Integrating Learning and Engagement in Narrative-Centered Learning Environments

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Abstract. A key promise of narrative-centered learning environments is the ability to make learning engaging. However, there is concern that learning and engagement may be at odds in these game-based learning environments and traditional learning systems. This view suggests that, on the one hand, students interacting with a game-based learning environment may be engaged but unlikely to learn, while on the other hand, traditional learning technologies may promote deep learning but provide limited engagement. This paper presents findings from a study with human participants that challenges the view that engagement and learning need be opposed. A study was conducted with 153 middle school students interacting with a narrative-centered learning environment. Rather than finding an oppositional relationship between learning and engagement, the study found a strong positive relationship between learning outcomes and increased engagement. Furthermore, the relationship between learning outcomes and engagement held even when controlling for students' background knowledge and game-playing experience.

Keywords: Narrative-Centered Learning Environments, Game-Based Learning, Engagement, Situational Interest, Presence.

1 Introduction

Narrative-centered learning environments show significant potential for providing engaging learning experiences that are tailored to individual students. By leveraging the motivational characteristics of narrative and games, along with the adaptive pedagogy of intelligent tutoring systems, narrative-centered learning environments offer a promising platform for students to acquire enhanced problem solving, strategic and analytical thinking, decision making, and other twenty-first century skills [1,2]. As an active and growing area of research, narrative-centered learning environments are under investigation in a range of domains, including language learning [3], anti-bullying education [4], and middle school science [5].

Despite the ITS community's growing interest in narrative-centered learning environments, there is concern that the narrative and gameplay elements of these

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systems may not contribute to improved learning outcomes. This belief stems in part from a view that gains in engagement achieved by a narrative-centered learning environment are primarily diversionary [6,7]. The view suggests that while students may become engaged in the rich virtual environments or compelling characters provided by many narrative-centered learning environments, the reasons for engagement are tangential to learning [8]. In this view, there is a tradeoff between learning and engagement, suggesting that on the one hand, students interacting with a game-based learning environment may be engaged but unlikely to learn, and on the other hand, traditional learning technologies may promote deep learning but provide limited engagement [7,9,10].

This paper challenges the above view by presenting findings from an empirical study investigating the relationship between learning and engagement in a narrative-centered learning environment. This work assesses engagement by considering a number of factors hypothesized to be associated with engagement, including presence, situational interest, avoidance of "gaming the system," and problem-solving efficiency. Findings are presented from a study with 153 eighth-grade students interacting with CRYSTAL ISLAND, a narrative-centered learning environment for middle school microbiology. Results show that students who experienced higher levels of engagement during interactions with the CRYSTAL ISLAND environment achieved improved learning outcomes. Notably, this result is independent of students' prior microbiology knowledge and gaming experience.

2 Background

Narrative-centered learning environments embed educational content and activities in story-centric, problem-solving scenarios and interactive virtual worlds. Multi-user virtual environments such as Quest Atlantis [11] and River City [5] use rich narrative settings to contextualize inquiry-based science learning scenarios with strong social and collaborative elements. Other work has utilized interactive narrative generation and agent behavior planning to foster adaptive narrative experiences that are pedagogically effective and tailored to individual students [4,12,13]. A key motivation for this line of work is the development of systems that simultaneously promote deep learning and high engagement.

For years, devising techniques for detecting and measuring student engagement has been an important area of investigation within the ITS community [14,15,16]. A number of techniques have been proposed to assess related factors such as student motivation [14,17] and affective states such as flow [18]. Other work has sought to devise automated models for detecting symptoms of disengagement, namely, off-task behavior [16,19]. One of the most salient examples of off-task behavior is "gaming the system," where students exploit elements of a learning environment interface to progress through a lesson without having mastered the associated content [19].

