Fifth Graders’ Flow Experience in a Digital Game-Based Science Learning Environment

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ABSTRACT

This mixed methods study examined 73 5th graders’ flow experience in a game-based science learning environment using two gameplay approaches (solo and collaborative gameplay). Both survey and focus group interview findings revealed that students had high flow experience; however, there were no flow experience differences that were contingent upon gameplay approaches. Results identified four game design features and student personal factors (reading proficiency) that significantly impacted student game flow experience. Students made significant science content learning gains as a result of gameplay, but game flow experience did not predict learning gains. The study demonstrated that the game was effective in supporting students’ flow experience and science content learning. The findings indicated that the adapted game flow experience survey provided a satisfactory measure of students’ game flow experience. The results also have implications for educational game design, as game design features that significantly contributed to students’ flow experience were identified.

Keywords: Collaborative Gameplay, Flow Experience, Game-Based Learning, K12 Education, Science Education

INTRODUCTION

In recent years the popularity of game-based learning has prompted increased attention to students’ subjective gameplay experience. Research in this area is important because students’ experience of playfulness/enjoyment during gameplay has been found to motivate them to engage in learning. Recently, researchers have begun to examine students’ gameplay experi-

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ence using Csikszentmihalyi’s (1975) flow theory. Flow describes an optimal experience of deep engagement that a person has when she/he is completely absorbed in an activity. Game flow experience studies focus on the context of gameplay and examine how game design features impact student flow experience. This type of research is especially valuable considering that educational game design and evaluation is still in its infancy. A full body of empirical literature has yet to be developed in terms of how to devise games that are both engaging and effective for student learning (Zheng, Spires, & Meluso, 2011).

The phenomenon of game flow experience has not yet been fully understood. Therefore, the primary purpose of this study was to investigate 5th graders’ flow experience in a 3D game-based science learning environment, which is called Crystal Island and funded by NSF. A second purpose of this study was to examine the impact of two different gameplay approaches (solo and face-to-face collaborative gameplay) on students’ flow experience. Employing a mixed methods research design (Creswell & Plano Clark, 2006), the study was guided by three research questions:

1. To what extent did 5th graders in a suburban elementary school in the southern US experience game flow while playing the Crystal Island game?
   a. What were the differences in students’ game flow experience based on two different gameplay approaches (solo and face-to-face collaborative gameplay)?
   b. What were the differences in students’ game flow experience based on individual differences (i.e., reading proficiency)?
2. How did game design features impact students’ game flow experience?
3. What was the relationship between students’ game flow experience and their science content learning gains?

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Research on Game Flow Experience

Overview of Flow Theory

Flow is an emotion of complete consciousness and engagement that is experienced by individuals who are deeply involved in doing an enjoyable activity. People who experience flow are often considered to be “in the zone” (Csikszentmihalyi, 1975, 1991). Csikszentmihalyi (1991) defined flow experience as having eight dimensions: (1) clear goals, (2) immediate and unambiguous feedback, (3) balance between the challenges of an activity and the skills required to meet challenges; (4) merging of action and awareness, (5) concentration, (6) sense of control, (7) loss of self-consciousness, and (8) a distorted sense of time. Jackson and Marsh (1996) proposed that autotelic experience (a state of the mind when the individual performs an activity out of the great enjoyment derived from performing the task itself instead of doing it for external rewards) be added as the 9th dimension.

In the studies of flow experience during human-computer interaction, these dimensions are often categorized into three stages, including flow antecedents, flow experience, and flow consequences (Ghani & Deshpande, 1994; Shin, 2006; Skadberg & Kimmel, 2004; Webster, Trevino, & Ryan, 1993). Kiili (2005) proposed a game flow experience scale to examine the three stages of flow experience with college students who played a computer science game (see Table 1). This survey was validated in a later study with a different group of college students (Kiili & Lainema, 2008). This present study was based on Kiili and Lainema’s (2008) game flow model.

