation. Confirmatory Factor Analysis supported this 2-factor solution, χ^2 (103, N = 100) = 100.62, p = .548; *RMSEA* < 0.01, *CFI* = 1.00, *IFI* = 1.02. In addition, standardized path coefficients indicating the relation between factors and their corresponding questions ranged from .19 to .61, and all coefficients were significant at $p < .05$. Internal consistency estimates between literal questions and between application questions were high at α = .89 and .86, respectively.

Application-level constructed responses. Edling (1993) found that knowledge transfer is a skill that can be developed through active engagement with a contextualized learning environment. As CRYSTAL ISLAND provided students with a highly contextualized learning environment, we anticipated that the game would enable students to better apply the information learned in the game.

To test this prediction, two application-level constructed responses were developed. Students were asked to answer the following questions as best as they could: 1) Imagine that you have three microbes that are three different sizes. Please explain how you could identify each microbe if you know that one is a virus, one is a bacterium, and one is a fungus and 2) A scientist wonders if a new microbe she has found could cause illness in humans. She wants to be a good scientist and has come to you for advice. In this specific situation, develop a set of instructions to complete each step of the scientific method. The

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concepts need to solve the two questions were central learning goals to the CRYSTAL ISLAND and Content Control conditions.

Coding of the application-constructed responses consisted of a 0 to 2 scale. Response 1 was coded as 0 = no relevant information or wrong; 1 = organized by size or lists relevant distributing information; 2 = fully explains which type of pathogen is largest and which is smallest. Response 2 was coded as 0 = no relevant info or wrong; 1 = lists steps of scientific method; 2 = explains the steps for this particular problem. Two coders achieved reliability on a subset of the questions ($\kappa \geq .91$). One coder then coded all remaining responses, while the other coded 25% of the responses to verify final reliability. Reliability for Response 1was $\kappa = .83$ and reliability for Response 2 was $\kappa = .89$. The average of the two scores was used in subsequent analyses.

Perceived interest questionnaire (PIQ). The PIQ was identical to the measure used in Study 1.

Measure of stance. To measure stance, students in the two CRYSTAL ISLAND intervention conditions were presented with the open-ended prompt "Tell us what you recall from the game" order to assess the most salient concepts recalled from the game. Similar measures of stance have been done in previous research (McEneaney, et al., 2009). The main purpose was to assess a student's stance at the end of the game, or in other words, whether the student focused on and therefore recalled more of the content or efferent aspects of CRYSTAL ISLAND or the emotive or aesthetic—the narrative—aspects of CRYSTAL ISLAND. It was not presented to the Content Control condition since there was no narrative component.

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The measure of stance was coded on the following 0 to 3 scale, borrowing from McEneaney, et al.'s (2009) procedures: 0 = no relevant info; 1 = narrative or aesthetic focus; 2 = efferent focus; 3 = both aesthetic and efferent focuses. Two coders achieved reliability on a subset of the questions ($\kappa \geq .93$). One coder then coded all remaining questions, while the other coded 25% of the questions to verify final reliability of κ = 1.00. Due to small cell sizes associated with the 0 to 3 scale, the coding scheme was dichotomized to 0 = Non-Efferent focus (previous coded 0 and 1) and 1 = Efferent focus (previously coded 2 and 3).

In-game performance. While students interacted with the CRYSTAL ISLAND software, their progress was recorded in the game (i.e., student traces). The present study examined one aspect of these traces, Goals Completed. To complete CRYSTAL ISLAND, participants had to complete seven goals; however, not all students completed all the goals in the 60 minutes allotted. Therefore, Goals Completed could range from 0 to 7.

Results

Science learning across experimental conditions. Pre- and post-intervention multiple-choice content questions' descriptive statistics are provided in Table 2. Preliminary analyses were conducted to ensure that there were no differences among the conditions' (Scaffolding, Non-Scaffolding, Content Control) pre-intervention factual and application test scores. An analysis of variance (ANOVA) indicated that as would be anticipated due to random assignment, there were no significant differences among condition for factual and application questions, $F(2, 96) = 0.19$, $p = .831$ and $F(2, 96) = 0.51$, $p = .604$, respectively.

