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Improving Academic Learning from Computer-Based Narrative Games

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Abstract

Although many strong claims are made for the power of computer games to promote academic learning, the narrative content of a game may reduce the learner's tendency to reflect on its academic content. The present study examines adding a low-cost instructional feature intended to promote appropriate cognitive processing of the academic content during play. College students played a computer adventure game in which they guided a character through a bunker in search of lost artwork, building electromechanical devices to open stuck doors along the way. In Experiment 1, students who filled out worksheets about wet-cell batteries before and during the game outperformed students who played the game without worksheets on a written explanation of how wet-cell batteries work ($d = 0.92$), multiple-choice comprehension questions about wet-cell batteries ($d = 0.67$), and open-ended transfer problems about wet-cell batteries ($d = 0.74$). In Experiment 2, participants who completed only the in-game worksheet outperformed the control group on a written explanation of wet-cell batteries ($d = 0.59$) and transfer problems ($d = 0.67$), whereas participants who completed only the pre-game worksheet did not outperform the control group on any measure. These findings point to the learning benefits of adding instructional features suggested by cognitive theories of learning.

Keywords: computer games, learning, transfer

1. Introduction

A narrative game (or adventure game) is a game that has a cover story that poses goals for the player. For example, as exemplified in Figure 1, in *Cache 17* (Koenig, 2008), the player views a cut scene showing that the player's goal is to recover stolen artwork that is hidden in a WWII bunker system, and along the way the player must build a wet-cell battery that can open a stuck door. As summarized in Table 1, in narrative games for learning there can be an inherent conflict between the goal of the game based on the narrative and the goal of the game based on the instructional objective. In the case of *Cache 17*, for example, the narrative theme suggests that the goal is to recover stolen artwork, whereas the instructional goal is help students learn about electromechanical devices. The narrative theme is intended to prime player motivation which can be expressed through persistence and intensity of game play, whereas the instructional material is intended to prime appropriate cognitive processing such as attending to the relevant information and trying to make sense of it.

Game designers have pointed to the potential contribution of narrative theme (or story line) in games (Dickey, 2006, 2015; Fullerton, 2008; Prensky, 2001; Schell, 2008). For example, Dickey (2006, p. 250-251) notes: "Within the adventure game genre, narrative provides two main functions: both motivation and a cognitive framework for problem solving." While acknowledging the potentially powerful role of storylines in games, Fullerton (2008, p. 101) notes that storylines can sometimes distract gameplay: "Game designers are still searching for better ways to integrate story into their systems without diminishing gameplay." Visionaries and developers also have recognized narrative theme as a core component in adventure games (Klopfer, 2008; Gee, 2007; McGonical, 2011; Prensky, 2006). Early ethnographic studies and analyses of video game playing noted that players appear to become engaged in game playing through the story line of games, even when the stores are quite simple such as in the case of PacMan (Kent, 2001; Loftus & Loftus, 1983; Turkle, 1995). Subsequently, Liberman (2004) showed how narrative theme could boost engagement in health games and Schank (1997, 2002) showed how rich case examples could boost engagement in business game-like simulations.

In contrast, in a recent review of empirical studies comparing learning from a base version of a game versus the same game with narrative theme added, there was not sufficient evidence showing superior learning for the narrative group (Mayer, 2014). Although narrative games for learning may prime the player's motivation, there is danger that the player's main goal can be to win the game rather than to understand the instructional content that is encountered in the game. For example, Adams, Mayer, MacNamara, Koenig, and Wainess (2012) found that students learned better about electro-mechanical devices from a PowerPoint presentation than from playing *Cache 17*. This reflects a larger pattern in research on educational games: although there is much excitement surrounding educational games, the evidence for their educational effectiveness is sparse and ambivalent (Mayer, 2014; National Research Council, 2011; O'Neil & Perez, 2008; Tobias & Fletcher, 2011; Vogel et al., 2006).

The present study examines ways to increase academic learning based on the instructional objectives from an adventure game with a strong narrative theme. From a cognitive load perspective (Sweller, Ayres, & Kalyuga, 2011; Mayer, 2009), learners have a limited working memory capacity for building new knowledge as they a play a game. If cognitive capacity is consumed by thinking about the narrative theme, the player may not have sufficient remaining capacity to think deeply about the academic material in the game. The solution attempted in this study is to include adjunct activities that refocus the learner's processing on the core academic content of the game and prime the learner to reflect on this content.