For flow antecedents, a game with good playability should have an easy user interface to allow the player to find necessary functionalities. There should not be too many distracting
Research of game players’ flow experience is limited but promising. Existing game flow studies have identified factors that contribute to game players’ flow experience, including the perceived balance of challenge and skills, clear goals, useful feedback, good playability, and gamefulness (Hsu & Lu, 2004; Inal & Cagiltay, 2007; Kiili, 2005; Kiili & Lainema, 2008; Zheng, Spires, & Meluso, 2011). Unfortunately, the existing gameflow experience studies have reported mixed results when it comes to the effects of flow experience on players’ learning gains. In a study of college student game flow experience, Kiili (2005) found that students experienced high flow and that game flow experience was highly related to their content learning outcomes. Other studies, however, have reported negative findings with regard to the relationship between learning outcomes and game flow experience. Kiili and Lainema (2008) examined college students’ flow experience while playing a computer science game, and found only a loose connection between students’ game flow experience and learning achievement. Lee and Kwon (2005) also studied how flow experience was connected to success in a simulation game with 100 university students. Similarly, the survey data indicated that game flow experience was not a significant learning predictor.

In addition to the reported mixed findings, these existing studies have been conducted exclusively with high school or college students. Based on a review of literature, only two game flow experience studies conducted with elementary school students were identified. For instance, in their game flow experience study with 3rd graders using a qualitative interview approach, Inal and Cagiltay (2007) found that a balance of challenge and skill, useful feedback, and a less cognitively demanding user interface were factors that led to students’ game flow experience. It was also found that the challenge provided by the game had greater impact on boys’ flow experience, while the game stories had greater impact on girls’ flow experience. Zheng and her colleagues (2011) examined gameplay experience differences between 5th graders in the U.S and China. The study revealed that students’ English proficiency significantly impacted their flow experience during gameplay.

**Research on the Effectiveness of Game-Based Learning**

Studies have demonstrated the positive impact of educational gameplay on student content learning (e.g., Brom, Preuss, & Klement, 2011; Gillispie, Martin, & Parker, 2009; Miller, Chang, Wang, Beier, & Klisch, 2011; Lester, Spires, Nietfeld, Minogue, Mott, & Lobene,
Brom and his colleagues (2011) reported that high school students who learned science through gameplay outperformed students in the control group in terms of knowledge acquisition and retention. Meluso and her colleagues (2012) also reported that 5th graders who played a 3D science learning game made significant content learning gains. Some other studies, however, have reported negative results in terms of the learning effectiveness of gameplay (e.g., Annetta, Minogue, Holmes, & Cheng, 2009; Wrzesien & Raya, 2010). For instance, in a study about game-based science learning with 8th graders (Spires, Turner, Rowe, Mott, & Lester, 2010), the authors found that significant learning differences between the two groups were not evident.

There are also studies providing evidence that collaborative gameplay positively impacts students’ content area learning. Foko and Amory (2008) found that middle school students overcame more misconceptions about the science content when they played the game in pairs. Howard, Morgan and Ellis (2006) also reported that students highly valued the usefulness of peer discussion during gameplay. Some other researchers, however, are more conservative in making their conclusions (e.g., González-González & Izquierdo, 2012; Shih, Shih, Shih, Su, & Chuang, 2010; Meluso, et al., 2012). In particular, Shih et al. (2010) promoted that the effectiveness of collaboration is highly dependent on the specific collaborative gameplay strategies used.

## Summary of Literature Review

Several themes emerged from the literature review. First, there is no consensus regarding the learning effects of educational gameplay and the effects of peer collaboration during game-based learning. Second, the few existing game flow studies have been conducted exclusively with older players (high school students and above). Third, findings also differ across studies, especially in terms of the extent to which flow experience impacts students’ learning outcomes. These identified gaps in the literature have guided the current study.

## RESEARCH METHOD

This research study employed an embedded mixed methods design. Quantitative and qualitative data were collected simultaneously (see Appendix A for the design diagram).