Engagement in narrative-centered learning environments can take several forms, including engagement in the learning scenario and engagement in tangential or aesthetic elements of the virtual environment [8]. Narrative-centered learning environments often provide vast interactive environments, realistic physics, and

engaging characters, which may risk introducing *seductive details* into learning experiences [20]. Seductive details have the potential to distract, disrupt, or divert students' attention from pedagogical objectives and to reduce students' time-on-task. To adequately investigate the complex nature of engagement in narrative-centered learning environments, assessments of engagement should consider a variety of factors. For example, students' problem-solving efficiency within the virtual environment is likely an indication of engagement, as well as resistance to seductive details. Off-task behavior such as "gaming the system" can be viewed as evidence of disengagement from a learning environment. In addition to these factors, we hypothesize that students' situational interest in a narrative-centered learning experience, as well as their sense of presence in the narrative environment, are likely contributors to engagement.

Situational interest is characterized by varying lengths of concentrated attention coupled with affective reaction activated during a particular time period by certain environmental stimuli [21,22]. Studies have shown that situational interest directed towards an instructional task can influence cognitive performance [23] and facilitate deeper learning [24]. Also, learning tasks and environments that yield significant situational interest have been shown to benefit students who have previously been disengaged in similar learning activities [25]. However, situational interest is not exclusive to learning tasks; game design and adaptive scaffolding should encourage interest in on-task actions, rather than interest in purely aesthetic or gameplay features of narrative-centered learning environments [8].

Presence contributes to the goal of transparency in technology-mediated interactions [26]. Although there has been substantial debate on formal definitions, there is a general consensus that *presence* describes a user's sense of "being there" when interacting with a mediated environment [27,28]. Presence has been alternatively defined as "the subjective experience of being in one place or environment, even when one is physically situated in another" [29]. It is related to students' sense of transportation into a story, which is an important contributor to the engaging quality of narratives. Presence is distinguished from related concepts such as immersion and involvement. *Immersion* generally refers to the extent and nature of technology-provided sensory stimuli; it is often associated with the pervasiveness and fidelity of visual, auditory, olfactory, and tactile inputs [28]. *Involvement* refers to the degree of attention and meaning devoted to some set of stimuli [29].

3 CRYSTAL ISLAND

Now in its third major iteration, CRYSTAL ISLAND (Figure 1) is a narrative-centered learning environment built on Valve Software's Source™ engine, the 3D game platform for Half-Life 2. The curriculum underlying CRYSTAL ISLAND's mystery narrative is derived from the North Carolina state standard course of study for eighth-grade microbiology. The environment is designed as a supplement to classroom instruction. Students play the role of the protagonist, Alyx, who is attempting to discover the identity and source of an infectious disease plaguing a newly established research station. Several of the team's members have fallen gravely ill, and it is the

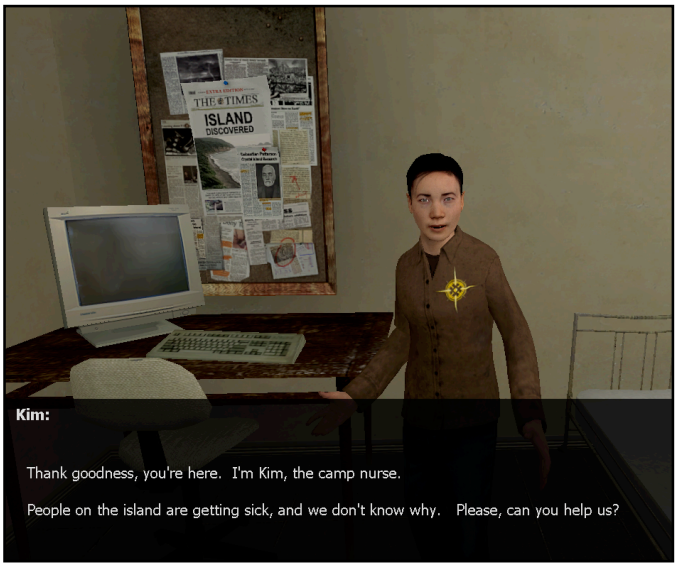

Figure 1. CRYSTAL ISLAND narrative-centered learning environment.

student's task to discover the nature and cause of the outbreak.