The value-added approach to research on educational games (Mayer, 2011) seeks to identify features that enhance learning by comparing a base version of a game to a version with an added feature. Recent meta-analyses by Mayer (2014) have identified promising features such as adding hints and advice throughout the game, using conversational wording rather than formal wording, using spoken text rather than printed text, prompting students to explain the material to themselves as they learn, or providing pre-training. Although these guidelines can help game designers build effective games, features that require modifying the game itself can be prohibitive for educators using off-the-shelf games. The addition of simple adjunct materials to games, such as paper-based worksheets (Fiorella & Mayer, 2012) or instruction slides (Erhel & Jamet, 2013), is therefore a practical domain of investigation.

The goal of the present study is to examine a low-cost technique intended to focus the narrative game player on cognitive processing relevant to the instructional goal, namely the use of pre-game and in-game worksheets. The pre-game worksheet is a sheet of paper that asks the player to write an explanation of how a wet-cell battery works, thereby drawing attention to the major instructional goal in the game. The in-game worksheet is a sheet of paper that asks the player to fill in answers concerning how to build a wet-cell battery during the game. The current study adds to the literature both in the type of game and the type of worksheet added. First, unlike Fiorella and Mayer (2012), the current study uses a narrative game, which involves conflicting goals based on the narrative and based on the educational information. Further, the worksheets in the current study are activity-based, whereas the worksheets employed by Fiorella and Mayer (2012) were more declarative.

The rationale for using simple pre-game and in-game worksheets is to increase appropriate cognitive processing aimed at the instructional objective, while still allowing the narrative game player to maintain motivation. A theoretical goal is to determine whether a simple device such as adjunct worksheets can encourage players to focus their limited cognitive resources on understanding the instructional material. A successful device must reduce the amount of cognitive resources dedicated to information outside the instructional goal [i.e., what Mayer (2009) calls *extraneous processing* in the Cognitive Theory of Multimedia Learning (CTML), or what Sweller, Ayres, & Kalyuga (2011) call *extraneous load* in Cognitive Load Theory (CLT)] in order to allow the learner to dedicate more resources to processing relevant information (i.e., *essential processing* in CTML or *intrinsic load* in CLT) and to making sense of the relevant information (i.e., *generative processing* in CTML or *germane load* in CLT). These processes can be inferred through students' completeness in writing explanations of how a wet-cell battery works, enhanced retention of key information on a comprehension test, and improved performance on a problem-solving transfer test. A practical goal is to determine whether the instructional effectiveness of an off-the-shelf narrative game can be enhanced by a low cost intervention that does not require modifying the game.

2. Experiment 1

2.1 Method

2.1.1 Participants and design. The participants were 62 undergraduates from the University of California, Santa Barbara. Participants were recruited from the Psychology Subject Pool and fulfilled a course requirement by participating in the experiment. There were 28 men and 34 women, and the mean age was 19.1 (SD = 1.3). The majority of participants reported playing video games less than one hour per week and none played more than 10 hours per week. The mean score on a self-report scale of prior knowledge of electricity was 2.1 out of

5 (SD = 1.0), which is considered low. Thirty participants served in the worksheet condition and thirty-two participants served in the control condition.

2.1.2 Materials.

2.1.2.1 Paper-based materials. The paper based materials consisted of a consent form, demographic questionnaire, pre-game worksheet, game instructions, in-game worksheet, post-game worksheet, transfer test sheet, comprehension test sheet, post-game questionnaire, and debriefing slip.

The demographic questionnaire asked for basic demographic information (e.g., gender and age), time spent playing video games per week, and prior knowledge about electricity. Time spent playing video games was assessed by the item, "How much time per week do you typically play video games?" with five response options: "I do not play video games"; "Less than 1 hour per week"; "1 to 5 hours per week"; "5 to 10 hours per week"; and "More than 10 hours per week". Prior knowledge about electricity was measured with a question asking participants to rate their knowledge of how electricity works on a scale from 1 ("very low") to 5 ("very high") and to complete a checklist of 13 electricity-related experiences. The checklist read, "Please place a check mark next to the items that apply to you: ___I own a book of basic electrical/electronic repair; ___ I enjoy watching documentaries about science on the Discovery Channel; ___ I have rewired an electrical device; ___ I have used rechargeable batteries; ___ I have built an electrical circuit; ___ I know the difference between AC and DC; ___ I have used a multi-meter to measure amperage, voltage, or resistance; ___ I know the formula to calculate Wattage; ___ I have soldered a circuit board; ___ I know Ohm's Law; ___ I have "jumped" a dead car battery; ___ I have installed a new light switch or electrical outlet; ___ My father/mother pursues a professional career in electricity/electronics."

The game instructions were printed double-sided on a single sheet of paper. They included instructions for how to play Cache-17, such as how to navigate in the environment, how to pick up objects, and how to use the tools and resources in the game.