### Participants and Research Context

Participants were 75 5th graders (males = 40, females = 35) at a public school in the southeastern United States. The students’ ethnic categories were: White/Caucasian (n = 49), Black/African American (n = 7), Hispanic/Latino (n = 7), Asian American (n = 3), and American Indian (n = 1). The rest of the students chose “other” as their demographic category (n = 8). Students were randomly assigned to either the solo or the face-to-face collaborative gameplay approach. Only students who completed all three sessions of gameplay and completed all items on the pre- and post measures (see below for details) were included in data analysis. This resulted in a final sample of 73 students (males=38, females=35; solo players=37, collaborative players=36).

Students played a 3D science learning game called Crystal Island (See Figure 1). The goal of the Crystal Island game was for students to complete a series of tasks which focused on landforms, map navigation, and modeling in 5th grade science. In order to complete these tasks, students chose an avatar to interact with the virtual environment and in-game characters. The tasks required students to place landform signs in the correct locations (e.g., waterfall, delta, plateau, and volcano), take photos of different landforms, use the map coordinates/scales to navigate to designated locations to collect flags, match pictures with 3D models of the Crystal Island, and rearrange dislocated objects to recreate the Crystal Island environment. To help students with the tasks, the game provided a virtual tablet with a series
of applications preloaded with multimedia resources that students could access anytime during gameplay. Students received instant feedback from the in-game characters each time they completed a task.

Quantitative and Qualitative Data Sources

Pre-Measures

The pre measures included a science content test and reading proficiency. The science content test was developed by the Crystal Island research team in collaboration with five content experts (fifth grade science teachers from a local elementary school). The content test was developed to align with the curriculum of the game based on the Full Option Science System (FOSS), a research-based K12 science curriculum, and fifth grade science End of Grade (EOG) tests. The test was piloted with another group of fifth graders and revisions were made accordingly before administering to students in the current study. The final test consisted of 27 multiple-choice questions that assessed both low-level recognition and higher-level application/transfer knowledge (see Appendix B). The test-retest reliability was .83.

Students’ End-Of-Grade (EOG) reading test scores, measured on a 4-point scale (Level I, II, III, and IV) were used as a measure of their reading proficiency. Students’ reading proficiency was examined because Crystal Island is a narrative-centered learning game that requires students to read and comprehend the gameplay instructions and resources. The EOG reading test is a reliable and valid instrument developed by the Department of Public Instruction to assess students’ reading achievements against state standards. EOG reading test raw scores ranging from 0 to 50 points were converted into scale scores ranging from 321 to 374, which were then converted into the 4-point scale scores used in the current study. The official cut-off scores were: Level 1 (equal to or less than 340), Level 2 (between 341 to 348), Level 3 (between 349 to 360), and Level 4 (equals to or higher than 361). For informa-
tion on the EOG reading tests, see http://www.ncpublicschools.org/accountability/testing/eog/reading/.

Post-Measures

The post measures consisted of science content test (identical to the pre test) and game flow experience. Game flow experience was measured using an adapted flow experience survey and semi-structured focus group interviews.

Adapted Game Flow Survey

As discussed earlier, students’ game flow experience was measured with a game flow questionnaire adapted from an existing flow scale developed and validated by Kiili and Lainema (2008). The original questionnaire consists of two parts: (a) eighteen 5-point Likert-scale items (1=strongly disagree to 5=strongly agree) measuring six flow antecedents (game design features), and (b) fifteen 5-point Likert-scale items measuring 5 theorized dimensions of game flow experience, including concentration, sense of control, sense of time distortion, loss of self-consciousness, and autotelic experience. In order for 5th graders to understand the survey questions, some items were reworded (see Appendix C for flow experience items).

