In this study we examined key individual differences variables within a narrative centered learning environment (NLE) called CRYSTAL ISLAND. CRYSTAL ISLAND features a science mystery set on a recently discovered volcanic island where the task is to determine the cause of disease that is spreading among the inhabitants. Eighth graders were tested for background knowledge in microbiology and self-efficacy for science. In addition, they entered their goals and strategies while playing CRYSTAL ISLAND and then provided a measure of situational interest for the game. Results revealed that students with high levels of background knowledge reported more on-task goals (e.g. reading virtual books and posters, taking on-screen notes) than their low background knowledge peers. High frequency gamers reported more on-task goals that utilize objects within the environment than their peers who reported low frequency levels of video game play. Neither self-efficacy nor situational interest significantly predicted any in-game goals. These findings contribute to efforts to develop more sophisticated computer-based environments and improved intelligent tutoring systems.

Narrative-centered learning environments have are theorized to benefit learning by increasing student engagement and intrinsic motivation for the material presented within the game based on evidence found during narrative-centered learning (Malone, 1981; Mott et al., 1999). Moreover, these environments are highly dynamic and offer simple, yet evident manipulations for individual student adaptation. Thus, we sought to examine individual gaming differences that increase engagement and learning gains in order to develop adaptive environments that maximize student performance and interest.

Understanding how learners develop and improve their self-regulation is currently of high importance for cognitive scientists and educational researchers. Self-regulated learning (SRL) refers to learning that results from students’ self-generated thoughts and behaviors that are systematically oriented toward the attainment of their learning goals (Schunk & Zimmerman, 2003). Research in SRL has made significant advancements as models have been developed and refined (Butler & Winne, 1995; Winne & Hadwin, 1998; Pintrich, 2000; Zimmerman, 2000; Greene & Acevedo, 2007). However, there is now a shift in efforts to understand self-regulation not only in traditional learning environments but also in computer-based environments capable of providing intelligent tutoring systems (ITS) (Azevedo, 2005; Graesser, McNamara, & VanLehn, 2005). This poses significant challenges for research design because hypermedia environments are complex and may require additional processing demands of the user (Lajoie & Acevedo, 2006; Schraw, 2007). In order to provide sophisticated models of SRL development in hypermedia environments and subsequently build ITS that support the development of SRL we must burrow down
into the models and examine relationships between the key variables, which are composed, at the broadest level, of strategic, metacognitive, and motivational components (Zimmerman, 2000). Another objective of this study was to examine the function of key variables within these components by students working within a rich computer-based gaming environment utilizing a scientific problem-solving curriculum. We chose to examine SRL variables by examining student overall goal and intermittent sub-goal setting.

We focused our examination of individual differences on three SRL variables: goal orientation, goal statement actions, and situational interest. Goal orientation of a learner is an individual difference (trait-like) construct that impacts motivation and classroom achievement (Elliot & Dweck, 1988), and two types of goal orientations to achievement-related situations have been identified: mastery orientation and performance orientation (Dweck, 1986). Mastery (or learning) oriented individuals are focused on gaining knowledge, increasing ability and mastering a certain amount of knowledge. Performance oriented individuals are interested in public achievement in order to prove competence; these individuals see academic failure as indicating low ability, thus they may avoid the risk of appearing inept by avoiding challenge (Dweck, 1986).

Interest can be broken down into personal and situational interest (Schraw & Lehman, 2001). Personal interest is enduring and context-general whereas situational interest is spontaneous and context-specific. Despite the extensive research on cognitive and motivational constructs, there is a general agreement that the relationships among self-regulatory constructs are largely unknown and that future research should continue to address relationships among self-regulatory measures in order to advance research and educational practice (Brownlee, Leventhal, & Leventhal, 2000). Therefore, we chose to examine the extent to which situational interest affects goal-setting and in-game behaviors.

Our analysis of individual differences according to the SRL variables also includes factors such as background knowledge, gender, science self-efficacy, and gaming experience. In text based studies, high levels of background knowledge allow students to attend to relevant parts of a text and more readily infer relationships among and between text elements (McNamara, Kintsch, Songer, & Kintsch, 1996). In addition, students with high background knowledge are more able to build mental models, which help them understand and remember what was read (Anderson & Pearson, 1984; Trabasso & Bouchard, 2002). Proficient readers create these mental models by combining the propositions contained in the textbase with their prior knowledge (Kintsch, 1983, 1992, 1998, 2005, van Dijk & Kintsch, 1983). Because students with high prior knowledge already have mental models in place, it was hypothesized that these students would exhibit greater comprehension, more elaborate note taking, and engage in more on-task behaviors within educational gaming environments than students with less prior knowledge.

In recent research, gender has been identified as an interesting variable within NLEs as well as pertaining to SRL (McQuiggan et al., 2008). Recent research has found that girls report higher self-efficacy for science and self-efficacy for SRL at the middle school level (Britner & Pajares, 2006; Britner & Pajares, in press). The extent to which this finding generalizes in an open-ended learning environment, such as CRYSTAL ISLAND, was also tested.