The pre-game worksheet was a single sheet of paper including text at the top of sheet stating, “In this experiment you will be playing a game called Cache-17. The purpose of this game is to teach you about electric circuits. As you play, you will learn about different concepts related to electric circuits, such as how a wet-cell battery works. Before you begin the game, we would like you to write an explanation of how a wet-cell battery works. It’s ok if you don’t know much about how they work now. As you play the game, make sure to pay attention to information that will help you write a better explanation after playing.” Below that text were instructions that read, “Please write a paragraph explaining how wet-cell batteries work, and label the diagram of a wet-cell battery below,” followed by blank space to write an explanation. At the bottom of the page there was a fill-in-the-blank diagram of a wet-cell battery (as shown in Figure 2). The post-game worksheet was identical to the pre-game worksheet, but omitted the initial text at the top of the sheet.

The in-game worksheet was a single sheet of paper with three questions and space to write in answers. The instructions at the top told participants to fill in the worksheet while playing the game and complete the worksheet before finishing the game. The three questions asked, “What are the parts of a wet-cell battery?,” “How do you choose metals for a wet-cell battery?,” and “How do you put the parts of a wet-cell battery together?”

The transfer test included four questions, each on a separate sheet of paper. The four questions reflected the four classes of transfer questions laid out by Mayer (2009): troubleshooting (“Two metals are submerged in a liquid and connected to a light bulb, but the bulb is not lit up. Why not? Name as many reasons as you can think of."), redesign ("What could you do to increase the voltage of a wet cell battery?"), prediction ("What would happen if you used two of the same metal to build a wet cell battery? Why?") and conceptual ("What does a brine solution have to do with wet cell batteries?"). At the bottom of each sheet was the statement: "Please keep working until you are told to stop."

The comprehension test consisted of 17 questions intended to assess participants' comprehension of the learning material in the game. Eight of the questions referred to wet-cell batteries (task 1 in the game), five referred to electric generators (task 2 in the game), and four referred to series and parallel circuits (task 3 in the game). The 8 questions about wet cell batteries are considered a test of intentional learning (i.e., target information) because the intervention in this study deals only with the wet-cell battery portion of the learning material; the other 9 questions are labeled *incidental* learning (i.e., non-target information). An example of an intentional question is, "The negative electrode in a wet cell battery typically consists of:; a. The same material as the positive electrode.; b. A different material than the positive electrode.; c. An electrically conductive liquid solution such as brine.; d. An insulating material." An example of an incidental question is, "Which of the following best describes the function of an electric generator?; a. It converts electrical energy into mechanical energy.; b. It converts mechanical energy into electrical energy.; c. It converts potential energy into electrical energy.; d. It converts chemical energy into electrical energy." The test questions were developed by Koenig (2008) for use as an embedded test in the original version of the game.

The post-game questionnaire asked four questions: "How difficult was the game you just played?" with 7 Likert-type responses from "Extremely easy" to "Extremely difficult"; "What level of effort did you put into the game you just played?" with 7 Likert-type responses from

"Extremely low" to "Extremely high"; "Please rate your agreement: 'I would like to play more games like this one.'" with 7 Likert-type responses from "Strongly disagree" to "Strongly agree"; and "Please rate your agreement: 'I thought the game was fun.'" with 7 Likert-type responses from "Strongly disagree" to "Strongly agree."

The debriefing slip informed participants of the purpose of the experiment, told them to ask the experimenter if they had questions, and thanked them for their participation.

2.1.2.2 Cache-17. Cache-17 is a 3-D, first person, narrative discovery learning game designed to teach concepts related to electric circuits. The game was developed by Koenig (2008) and intended for play on a desktop computer. Koenig (2008) provides a detailed description of the design of the game as well as the characteristics that make it a game, including alignment with Malone's (1981) criteria of challenge, fantasy, and curiosity. Koenig focused on using narrative theme as a way of motivating the learner. Figure 1 shows screenshots from the game. Cache-17 begins with a 5-minute cut scene that sets up the story—a male insurance investigator named Alex is investigating a stolen painting with his partner, Kate. Their investigation leads them to a bunker where the game begins. The player navigates the bunker as Alex.

Although the cover story sets the goal of the game as recovering stolen artwork from a bunker system, the instructional goal is to learn how electromechanical devices work such as a wet-cell battery, which is used to open a stuck door. Throughout the game, the player has resources available via a menu bar at the bottom of the screen: a map of the bunker, a multimeter to measure the voltage of devices, a *Notes* tab with the goal of their current mission, and a personal digital assistant (PDA). The PDA contains educational information that can help the player complete the tasks in the game, such as information about electric circuits, the galvanic series of metals, and electric motors and generators. Players navigate the PDA through a drop-down menu.