An exploratory factor analysis (EFA) using Maximum Likelihood factoring and an Oblique rotation (i.e., Direct Oblimin) was conducted on the adapted survey (Costello & Osborne, 2005). During the first round of EFA, one item measuring students’ sense of concentration was found to be double loaded with higher loading on the non-theorized factor. After removing this item, the 2nd EFA extracted 4 factors with Eigenvalue greater than 1.0, accounting for 56.80% of the total variance. Specifically, items measuring the two flow experience subscales of time distortion and loss of self-consciousness loaded on the same factor to form the new 4th factor. This might indicate that these two concepts were not distinct enough for 5th graders. Overall, the 4-factor game flow experience structure was interpretable, indicating that even though flow experience is theorized to have 5 subscales for adults, it only has 4 subscales for upper elementary students in this current study. These 4 subscales are concentration, sense of control, time distortion and loss of self-consciousness, and autotelic experience. The factor correlations are presented in Table 2. The reliability for each of the 4 subscales as measured by Cronbach’s alpha ranged from .77 to .84. The item-total correlations were all within the “good” range (from .44 to .74) based on Ebel’s (1965) guidelines that item-total correlation values above .40 are good. The mean inter-item correlations for these 4 subscales ranged from .39 to .64.

These results indicated that even though there are some items that warrant future work, the 4-dimension game flow experience instrument worked well with 5th graders in this current study, and provided a useable basis for subsequent data analyses of participants’ experiences with Crystal Island.

Semi-Structured Focus Group Interview

During focus group interviews, students from both gameplay groups were asked questions about their game flow experience based on

<table>
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</tr>
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<td>2</td>
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<tr>
<td>4</td>
<td>.16</td>
<td>.48</td>
<td>.43</td>
<td>1.00</td>
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</table>
the flow experience subscales, and questions about Crystal Island game design features. Focus group participants were selected based on three criteria: First, students indicated whether they were willing to be interviewed. Second, based on students’ willingness, the classroom teachers recommended those who were more talkative. Finally, to reduce potential bias, the researchers selected 5 solo game players and 5 collaborative game players from both genders and different ethnic/racial backgrounds. In qualitative research, it is common for “information rich” participants to be selected to allow the researchers to fully understand a complex issue (Marshall, 1996). More talkative students were selected for the focus group interview in the current study to provide “richer” information to better understand the complex phenomenon of game flow experience. Due to the design of the study, focus group participants were not selected based on their self-reported flow experience levels. Students either participated in the focus group one day prior to completing the flow survey or immediately following the flow survey (see below for details).

Data Collection

One week prior to gameplay students took the science content test. Using the school’s computer lab, students played the Crystal Island game on three consecutive days for 40 to 50 minutes each day. On the first day of gameplay, participants were randomly assigned to either the solo or face-to-face collaborative gameplay approaches. Students then viewed a background story video about Crystal Island, followed by a tutorial familiarizing them with game controls. Students then played the game for 45 minutes, progressing at their own pace. Immediately after gameplay, 5 solo game players (girls=2, boys=3; White Americans=3, African Americans=1, Asian Americans=1) were selected to participate in a 30-minute focus group interview. On the 2nd day, students played the game for 50 minutes, and at the conclusion of the gameplay session the flow experience survey was administrated through Survey Monkey. Immediately after the flow survey, 5 collaborative game players (girls=3, boys=2; White Americans=3, African Americans=1, Latino Americans=1) were selected to participate in a 30-minute focus group interview. On the third day, the time for gameplay was shortened to 40 minutes to allow students time to take the post science content test.

Solo game players worked individually. Collaborative game players worked in dyads, with one of them being the game driver (driving the in-game characters around) and the other one being the game planner (observing and providing suggestions to help with gameplay). Students in the dyads switched the roles halfway through each gameplay sessions.

Note that during the game-based learning process, students did not receive supplementary classroom instruction on the science curriculum covered in the game from their teachers. The teachers were not present in the computer lab during gameplay sessions. Only the researchers were present to help students get seated, log in to the game, and solve potential technical problems during gameplay.