CRYSTAL ISLAND's narrative takes place in a small research camp situated on a recently discovered tropical island. As students explore the camp, they investigate the island's spreading illness by forming questions, generating hypotheses, collecting data, and testing hypotheses. Throughout their investigations, students interact with virtual characters offering clues and relevant microbiology facts via multimodal "dialogues" delivered through student menu choices and characters' spoken language. The dialogues' content is supplemented by virtual books, posters, and other resources encountered in several of the camp's locations. As students gather useful information, they have access to a personal digital assistant to take and review notes, consult a microbiology field manual, communicate with characters, and report progress in solving the mystery. To solve the mystery, students complete a *diagnosis worksheet* to manage their working hypotheses and record findings about patients' symptoms and medical history, as well as any findings from tests conducted in the camp's laboratory. Once a student enters a hypothesized diagnosis, cause of illness, and treatment plan into her diagnosis worksheet, the findings are submitted to the camp nurse for review and possible revision.

To illustrate the behavior of CRYSTAL ISLAND, consider the following scenario. Suppose a student has been interacting with non-player characters in the storyworld and learning about infectious diseases. In the course of having members of the research team become ill, she has learned that a pathogen is an illness that can be transmitted from one organism to another. As she concludes her introduction to infectious diseases, she learns from the camp nurse that the mystery illness seems to be coming from food items the sick members recently ate. Some of the island's characters are able to help identify food items and symptoms that are relevant to the

scenario, while others provide helpful microbiology information. The student is careful to take notes recording information about bacteria and viruses in her personal digital assistant, and corroborates these notes with information contained in her microbiology field manual. After forming several hypotheses about which food items may be sickening the team members, the student discovers through a series of tests that a container of unpasteurized milk in the dining hall is contaminated with bacteria. By combining this information with her knowledge about the characters' symptoms and recent dining habits, the student infers that the disease is *E. coli*, for which ample rest is the best immediate treatment plan. She records her findings in a diagnosis worksheet, and submits them to the camp nurse for review and implementation.

4 Empirical Study

An experiment involving human participants was conducted with the entire eighth grade population of a North Carolina middle school. The primary goal of the experiment was to investigate the impact of different scaffolding techniques on learning and engagement in the CRYSTAL ISLAND narrative-centered learning environment. However, no condition effects were observed for either learning or engagement. This paper's findings come from a secondary analysis of the data, which considers the experiment's conditions as a whole.

4.1 Participants

A total of 153 eighth grade students ranging in age from 12 to 15 (M = 13.3, SD = 0.48) interacted with the CRYSTAL ISLAND environment during the study. Three of the participants were eliminated due to incomplete data. Among the remaining students, 80 were male and 70 were female. Approximately 3% of the participants were American Indian or Alaska Native, 2% were Asian, 32% were African American, 13% were Hispanic or Latino, and 50% were White. Although CRYSTAL ISLAND is ultimately intended to be used concurrently with classroom coverage of an associated microbiology unit, scheduling issues necessitated that the study be conducted prior to students being exposed to the microbiology curriculum unit of the North Carolina state standard course of study in their regular classes.

4.2 Materials and Apparatus

Students completed an online demographic survey and CRYSTAL ISLAND curriculum test prior to the intervention. The curriculum test consisted of 16 multiple-choice questions created by an interdisciplinary team of researchers. The test consisted of eight factual and eight application questions assessing students' knowledge of pathogens, select diseases, and the scientific method.

Post-experiment materials were completed immediately following the CRYSTAL ISLAND intervention. Included in these materials were the same curriculum test used in the pre-experiment, a variation of the Perceived Interest Questionnaire [30], and the

Presence Questionnaire [29]. The interest scale was adapted from measures used by Schraw to examine within-subject relationships with learning outcomes [30]. The measure consists of ten Likert items measuring students' situational interest related to CRYSTAL ISLAND. To illustrate the scale, example items include the following: "I got absorbed playing CRYSTAL ISLAND without trying to," and "CRYSTAL ISLAND really grabbed my attention." The Presence Questionnaire (PQ) is a validated measure containing several subscales, including involvement/control, naturalism of experience and quality of interface [29]. The natural subscale is intended to assess the student's perception of the virtual environment's consistency with reality, in terms of locomotion and nature of the interaction. The interface quality subscale indicates how seamlessly the control and display devices are integrated into the interactive experience. Example items include the following: "How compelling was your sense of moving around inside the virtual environment," "How much did your experiences in the virtual environment seem consistent with your real-world experiences," and "How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?"