**CRYSTAL ISLAND**

In our laboratory we are developing a narrative-centered learning environment (NLE) that is inquiry-based (Figure 1). The prototype learning environment, CRYSTAL ISLAND, is being created in the domains of microbiology for middle school students. CRYSTAL ISLAND features a science mystery set on a recently discovered volcanic island where a research station has been established to study the unique flora and fauna. The user plays the protagonist attempting to ultimately discover that eggs on the island are carrying an unidentified infectious disease by utilizing resources at the research station. The story opens by introducing her to the island and the members of the research team for which her father serves as the lead scientist. As members of the research team fall ill (Figure 2), it is her task to discover the cause of the specific source of the outbreak. She is free to explore the world and interact with other characters while forming questions, generating hypotheses, collecting data, and testing her hypotheses. Throughout the mystery, she can walk around the island and visit the infirmary, the lab, the dining hall, and the living quarters of each member of the team. She can pick up and manipulate objects, and she can talk with characters to gather clues about the source of the disease. In the course of her adventure she must gather enough evidence to correctly identify that is in fact the eggs that are the source of the infectious outbreak.

To illustrate the behavior of the CRYSTAL ISLAND learning environment, consider a student who has been interacting within the storyworld and learning about infectious diseases and related topics. In the course of having members of
her research team become ill, she has learned that an infectious disease is an illness that can be transmitted from one organism to another. As she concludes her introduction to infectious diseases, she hypothesizes based on information obtained from the camp nurse that the mystery illness seems to be salmonellosis and that the source of the disease must be identified. Specifically, the student must identify salmonellosis as the illness and the contaminated eggs as the source of the bacterial infection to solve the mystery.

Research Questions

Within CRYSTAL ISLAND we sought to examine the following questions:

1. How do individual differences impact performance in a narrative-centered learning environment?
2. What types of overall and sub-goals do students set while interacting in narrative-centered learning environments?

Method & Procedure

Participants
The participants included 75 eighth grade students from a rural (96% White, 54.2% reduced lunch) middle school in Burnsville, North Carolina. Fifty girls and 24 boys took part in the study.

Materials
The students completed all of the following tasks:

Microbiology Content Knowledge Test. This is a 15-item, four-option multiple choice test based upon North Carolina’s standard science curriculum for eighth grade students. The questions were written at both the identification and application level, and the content of the questions was contained within the CRYSTAL ISLAND environment. For example, the content test asked the students to: Rank the order of bacteria, fungi, and viruses from the smallest to the largest: (a) Fungi, Bacteria, Viruses, (b) Viruses, Bacteria, Fungi, (c) Bacteria, Viruses, Fungi, (d) Bacteria, Fungi, Viruses.

AGQ (Achievement Goals Questionnaire). This is a 12-item scale that measures achievement goal orientation in the form of four factors: mastery approach, mastery avoidance, performance approach, and performance avoidance (Elliot & McGregor, 2001). The four factors have been shown to have strong reliability and validity through a validation study (Finney, Pieper, & Barron, 2004). The AGQ was given both as a pretest and posttest.

Gaming Survey. The Gaming Survey was created for this study and asked questions about experience with video games and computer use. For this study we were particularly interested in two 5-point Likert scale items that included “Do you play videogames” that measured the frequency of game play and “How skilled are you when playing video games” that measured perceived skill in video game play. The Gaming Survey was given only as a pretest.

PIQ (Perceived Interest Questionnaire). At the end of CRYSTAL ISLAND interaction, participants were asked to complete a 10 item survey measuring their interest in the game (“Did you enjoy this game”). Students responded to the PIQ items on a 5 point Likert scale with one being “Not at all true of me” and 10 being “Very true of me.”

Overall Goal Statement. Prior to playing CRYSTAL ISLAND, students were asked to state their overall goal for the game. Students responded by entering their overall goal in their own words in a text box on the screen.

Current Goal and Strategy Statements. At intervals of 3 minutes during interaction with CRYSTAL ISLAND, students were asked, “What is your current goal?” Also, students were asked to report their current strategy for accomplishing each goal. Students responded to these questions by filling in a blank text box on the screen. These responses were open-ended, so students were able to uniquely write out their own goals and strategies.

Dependent measures from interaction in CRYSTAL ISLAND included overall goal report, sub-goal reports, and strategy reports.

Procedure
Before playing, all students were given background information about the game, a sheet listing the characters in CRYSTAL ISLAND, and a map with a top-down view of CRYSTAL ISLAND. Prior to game play, students completed the demographics inventory, gaming survey, and AGQ. Then, students were told that during the game they would be asked to describe the strategies they were using to reach their goals. The term strategy was defined and students were given examples of strategies that they might use in their lives to accomplish everyday goals. Specifically, the students were given a brief overview of when and why strategies are used, the actual definition of a strategy, and examples of strategies. Next, students completed pretests, set an overall goal for the game, and played CRYSTAL ISLAND for 45 minutes. During game play, the students were asked to report their current goal statements and strategies every three minutes. Upon completion of the game or at the end of the 45 minutes, the students completed the interest inventory.