DATA ANALYSIS AND FINDINGS

Data Coding

For science content tests, a total score was calculated for each student. For the flow experience survey, for each student, a mean score was calculated for each subscale (i.e., sum of all items measuring the same subscale divided by the number of items measuring the subscale). Focus group interview data was coded using a prior coding guided by flow theory at the first round, and open coding at the second round to identify additional themes mentioned by students. Interview coding results were triangulated with the flow survey data. Since the interview questions were constructed based on the flow
experience subscales (see Appendix D), the corresponding codes were readily apparent to the researcher (Creswell & Plano Clark, 2006).

Findings for Research Question One

Descriptives

These results in Table 3 demonstrated that, regardless of students’ gameplay approaches (solo and collaborative gameplay), the mean scores for the 4 flow experience subscales were greater than 4 on a 5-point scale, indicating high game flow experience for students.

The results from the flow survey were supported by data from focus group interviews. For the flow experience subscale of sense of concentration, the focus group interview data also indicated that, regardless of gameplay approaches, students were highly concentrated during gameplay. For the flow experience subscale of autotelic experience, students’ interview responses also supported the survey results. Students commented that they “played the game for the fun of it”, an indicator of students’ intrinsic motivation. For the flow experience subscale of sense of control, all 10 students interviewed reported that they felt in good control of their gameplay actions. However, 8 out of the 10 interviewed students also reported that sometimes they felt “frustrated” because it was difficult to control the movement of the game characters using the keyboard.

Finally, for the 4th flow experience subscale of time distortion and loss of self-consciousness, both solo and collaborative game players in the focus groups reported that they felt time went by faster than usual. One solo player commented, “…you were just having so much fun…and you felt like you have played for only 10 minutes.” One collaborative player also commented, “Time went so fast that it is almost time to go and I got so mad…” Regarding loss of self-consciousness in this 4th subscale, students’ focus group responses illustrated that flow experience in the Crystal Island game was categorized as the tendency to shut themselves off from the outside world. Students used phrases such as “zoned out” and “did not hear anybody” to describe their gameplay experiences.

Reading Proficiency and Flow Experience

Simple regression analyses were conducted to examine the relationship between students’ reading proficiency and their game flow experience. The results revealed that reading EOG scores significantly predicted students' autotelic experience, $R^2 = .07, \beta = .13, t = 2.35, p = .02$.

Gameplay Approaches and Flow Experience

A 2(Gameplay approaches: solo and collaborative players) *2(Gender: male and female) MANCOVA analysis controlling for the effect of reading EOG scores was conducted to examine flow experience differences based on the two gameplay approaches. The results failed to reveal a main effect for gameplay approaches. The results also failed to reveal a main effect for gender. However, there was a significant

Table 3. Descriptive data for game flow experience based on gameplay conditions

<table>
<thead>
<tr>
<th>Subscales</th>
<th>Solo (n=37)</th>
<th>Collaborative (n=36)</th>
<th>All (n=73)</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Attention focus</td>
<td>4.51</td>
<td>.48</td>
<td>4.36</td>
</tr>
<tr>
<td>Sense of control</td>
<td>4.20</td>
<td>.70</td>
<td>4.06</td>
</tr>
<tr>
<td>Loss of time and self-consciousness</td>
<td>4.03</td>
<td>.56</td>
<td>3.99</td>
</tr>
<tr>
<td>Autotelic experience</td>
<td>4.58</td>
<td>.53</td>
<td>4.63</td>
</tr>
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</table>
main effect for reading EOG score on the flow subscale of autotelic experience, $F(1, 68) = 4.21$, $p = .04$, partial eta squared = .06.

### Findings for Research Question Two

#### Descriptives

Table 4 demonstrated that the mean scores of the 6 flow antecedents (game design features) were all approaching or greater than 4 on a 5-point scale, indicating that students thought that the game was designed with desirable features.

As shown in Table 4, a mean score of 4.15 indicated that the challenge level of the game tasks was appropriate for the students, which was supported by students’ responses to the focus group interview questions. However, for the game design feature of clear goals, even though a mean score of 4.04 indicated that students knew about the goals of the game, only 3 out of the 10 students interviewed were able to correctly articulate the goal of the game. For the game design feature of clear and immediate feedback, a mean score of approaching 4 also indicated that students perceived this to be a desirable feature of the game. Qualitatively, all students interviewed also commented that the game did a good job in providing encouraging and useful feedback. The focus group interviews also revealed that students easily learned how to play the game, an indicator of good playability. This was also consistent with findings from survey.