In addition to pre- and post-experiment subjective measures, the CRYSTAL ISLAND software calculated a numerical score to assess students' progress and efficiency in completing the science mystery. Students could view their scores in the upper left corner of their screens throughout their interactions with the software. The score consisted of a weighted sum of gameplay sub-scores, and incorporated time taken to accomplish important goals, students' ability to demonstrate microbiology content knowledge, and evidence of careful hypothesis formulation. Students were penalized

Table 1. Point values for calculation of final game score.

Action	Points (pts)
Overall Mystery Solution	
Correct Solution	500 pts
Solution Efficiency	(7500 / elapsed time) pts
Incorrect Solution Attempt	-100 pts
In-game Quiz Questions	
First Attempt Correct	25 pts
Second Attempt Correct	10 pts
Second Attempt Incorrect	-10 pts
Object Contaminant Testing	
Test Milk for Pathogens	200 pts
Incorrect Object	-10 pts
Incorrect Contaminant	-25 pts
Character Interactions	
Talk to Kim	(25 / elapsed time) pts
Talk to Teresa	(50 / elapsed time) pts
Talk to Ford	(125 / elapsed time) pts
Talk to Robert	(125 / elapsed time) pts
Talk to Quentin	(125 / elapsed time) pts
Pathogen Labeling Activities	
Correct Answer	10 pts
Incorrect Answer	-10 pts
Total Maximum Points	**≈ 1665 pts**

for any attempt to "game the system" by repeatedly submitting incorrect diagnoses to the camp nurse or guessing on content knowledge quizzes. Details of the score's calculation are shown in Table 1. As an objective measure assessing students' understanding of the curricular content and performance at completing the CRYSTAL ISLAND mystery, students' final score is treated as a measure to investigate engagement alongside subjective measures of presence and situational interest.

4.3 Participant Procedure

Participants entered the experiment room having completed the majority of pre-test materials one week prior to the intervention. Students were initially provided general details about the CRYSTAL ISLAND mystery and game controls during an introductory presentation by a researcher. After the presentation, students completed the remaining pre-test materials and received several CRYSTAL ISLAND supplementary documents. These materials consisted of a CRYSTAL ISLAND backstory and task description, a character handout, a map of the island, and an explanation of the game's controls.

Participants were given 60 minutes to work on solving the mystery. Solving the mystery consisted of several objectives including: learning about pathogens, viruses, and bacteria; compiling the symptoms and recent history of the sick researchers; recording details about diseases believed to be potentially afflicting the team members; testing a variety of possible sources for the disease; and reporting the solution—including cause, source, and treatment—to the camp nurse. Immediately after solving CRYSTAL ISLAND's science mystery, or 60 minutes of interaction, participants completed the post-experiment questionnaires. Completion of post-experiment materials took no longer than 30 minutes for participants. In total, sessions lasted up-to 120 minutes.

5 Results

An investigation of learning found that on average, students answered 2.35 (SD = 2.75) more questions correctly on the post-test than they did on the pre-test. Matched pairs t-tests (comparing post-test to pre-test scores) indicated that students' learning gains were significant, $t(149) = 10.49$, $p < .001$.

5.1 Learning and Engagement

Examining factors believed to reflect engagement and students' understanding of the curriculum, Pearson correlations indicated significant relationships between microbiology background knowledge and presence, $r = .17$, $p < .05$, and final score, $r = .28$, $p < .01$. Similar relationships were found between microbiology post-test scores and presence, $r = .295$, $p < .01$, final score, $r = .445$, $p < .01$, and situational interest, $r = .239$, $p < .01$. To more closely investigate the relationships between learning and engagement, additional analyses controlling for background knowledge were conducted.