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Table 2

Study 2 Multiple-Choice Content Questions Descriptive Statistics

	Pretest		Posttest	
	Mean	SD	Mean	SD
Scaffolding (*n* =28)				
Factual Questions	3.11	1.13	4.64	1.81
Application Questions	3.50	1.23	3.75	1.62
Non-Scaffolding (*n* =37)				
Factual Questions	3.28	1.39	4.57	1.91
Application Questions	3.14	1.55	4.35	1.44
Content Control (*n* = 35)				
Factual Questions	3.14	1.06	4.37	2.22
Application Questions	3.31	1.43	4.23	2.26

To examine the effect of the intervention on student performance on factual-level multiple-choice questions, a RM-ANOVA was conducted with the within-subjects factor of occasion (pre- and post-intervention) and the between-subjects factor of condition (Scaffolding, Non-Scaffolding, Content Control). Analysis indicated that there was a main effect for occasion, $F(1, 96) = 42.79$, $p < .001$, $\eta^2 = .31$, such that collapsed across condition, students experienced a significant gain in performance from the pre- to the post-intervention assessment. Bonferroni post-hoc comparisons revealed that all conditions experienced significant learning gains, *p*s ≤ .001. Largest learning gains occurred in the Content Control condition ($M = 1.54$, $SD = 2.06$), followed by the Non-Scaffolding condition ($M = 1.33$ items, $SD = 2.06$), and the Scaffolding condition ($M = 1.23$, $SD = 2.09$). Additionally, there was not a significant occasion by condition

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interaction, $F(2, 96) = 0.18$, $p = .840$, indicating that learning gains did not differ by condition.

To examine the effect of the intervention on student performance on application-level multiple-choice questions, a RM-ANOVA was conducted again with the within-subjects factor of occasion (pre- and post-intervention) and the between-subjects factor of condition (Scaffolding, Non-Scaffolding, Content Control). Analysis indicated that there was a main effect for occasion, $F(1, 96) = 42.79$, $p < .001$, $\eta 2 = .31$, such that collapsed across condition, students experienced a significant gain in performance from the pre- to the post-intervention assessment. Bonferroni post-hoc comparisons revealed that the Non-Scaffolding ($M = 1.19$, $SD = 2.07$) and Scaffolding ($M = 0.91$, $SD = 1.45$) conditions experienced significant learning gains, $p\text{s} \leq .009$. However, the Content Control condition ($M = 0.25$, $SD = 1.95$) did not experience a significant gain ($p = .518$) even though the occasion by condition interaction was not significant, $F(2, 96) = 1.74$, $p = .182$.

Lastly, to examine the transfer effect of the intervention, an ANOVA was conducted to examine if there were condition differences in performance on the averaged performance on the two application-level constructed responses. Results indicated that there were no differences among the Scaffolding ($M = 0.76$, $SD = 0.71$), Non-Scaffolding ($M = 0.75$, $SD = 0.57$) and the Content Control ($M = 0.73$, $SD = 0.66$) conditions, $F(2, 97) = 0.02$, $p = .983$.

Engagement ratings across experimental conditions. To test if students reported differential levels of engagement across the experimental conditions, an analysis of

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variance was conducted (ANOVA) with the between-subjects variable of condition (Scaffolding, Non-Scaffolding, Content Control) and the dependent variable of PIQ score. Results indicated that there was not a significant effect of condition, $F(1, 95) = 1.16$, $p = .318$, such that engagement ratings for the Scaffolding ($M = 3.08$, $SD = 0.93$), Non-Scaffolding ($M = 3.37$, $SD = 0.88$), and Content Control ($M = 3.14$, $SD = 0.59$) did not significantly differ.

CRYSTAL ISLAND and efferent stance. A preliminary analysis was conducted to examine if there were differences in the distribution of Efferent and Non-Efferent stances at the end of the game between the two CRYSTAL ISLAND conditions (Scaffolding, Non-Scaffolding). Results indicated that students' stances did not differ as a function of condition; χ^2 $(1, N = 65) = 1.25$, $p = .385$. Therefore, there was an approximately equal number of students who took an Efferent and Non-Efferent stance in both the Scaffolding, $n = 16$ and 12, respectively, and Non-Scaffolding conditions, $n = 19$ and 18, respectively. Due to the fact that there were no differences between the two CRYSTAL ISLAND conditions in terms of learning gains and stance, the two conditions were collapsed in subsequent analyses.