For the game design feature of gamefulness, a mean score of 3.95 indicated that this was a desirable feature of the **Crystal Island** game design. When students were asked about their gameplay experience, both solo and collaborative players mentioned features that could be categorized as high gamefulness. One boy in the solo gameplay group reported that the **Crystal Island** game was fun because it had “different (difficulty) levels,” an important feature of high gamefulness. A girl in the collaborative gameplay group also commented that she enjoyed playing the game because she could use the earned in-game rewards to perform other gameplay tasks, another indicator of high gamefulness. The high mean score for game frame story was also supported by students’ focus group interview responses in that students orally commented that the game background story video was very “cool” and it told them what they needed to do in the game.

#### Impact of Game Design Features on Flow Experience

To examine the relationship between the 6 game design features and students’ flow experience as measured with the 4 subscales, separate multiple regression analyses were conducted. The results showed that 4 game design features, including balance of challenge and perceived skills, playability, gamefulness, and game frame/background story, significantly predicted students’ game flow experience (See Tables 5 through 8).

### Table 4. Descriptive data for game flow antecedents across gameplay conditions

<table>
<thead>
<tr>
<th>Flow Antecedents</th>
<th>Mean</th>
<th>Std. Deviation</th>
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<tr>
<td>Challenge/skill balance</td>
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<tr>
<td>Playability</td>
<td>4.03</td>
<td>.65</td>
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<tr>
<td>Gamefulness</td>
<td>3.95</td>
<td>.56</td>
</tr>
<tr>
<td>Clear goals</td>
<td>4.04</td>
<td>.63</td>
</tr>
<tr>
<td>Immediate &amp; unambiguous feedback</td>
<td>3.82</td>
<td>.68</td>
</tr>
<tr>
<td>Game frame story</td>
<td>4.14</td>
<td>.54</td>
</tr>
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</table>
Findings for Research Question Three

Science Content Learning Gains

To examine group differences in science content learning gains from pre- to post-test, a 2 (Groups: solo player, collaborative player) x 2 (Test: pre, post) repeated measures analysis of variance (RM-ANOVA) was conducted. The results revealed a main effect of test, indicating that students demonstrated significant increases in correct responses to the science content test from pre- ($M = 14.64, SD = 4.97$) to post-test ($M = 15.74, SD = 5.41$), collapsed across gameplay approaches, $F(1,71) = 5.26, p = .03$, partial eta squared = .07. However, the RM-ANOVA failed
to reveal a main effect of gameplay approaches, indicating that the solo and collaborative game players did not differ in terms of learning gains from pre- to post-content-knowledge test, $F(1, 71) = .01, p = .93$.

**Flow Experience and Content Learning Gains**

Residual gain scores for the science content test (post-pre) were calculated for all students. A multiple regression analysis was then conducted to examine how flow experience predicted science learning gains. Results indicated that, none of the 4 flow subscales significantly predicted science content learning gains.

**CONCLUSION AND IMPLICATIONS**

**Flow Experience in the Crystal Island Game**

The study examined 5th graders’ flow experience in the Crystal Island game environment, its impacting factors, and the relationship between game flow experience and science learning gains. Both quantitative and qualitative data indicated that the game afforded students an enjoyable flow experience regardless of gameplay approaches. The results also indicated that flow theory provided a new lens to examine students’ playful science learning experience in the game environments, and that the adapted survey provided a satisfactory measure of students’ game flow experience. More importantly, the study revealed that game flow experience only has 4 subscales for 5th graders instead of 5 theorized dimensions. As previously discussed, this might be because the concepts of time distortion and loss of self-consciousness were not distinct enough for 5th graders. It might also imply that these items need to be further reworded to make the two concepts clearer for young participants. Meanwhile, note that the EFA results were based on a relatively small sample size. In future studies, a larger sample size should be recruited to further validate the survey. In addition, the current study included only 3 items for each subscale in the survey, which might not produce stable results (Costello & Osborne, 2005). Moving forward in working on the adapted survey, more items need to be written.