Results

Coding Procedures
Two raters independently scored all of the reported goals and strategies with over 90% agreement as to classification. Any discrepancies were resolved through discussion.

What individual differences impact performance?
To answer this question we examined five individual difference variables that impacted performance within CRYSTAL ISLAND: background knowledge, gender, gaming frequency, situational interest, and gender. Interestingly, although initially predicted, individual differences were not revealed for situational interest. Comparisons of found individual differences are discussed in depth in the following sections. Refer to Figure 3 for a graphical representation of the results.

Background Knowledge. Background knowledge was measured using the Microbiology Content Knowledge Test, which was administered prior to interacting with the game environment. Content test scores falling in the upper or bottom third of the distribution were examined for the analysis of individual differences. Students scoring in the upper third of the distribution on the content test engaged in more mission-based actions ($t_{40} = -1.78, p < .10$) as opposed to students scoring in the bottom-third. In addition, students with higher background knowledge reported significantly more non-player character (NPC) interactions than their low-background knowledge peers ($t_{40} = -2.02, p < .05$). Non-player characters are any character agent within the environment that is not actually playing the game. Within CRYSTAL ISLAND, NPCs are any other character since the environment is single player. Therefore, the amount of background knowledge appears to have an effect on students’ on-task behaviors within a narrative-centered learning environment.

Gender. An analysis of gender differences found that females reported more mission-based goals ($t_{72} = 2.19, p < .05$) than did males. A borderline significant difference was found for NPC interactions as females reported more of these goals ($t_{72} = 1.80, p < .10$) than males. Although predicted, significant differences in science self-efficacy were not found for gender.

Video Game Frequency. Video game frequency was measured using the gaming survey. One question found on the gaming survey asked the students to rank their gaming frequency on a 5-point Likert scale. A score of one corresponded to “never” whereas a score of five corresponded to “very frequent.” Students were placed into three groups based on their response. Low-frequency gamers (those responding with a one or two) were measured against the frequent gamers (those responding with a four or five). Borderline significance was found for non-character, mission-based goals between the frequently gaming students ($t_{40} = -1.71, p < .10$) and the low-frequency gaming students. Thus, the students who play video games more frequently tend to utilize auxiliary objects (other than NPCs) within the environment to assist in game success.

What goals do students report while interacting in NLE’s?
A coding analysis of the overall goal reports indicated that most students either reported performance-oriented or mastery-oriented goals. A small number of students made non-goal statements that were neither mastery nor performance oriented (see Figure 4). Also, an analysis of the intermittent current goal self-reports determined that students reported both mission-based and seductive object interactions (see Figure 5). Mission-based interactions refer to productive actions and goals related to solving the game’s mystery. These actions include interacting with non-player characters (NPC), reading maps, posters, and books, and testing potentially contaminated objects.
Seductive object interactions include driving a virtual jeep, throwing around oil barrels, and swimming in the water. As shown in Figure 5, mission-based goals (shades of green) were reported slightly more frequently than seductive object interactions (shades of blue). Interacting with NPC’s was the most frequent goal stated; however, these interactions were required to progress throughout the game and were therefore omitted from Figure 5.

**Implications**

The complexity of the CRYSTAL ISLAND environment itself lends itself to a wealth of questions related to individual differences in learning efficiency. Moreover, NLEs can be easily manipulated and programmed to maximize student experience and SRL, which is dependent on certain individual differences. As we know, certain game aspects, such as interacting with expert characters, reading virtual books and posters, and taking notes, are beneficial for the learning experience within NLEs. Therefore, we can capitalize on the results that indicate which individual qualities lead to higher levels of beneficial interactions by scaffolding students who exhibit fewer of these favorable actions within NLEs.

More specifically, students with more gaming experience tend to utilize auxiliary game-enhancing objects within the environment than do less-frequent gamers. This finding suggests scaffolding students with less gaming experience to exploit these objects would be beneficial considering these objects contain important educational information. Also, males and students with lower levels of background knowledge should be further encouraged to engage in more mission-based than seductive-based interactions, particularly interacting with NPCs. The significant difference found between students with high and low background knowledge with respect to science self-efficacy is expected. Naturally, students with higher levels of science content knowledge tend to be more self-efficacious than those with lower content knowledge.

**References**


Figure 1. Overview of CRYSTAL ISLAND

Figure 2. Jin, the camp nurse, with a sickened Bryce, lead researcher on CRYSTAL ISLAND.

<table>
<thead>
<tr>
<th>Group</th>
<th>Science Self-Efficacy</th>
<th>Interest</th>
<th>Seductive Goals</th>
<th>Mission-Based Goals</th>
<th>Character Interactions</th>
<th>Non-Character Mission Goals</th>
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Figure 3. Individual Differences within CRYSTAL ISLAND

Figure 4. Student reported overall goals for CRYSTAL ISLAND divided upon goal type.

Figure 5. Student reported sub-goals during CRYSTAL ISLAND divided based upon mission-based or seductive goals.