To examine the effect that students' stances had on gains in performance on multiple-choice questions, zero-order correlations between stance and standardized residual gain scores (i.e., post-intervention performance controlling for pre-intervention performance) for the factual-level and application-level multiple choice questions were conducted. Zero-order correlations were conducted in preparation for hypothesized mediation analyses, which are to follow. Analyses indicated that stance was positively

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related to residual gains on factual-level multiple-choice questions, $r(64) = .22$, $p = .038$; however, the relation for application multiple-choice questions was non-significant, $r(64) = .15$, $p = .125$. Therefore, taking an efferent stance when reflecting on the CRYSTAL ISLAND interaction was predictive of greater factual-level learning gains.

To examine the effect that students' stances had on post-intervention application-level constructed responses, correlations were conducted between stance and the averaged performance on the two application-level constructed responses. Results indicated that taking an efferent stance when reflecting on the CRYSTAL ISLAND interaction was predictive of better performance on the application constructed responses, $r(64) = .34$, $p = .006$.

CRYSTAL ISLAND in-game performance and science learning. To examine if students' in-game performance predicted standardized residual gain scores on factual-level and application-level multiple choice questions, a series of zero-order correlations were conducted with the independent variable of Goals Completed ($M = 5.88$, SD = 1.27). Analysis indicated that Goals Completed positively predicted factual-level residual gains, $r(64) = .38$, $p = .002$. In particular, completing more goals was associated with greater gains on factual-level multiple-choice questions. Similarly, analysis indicated that Goals Completed positively predicted application-level residual gains, $r(64) = .32$, $p = .009$, such that completing more goals was associated with greater gains on application-level multiple-choice questions.

Lastly, to examine if in-game performance was associated with application-level constructed response performance, a zero-order correlation was conducted. Results

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indicated that both Goals Completed positively predicted transfer performance on application-level constructed response questions, $r(64) = .28$, $p = .022$.

CRYSTAL ISLAND in-game performance and stance. Analyses were conducted to determine if the effect of students' efferent stance and students' learning (i.e., factual multiple-choice scores residual gains and application constructed response scores) was mediated by in-game performance (i.e., Goals Completed). As indicated previously, factual multiple-choice scores residual gains and application-constructed response scores were related to both students' stances and in-game performance. Students' stances were also positively related to in-game performance, $r(64) = .40$, $p = .001$.

As represented in Figure 2, to examine mediation on factual multiple-choice residual gains, a hierarchical regression was conducted with students' stances entered into the equation in the first step and the mediating variable (in-game performance) in the second step. In step 1, taking an efferent stance was positively related to factual multiple-choice gains ($\beta = .22$, $p = .038$). With the addition of in-game performance in the second step, students' stances were no longer significantly related ($\beta = .04$, $p = .754$). Therefore, it is suggested that in-game performance mediated the effect of students' stances on learning gains on factual multiple-choice questions. Using the PROCESS macro (Preacher & Hayes, 2004), bootstrapped indirect effect of students' stance on factual knowledge gains through goals completed was significant with a 95% Confidence Interval of [0.13, 0.70]. Hence, the number of goals completed in-game did significantly mediate the relationship between student stance and learning gains. A commonality analysis was conducted to determine the amount of predicted variance that was shared

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among and unique to stance and in-game performance. Results indicated that the two variables shared approximately 5% of the variance in factual multiple-choice learning gains. Students' stances uniquely explained about 1% of the variance in learning gains, and in-game performance uniquely explained 17% of the variance.