**Flow Experience Impacting Factors**

The study demonstrated that the Crystal Island game was designed with several desirable features, including balance between challenge and student perceived skill, playability, gamefulness, and game background story, that contributed to students’ flow experience. It is possible that future educational game designs that take these design principles into consideration may be more likely to support students’ flow experience. This is important in that although flow experience did not predict student content learning gains in the current study, some

<table>
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<tr>
<td>Challenge/skill balance</td>
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<tr>
<td>Playability</td>
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<td>Gamefulness</td>
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<td>Clear goals</td>
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<td>Immediate and unambiguous feedback</td>
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<td>Game frame story</td>
<td>.31</td>
<td>2.87</td>
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</table>

Note: $R^2 = .35, p < .05$
previous studies have demonstrated that flow experience is positively related to content learning outcomes in the virtual learning environments (e.g., Kiili, 2005; Skadberg & Kimmel, 2004). On the other hand, while not supported in the current study, the game design features of clear goals and unambiguous feedback were both found to be predictors of students’ game flow experience in several previous studies. These two factors may not have been significant predictors in this study due to the fact that the game was still at a developmental stage at the time of implementation.

Besides the several desirable game design features, the novelty of game-based learning might have also contributed to students’ high game flow experience, especially considering that students only played the Crystal Island game for a relatively short period of time. Students who are easily attracted by novel events may experience higher flow when playing the Crystal Island game. Future research should examine how students’ motivation in game-based learning might be sustained. For instance, students may be continuously engaged with games based on certain desirable design features as well as the ways in which games are integrated in the school curriculum.

Effectiveness of Collaborative Gameplay

Students in both gameplay approaches not only experienced high flow but also made significant content learning gains, supporting the findings reported in previous studies that well designed games have the potential of supporting students’ science learning. Collaborative game players in this study, however, did not make higher content learning gains than solo game players. Shih and his colleagues (2010) asserted that for collaboration to contribute to learning, students need to engage in meaningful discussion and idea exchanges. However, during collaborative gameplay, it was observed that some students were talking about other things such as funny gameplay actions. Apparently, a clear role should be set for students in the gameplay dyads in order for meaningful peer collaboration to occur (Hämäläinen, Manninen, Järvelä, & Häkkinnen, 2006). In particular, in future studies students need to be more explicitly instructed as to how to engage in active acquisition of information together with a partner. In this current study, even though students in the gameplay dyads were told to work together to complete the game quests, no further instruction on effective collaborative gameplay was provided.

Relationship between Flow Experience and Science Content Learning

In this study, even though students across both gameplay approaches made significant content learning gains, game flow experience was not found to significantly predict content learning gains. One possible reason is that students played the game for only a relatively short amount of time, which may have limited the possibility to observe the actual impact of game flow experience on science learning gains. Graesser and his colleagues (2009) point out that there is often a tradeoff between deep learning and students’ positive emotion in the virtual environment. Students’ deep enjoyment doesn’t translate into better performance, probably because their attention has been focused too much on the entertainment aspect of the game. A certain degree of scaffolding might help direct students’ attention to the learning aspect of the game. For example, the researchers/facilitators should monitor student gameplay behaviors to correct their off-task behaviors.

The finding that students’ game flow experience did not predict their science learning gains also has implications for game design. While playing the Crystal Island game, students had the freedom to navigate through the game environment in whatever ways they would like to. As a result, some of them easily went off-task by driving their characters around for fun. Therefore, for these young students who lack the self-regulation skills of keeping attention
on content-related game quests, it is important to take this into account when designing games in order to maintain a balance between the degree of autonomy given to students and their self-regulated gameplay behaviors. For instance, the game could be designed in such a way that when students went off task, they would be alerted to redirect their attention to the game quests.