A partial correlation controlling for pre-test score found significant relationships between microbiology post-test scores and two of our engagement measures, presence, $r = .25$, $p < .01$, and final game score, $r = .38$, $p < .01$. The same type of analysis also found a borderline significant relationship between situational interest and post-test score, $r = .15$, $p < 0.1$. Offering further evidence for a connection between learning and engagement in CRYSTAL ISLAND, a linear regression indicated that microbiology background knowledge, presence, and final score were all significant predictors of performance on the microbiology post-test, and the model as a whole was significant, $R^2 = .33$, $F(3, 143) = 23.46$, $p < .001$.

As a supplement to these findings, further analyses were conducted to determine whether similar relationships held for the involved/control subscale of the Presence Questionnaire, which provides a more specific measure of involvement in the environment. A partial correlation controlling for microbiology background knowledge revealed significant relationships between the involved/control subscale and final score, $r = .376$, $p < .01$, situational interest, $r = .181$, $p < .05$, and microbiology post-test performance, $r = .334$, $p < .01$.

5.2 Engagement and Individual Differences

Additional analyses were conducted to determine whether particular subpopulations experienced different levels of engagement while interacting with the CRYSTAL ISLAND environment. Pearson correlations indicated significant relationships between game-playing frequency and presence, $r = .269$, $p < .01$, as well as between self-perceived game-playing skill and presence, $r = .178$, $p < .05$. Game-playing frequency was found to have a significant relationship with the PQ's involved/control subscale, $r = .327$, $p < .01$, as did game-playing skill, $r = .211$, $p < .05$. A significant relationship between game-playing frequency and the PQ's natural subscale was observed, $r = .17$, $p < .05$. No significant relationships were found between game-playing frequency and the PQ's interface quality subscale, nor between game-playing skill and the naturalism of experience or interface quality subscales. No significant correlation was found between either of the game-playing demographics and situational interest, or between either of the game-playing demographics and final game score.

A regression analysis was conducted to examine the simultaneous contributions of game-playing frequency, microbiology background knowledge, presence, and final score on microbiology post-test scores. The overall model was significant, $R^2 = .327$, $F(4, 136) = 16.535$, $p < .01$, but only microbiology background knowledge, presence, and final score were significant predictors of post-test performance, not game-playing frequency. A similar regression analysis was conducted to examine the contributions of self-assessed game-playing skill, microbiology background knowledge, presence, and final score on microbiology post-test scores. The overall model was significant, $R^2 = .33$, $F(4, 136) = 16.750$, $p < .01$, but again only microbiology background knowledge, presence, and final score were significant predictors, not self-assessed game-playing skill.

Examining gender, an independent samples t-test analyzing the relationship between gender and presence found that males tended to feel more present in the environment than females, $t(139) = 3.01$, $p < .01$. Similar results were found for the

Table 2. Raw scores by gender on content knowledge, situational interest, and presence questionnaires.

Group	Microbiology Pre-Test	Microbiology Post-Test	Situational Interest	Overall Presence	Presence Subscales		
					Involved / Control	Natural	Interface Quality
Males	6.37 (2.23)	8.60 (3.03)	31.8 (8.73)	89.5 (16.4)	53.1 (10.4)	13.5 (3.44)	13.6 (3.45)
Females	6.31 (1.77)	8.62 (2.94)	31.4 (8.37)	82.3 (15.6)	48.0 (9.99)	12.5 (3.47)	12.6 (2.37)
Total	6.34 (2.02)	8.61 (2.98)	31.6 (8.54)	86.2 (16.4)	50.8 (10.5)	13.0 (3.48)	13.2 (3.04)

involved/control subscale of the Presence Questionnaire: an independent samples t-test analyzing the relationship between gender and the involved/control measure found that males tended to feel significantly more involved/control when interacting with CRYSTAL ISLAND than females, $t(140) = 2.96$, $p < .01$. Males also tended to rate the interface quality more highly, $t(140) = 1.97$, $p < .01$, but no gender effect was found on the PQ's natural subscale. Table 2 displays raw scores, by gender, for each of the content knowledge, situational interest, and presence measures.