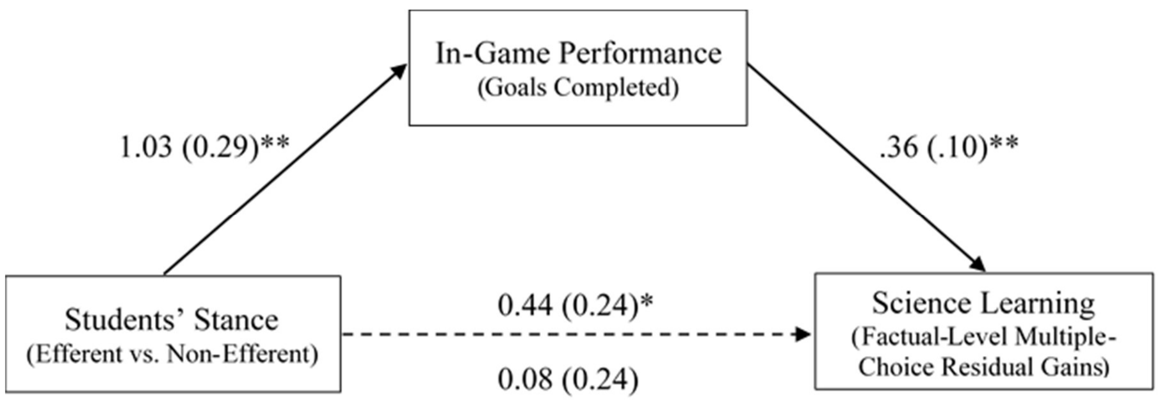

Figure 2. Representation of students' in-game performance mediating the relationship between students' stance and factual-level multiple-choice residual gains. Unstandardized *B* coefficients and standard errors are presented. The coefficient presented above the arrow connecting stance and science learning is the relation between the two variables not accounting for in-game performance. The coefficient presented below the arrow connecting stance and science learning is the relation between the two variables while controlling for in-game performance. Note: $^{**}p < .01$, $^{*}p < .05$.

As represented in Figure 3, to examine mediation on application construct responses, a hierarchical regression was conducted with students' stances entered into the equation in the first step and the mediating variable (in-game performance) in the second

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step. In step 1, taking an efferent stance was positively related to application construct response scores (β = .35, p = .004). With the addition of in-game performance in the second step, students' stances were still statistically significant; however, significance was reduced (β = .28, p = .036). Therefore, it is suggested that in-game performance mediated the effect of students' stances on students' performance on application constructed responses. However, bootstrapped indirect effect of students' stances on application gains through goals completed was significant with a 95% Confidence Interval of [0.11, 0.62]. Hence, the number of goals completed in-game significantly mediated the relationship between students' stances and learning gains. A commonality analysis was conducted to determine the amount of predicted variance that was shared among and unique to stance and in-game performance. Results indicated that the two variables shared approximately 6% of the variance in application constructed responses. Students' stances uniquely explained 6% of the variance in learning gains, and in-game performance uniquely explained 3% of the variance.

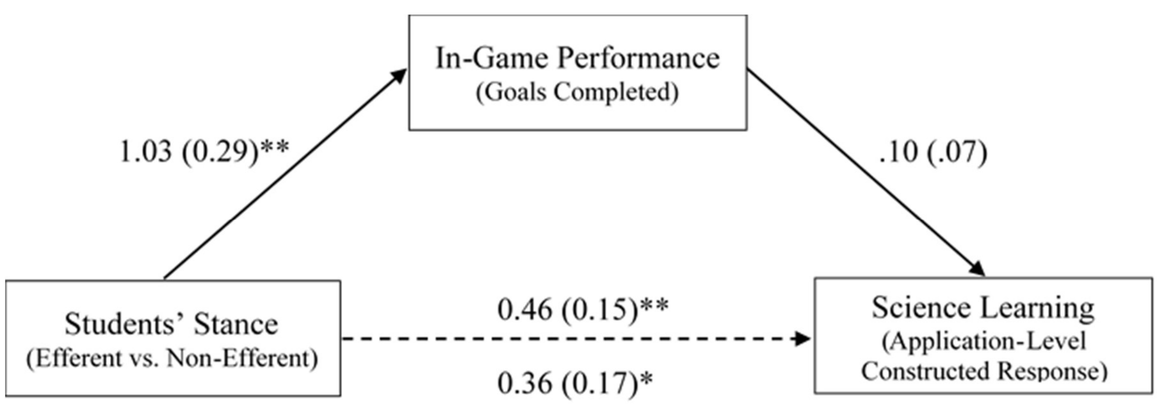

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Figure 3. Representation of students' in-game performance mediating the relationship between students' stance and application-level constructed response scores. Unstandardized *B* coefficients and standard errors are presented. The coefficient presented above the arrow connecting stance and science learning is the relation between the two variables not accounting for in-game performance. The coefficient presented below the arrow connecting stance and science learning is the relation between the two variables while controlling for in-game performance. Note: $^{**}p < .01$, $^{*}p < .05$.