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APPENDIX A

See Figure 2 for a mixed methods research design diagram.

APPENDIX B

Science Content Test (Sample Questions)

• Which of the following is NOT a model?
  ◦ A globe
  ◦ A doll
  ◦ A waterfall
  ◦ A map

• Which is the MOST accurate way to locate an exact position on a map?
  ◦ Scan the map visually
  ◦ Use the map key
  ◦ Use the compass
  ◦ Use the map grid

• You need to get from Ranger Station 1 to Ranger Station 3. About how many meters long would this hike be if you stay on the road?
  ◦ 100 meters
  ◦ 1600 meters
  ◦ 1200 meters
  ◦ 700 meters

Figure 2. Embedded mixed methods research design diagram
APPENDIX C

Adapted Game Flow Experience Survey (Kiili & Lainema, 2008)

Flow Experience Items

- Attention focus
  - The Crystal Island game really grabbed my attention.
  - It was easy for me to pay all my attention to the game.
  - I was completely concentrated in playing the game.

- Sense of potential control
  - It was easy for me to control my playing actions in the game.
  - I was able to decide on my own playing actions and made progress in the game.
  - I was in good control of my playing actions.

- Loss of self-consciousness
  - When I was playing, I did not care about what others thought about how well I was playing.
  - I just kept playing and was not worried about how well I was doing.
  - While I was playing the Crystal Island game, I forgot about unhappy things.

- Sense of time distortion
  - While I was playing the Crystal Island game, I felt time seemed to go in an unusual way (either much faster or slower than usual).
  - During gameplay, I forgot about time because I really got into the game.
  - During gameplay, the time seemed to pass very fast. Suddenly, the playing session was almost over.

- Autotelic experience
  - I really enjoyed playing the Crystal Island game.
  - I liked the feeling of playing and want to play it again.
  - I enjoyed playing the Crystal Island game because it made me feel good.

Flow Antecedents (Game Design Features) Items

- Balance between challenge and perceived skills
  - The game tasks were challenging, but I had the skills to meet the challenge.
  - The difficult level of the game equaled to my skill level.
  - As I played the game, my skills got improved and so I was able to complete more difficult tasks.

- Good playability
  - I understood the game on the screen quickly and knew what to do without having to think.
  - I learned how to lay the game very easily.
  - It was easy for me to understand how to play the game.

- Gamefulness
  - The game did not get any more difficult as I played.
  - I was able to play in many different ways.
  - I could use the rewards (i.e., sand dollars) I gained later when I did other tasks.
• Clear goals
  ◦ I knew clearly what I needed to do in the game.
  ◦ The goal of the game was very clear to me.
  ◦ I understood the goal of the game from the very beginning.

• Immediate and useful feedback
  ◦ The feedback given by the game helped me know how well I was doing in the game.
  ◦ The game provided quick feedback of how well I was playing.
  ◦ The feedback that the game provided was very helpful.

• Game frame (background) story
  ◦ The game background story was part of the reason why I liked playing the game.
  ◦ The game story made it easier for me to understand what happened in the game.
  ◦ The game story helped me to understand what I needed to do in the game.

**Peer Interaction during Collaborative Gameplay Items**

• I enjoyed playing the game with my partner.
• My partner helped me to do better in the game.
• I would like to play the game with my partner again.

**APPENDIX D**

**Game Flow Experience Focus Group Interview (Sample Questions)**

• **Attention focus:** Did you pay all your attention to the game?
• **Sense of control:** Did you feel you were able to easily control your own playing actions?
• **Time distortion:** When you were playing the Crystal Island game, what was your feeling about time? Did you feel that time went very fast?
• **Loss of self-consciousness:** When you were playing the Crystal Island game, did you worry about what your friends may think about how you were doing in the game?
• **Autotelic experience:** Do you think playing the Crystal Island game make you feel good? Do you think you enjoyed playing the Crystal Island game so much that you would like to play it again in the future?