Significant differences were observed between genders for gaming demographics. Males reported significantly higher ratings for self-perceived game-playing skill, $F(1, 143) = 57.49$, $p < .001$, and reported playing games more frequently, $F(1, 143) = 60.15$, $p < .001$, than females. Although males tended to feel more present in CRYSTAL ISLAND, an analysis of covariance controlling for game-playing frequency found no significant effect of gender on presence, $F(1, 138) = 2.01$, $p = .158$. Significant differences were not found between genders for situational interest or final score.

A linear regression considering only the female population yielded a significant model for predicting microbiology post-test performance, $R^2 = .25$, $F(2, 62) = 10.12$, $p < .01$, but only microbiology background knowledge and final score were significant predictors, not presence.

6 Discussion

The findings indicate that student engagement with the CRYSTAL ISLAND environment was associated with improved learning outcomes. Results showed a significant relationship between students' pre-test scores and presence, as well as between pre-test scores and final game scores. This suggests that students who demonstrated greater prior content knowledge tended to become more engaged with the narrative environment. However, all three measures for engagement—presence, situational interest, and final game score—were found to be significantly associated with post-test score, independent of pre-test score. These findings suggests that students who were more engaged with the CRYSTAL ISLAND narrative environment tended to experience greater learning gains, regardless of prior knowledge. The findings contrast with perspectives that place engagement and learning at odds with one another in narrative-centered learning environments. Further, analyses found no

relationships between game-playing experience and learning. This finding suggests that both gamers and non-gamers who were engaged in the narrative-centered learning experience achieved improved learning outcomes. Students can be productively engaged in a narrative-centered learning environment, and this relationship is independent of prior knowledge or game-playing experience.

The findings suggest that engagement and learning need not be at odds in narrative-centered learning environments, and may in fact reinforce one another. We hypothesize that well-designed story and gameplay elements may contribute to this synergistic relationship. However, poorly designed story and gameplay elements may detract from both engagement and learning by introducing seductive details and promoting off-task behavior. Additional investigation is needed to determine which elements of narrative-centered learning environments are most closely associated with learning and engagement. These efforts will contribute to the development of models to automatically detect student engagement and learning during narrative-centered learning interactions.

Interesting findings were also observed concerning the effects of gender and game-playing experience on presence. Males tended to be more present during CRYSTAL ISLAND interactions than females. An initial interpretation might be that the game was better designed for males than females. However, a significant correlation was also observed between presence and game-playing experience. Furthermore, males tended to have significantly greater game-playing experience than females. An ANCOVA suggested that game-playing experience, not gender, may be the more predominant factor associated with presence. These findings raise important questions about the effective design of narrative-centered learning environments for males and females, as well as gamers and non-gamers. However, additional investigation is necessary to better understand these relationships.

Extending studies of narrative-centered learning interactions beyond individual sessions is an essential next step for understanding the relationship between engagement and learning in narrative-centered learning environments. Studies spanning multiple sessions, along with in-class integration, are important to assess how engagement can be sustained over time with narrative-centered learning environments, how long-term engagement is related to deep learning and transfer, and whether engagement can impact student attitudes and self-efficacy. To accommodate these larger scale studies, devising additional subjective and objective measures for engagement beyond those used in this work will also be important.

7 Conclusions

Narrative-centered learning environments offer a promising vehicle for delivering experiences that are both effective and engaging. To investigate the hypothesis that learning and engagement need not be in opposition in narrative-centered learning environments, an empirical study was conducted with middle school students interacting with the CRYSTAL ISLAND learning environment. It was found that increased engagement was associated with improved learning outcomes, independent of students' prior content knowledge or game-playing experience. As narrative-

centered learning environments mature, it will become increasingly important to understand how students can most effectively interact with them, and what role narrative and game features can play in scaffolding learning and realizing sustained engagement.

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