Discussion for Study 2

To explore whether transactional theory could serve as an interpretive lens for narrative-centered game-based learning, efferent scaffolds were embedded within the game in hopes of helping students create an optimal balance among cognitive load and efferent and aesthetic game-player stances. The first step in testing the effectiveness was to examine if students using the CRYSTAL ISLAND learning environment made significant gains in microbiology content knowledge and to see if these gains differed by condition. It was predicted that gains would be greatest for the content-scaffolding condition. Results from Study 2 indicated that there were significant factual and application multiple-choice learning gains in all conditions of the study; however, there was not a significant difference in learning gains as a function of condition. This indicated that students in Scaffolding, Non-Scaffolding, and Content Control (i.e., PowerPoint) conditions knew the microbiology concepts presented better following the intervention. There were also no differences among conditions on the application-level constructed responses developed to assess possible transfer effects. This measure was only presented

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following the intervention, as such conclusions about potential intervention effects on responses to the questions are not able to be assessed.

The second goal of the present study was to explore if individual differences in stance predict effectiveness in gameplay as indicated by learning gains and completion of in-game goals. Contrary to what we predicted, the content-scaffolding condition did not increase the likelihood that a student would take an efferent stance. Nonetheless, results did indicate that taking an efferent stance, compared to a non-efferent (i.e., aesthetic) stance, was positively predictive of learning gains on factual-level multiple-choice questions and of better performance on the application-level constructed responses. Yet, this relation was not present for application multiple-choice questions. In addition to learning gains, results also indicated that students' stances were related to in-game goals completed. In particular, students who took an efferent stance were more likely to complete more of the in-game goals compared to their non-efferent counterparts.

Lastly, it was Study 2's goal to examine if the stances that students brought to the learning interaction influenced their completion of in-game goals, which in turn affected their learning gains. An initial step required to test the proposed mediation analyses involved establishing that in-game performance (Goals Completed) was related to the learning outcomes that were predicted by stance (i.e., factual multiple-choice residual gains and application constructed response score). The number of goals completed positively predicted both learning outcomes. Subsequent mediation analyses indicated that in-game performance mediated the relation between stance and factual multiple-choice gains as well as the relation between stance and performance on the application-

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constructed responses. In particular, it was found that students who took an efferent stance, as opposed to a non-efferent stance, were more likely to complete more of the game's goals, which in turn predicted greater performance on the learning outcomes. In other words, how students approached the learning environment (i.e., stance) affected how they interacted with the environment and in turn how much of the microbiology lesson they learned.

The results from Study 2 help provide insights into understanding how students approach interactive learning environments directly affects how they interact with and learn from these environments. Interestingly, the present studies' attempt to experimentally manipulate students' stances through in-game scaffolds were not successful. Contrary to what was hoped, students in the Scaffolding condition were not more likely to take an efferent stance than students in the Non-Scaffolding condition. As such, further experimental research is needed to examine if students' approach to interactive learning environments can be influenced to focus in on the efferent or learning aspects of the environment.

General Discussion

The overall goal of the studies presented was to investigate how theoretical perspectives from the literacy field, specifically transactional theory (Rosenblatt, 2004), could potentially benefit game research. Utilizing CRYSTAL ISLAND, a narrative-centered learning environment, we examined how the game affected eighth-grade students' content-based learning of microbiology.

As demonstrated by our study, narrative-centered learning environments pose a

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challenge to designing games which are simultaneously effective learning tools and engaging. To meet this challenge, an iterative design approach was used to create the game, implement it with students, and then refine the game. This design approach has led to theoretical and practical implications for game design and classroom implementation.

Findings Related to Cognitive Load Theory

As mentioned earlier, CRYSTAL ISLAND, as a game, is a multimodal text as well as a multimedia learning environment. As such, it allows users to interact with printed text, images, movements, and sound to derive meaning from the messages conveyed throughout the game. If the interactions of these various modes and media are not well-designed or controlled, users may experience cognitive overload (Keller, 2008). However, cognitive load theory (Sweller, 2005) notes that learning, or acquiring and automating new schemas, can be made easier for students if the instructional methods used reduce students' cognitive load (Chandler & Sweller, 1991; Mousavi, Low, & Sweller, 1995; Tindall-Ford, Chandler, & Sweller, 1997). Research has shown that using multimodal instructional tools appropriately can reduce cognitive load by reducing demands on the students' working memories, thereby helping them learn faster (Mayer, 2014; Mousavi, Low, & Sweller, 1995; Oviatt, Coulston, & Lunsford, 2004). During Study 1, two versions of CRYSTAL ISLAND were used—Narrative and Narrative-Light—in order to examine how the narrative feature of the game affected student learning. As seen in the results of Study 1, students in the Narrative condition had significantly fewer learning gains than students in the Narrative-Light or Content Control conditions, indicating that the students in the Narrative condition may have experienced a heavier cognitive load than those in the other conditions.

In order to lessen the cognitive load, the narrative condition was minimized in the second study and efferent content scaffolding was added to help reduce demands on students' cognition. This proved successful, as the Study 2 results showed no significantly different learning gains between students in the Content Control condition or the students who were in either of the conditions using CRYSTAL ISLAND, Scaffolding or Non-Scaffolding. The Study 2 results differed from Study 1, which indicated students in the Content Control condition had more significant learning gains than the Narrative and Narrative-Light conditions.

Findings Related to Transactional Theory

The Scaffolding and Non-Scaffolding conditions were created following the Think-Aloud Protocols (TAPs) held during Study 1 using Rosenblatt's (2004) transactional theory. We examined the TAPs and developed the new efferent content scaffolding conditions in order to know more about how these scaffolds might affect students' approaches to interactive learning environments and how they interact with and learn from these environments. Though we hypothesized that the efferent content scaffolding would help students focus more on the science content and adopt an efferent stance more often within game and in the recall of the game, results did not support this hypothesis. However, we did find that the students who adopted an efferent stance in their recall completed more in-game goals, which was related to more significant learning gains in regards to both factual, multiple choice content and application constructed

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content. The current findings differ from those of McEneaney et al. (2009), who found that readers with an aesthetic stance demonstrated higher understanding of nonliterary hypertext. A possible explanation for the current study's finding in relation to game-based learning is that players whose recall indicates they take an efferent stance are more well-suited to learning conditions within a game-based environment. Future research should examine this finding further.

Limitations

All studies have limitations, and the current study is no exception. First, using multiple-choice responses to measure complex inquiry and cognition processes within a digital learning environment like CRYSTAL ISLAND poses issues. As Schaffer, Hatfield, Svarovsky, Nash, Nulty, & Bagley (2009) noted, "Assessments of digital learning need to focus on performance in context rather than on tests of abstracted and isolated skills and knowledge" (p. 34). Using student trace data for analysis offers future occasions to use evidence-centered design, which aligns learning theory and assessment method. Additionally, future CRYSTAL ISLAND studies will use transfer measures to measure how well students apply the information in the game to new learning contexts.

Another limitation with this study is that, although the game is a narrative-centered learning environment, CRYSTAL ISLAND does not provide the visual engagement and action that commercial games offer. The lack of action and visual stimulation when playing academic games can be disappointing to students, who are accustomed to a higher level of entertainment and engagement.

Lastly, a limitation regarding stance is that those results (including the mediation

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analyses) are correlational. We cannot determine that stance caused differential learning gains. Future research should explore if we can manipulate stance and if inducing a more efferent stance yields greater gains.

Conclusion and Future Research

The current study corroborated existing results that game-based learning not only improves students' motivation and engagement with content, but also helps students learn new information (Zhonggen, 2019; Lester, Spires, Nietfeld, Minogue, Mott, & Lobeni, 2014; Perrotta et al., 2013; Wouters et al., 2013). As seen in our study, game designers must consider a game's cognitive demand on students, as overusing multimodal tools or narrative elements may result in fewer learning gains. Games must be purposefully and carefully designed to manage the cognitive load required by the content without increasing the cognitive load needed to navigate the features of the game. Of particular note, this study also explored how transactional theory, from the literacy field, may be used as a theoretical lens to interpret how gameplayers' stances affect game play and learning.

Future research with CRYSTAL ISLAND will involve more in-depth analyses of in-game performance and how it relates various pedagogical game features and learning outcomes. We will continue to explore how transactional theory can be used to understand students' approach to gameplay using a combination of aesthetic and efferent stances. No solitary educational approach, including game-based learning, is successful for all students or across all subjects. As the world is moving more toward apps, social media and handheld devices, the methods of and obstacles to learning will continue to

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change. Research on game-based learning must continue to focus on what works in, with whom, and in which context. Adequately addressing this concern will result in games that are more compatible with school contexts, which may result in a greater impact on the development of students' literacy skills and dispositions.

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