The first task the player encounters in the game is to create a wet-cell battery in order to power a door panel and open a door. This task is completed by selecting from a variety of metals in a storage room, placing the correct metals in a brine solution, and connecting the metals to the door panel with jumper cables. There were 30 possible combinations of metals in the storage room but only 2 would generate the voltage to open the door panel. Behind the door is a prisoner that gives information about a vault to be opened, as well as materials required to complete the next two tasks. The second task is to charge a dead battery using a Stirling engine and an electric motor. The third task is to connect the recharged battery with another battery in series to open a vault.

After opening the vault, the player learns that Kate was a double agent and they do not retrieve the painting. The game is completed when they exit the bunker through an escape hatch.

2.1.2.3 Apparatus. The apparatus consisted of five Dell desktop computers with 20-inch color monitors and Panasonic headphones, situated on tables in individual cubicles.

2.1.3 Procedure. The experiment took place in a laboratory with up to five participants per session. Participants were randomly assigned to a condition by session. Each participant was seated in an individual cubicle, facing a computer station, without visual access to the other participants. First, following a brief introduction from the experimenter, participants signed a consent form and filled out the demographic questionnaire. Participants in the control group were then given the game instruction sheet and told they would be playing an educational computer game called Cache 17. After a few simple instructions about the game, the experimenter asked for questions, turned on each computer screen, and instructed participants to wear their headphones and begin the game.

Participants in the worksheet group received the same procedure as those in the control group but completed the pre-game worksheet before playing the game and the in-game worksheet during the game. The experimenter read the instructions for the pre-game worksheet aloud to the participants and told them they had four minutes to complete the worksheet. After four minutes the worksheet was collected. Participants in the worksheet group were also given the in-game question worksheet and told to complete the worksheet while playing the game.

Participants were given 75 minutes to complete the game. If a participant did not finish the game in 75 minutes, they were instructed to stop playing. When participants finished they were given the post-game explanation worksheet, which asked participants to write an explanation of how a wet-cell battery works. They were given 4 minutes to complete the worksheet. After 4 minutes the worksheet was collected, and participants were given the four transfer questions one at a time. They had two and a half minutes to complete each transfer question. This was followed by the comprehension test and post-game questionnaire, both of which were untimed. Participants were excused after reading a debriefing sheet with information about the experiment.

2.2. Results

2.2.1 Data source. Participants who did not complete all three tasks in the game within the allotted time were eliminated from the analysis. As a result, 23 participants remained in the worksheet group and 28 in the control group. There was not a significant difference between groups in number of eliminated participants, $X^2(N = 62) = 1.25$, $p = .264$. All analyses reported in the results section refer to this subset of the participants.

2.2.2 Are the groups equivalent on basic characteristics? A preliminary step is to determine whether the groups are equivalent on basic demographic characteristics. A composite prior knowledge of electricity score was calculated by combining self-rated knowledge of electricity with the 13-item prior knowledge measure. Individual t-tests revealed no significant differences (at $\alpha = .05$) between the worksheet and control groups on age, t(49) = -0.53, *p* = .597, or prior knowledge of electricity, t(49) = -0.43, *p* = .670. A chi-square test found no significant differences between the groups on proportion of men and women, X^2(N = 51) = 0.17, *p* = .683. A Kruskall-Wallis test revealed no significant difference between groups on time spent playing video games per week, X^2(N = 51) = 0.49, *p* = .485. We conclude that the groups were not different on basic characteristics.

2.2.3 Does adding worksheets affect in-game experience? Time to finish the game was based on the number of minutes it took players to reach the end of the game; time to finish was set at 75 minutes for students who completed all three tasks but did not complete the game within the 75-minute deadline. As expected, the worksheet group (*M* = 56.93, *SD* = 10.44) took significantly more time to finish the game (in minutes) than the control group (*M* = 49.17, *SD* = 11.70), *t*(49) = 2.47, *p* = .017. There was no significant difference between worksheet and control group on post-game ratings of difficulty, *t*(49) = -0.63, *p* = .534; effort, *t*(49) = 1.39, *p* = .172; liking the game, *t*(49) = 1.13, *p* = .264; or thinking the game was fun, *t*(49) = 0.21, *p* = .835. We conclude that asking students to complete a worksheet during the game caused game play to take longer but did not affect other aspects of in-game experience.

2.2.4 Does adding worksheets affect the quality of explanations? The participant's explanation of the wet-cell battery on the post-game worksheet was scored for the number of correct idea units in the paragraph and diagram. Correct idea units were separated into conceptual idea units (i.e., ideas corresponding to the concept of how wet-cell batteries work such as “the metals must differ in voltage”; 15 possible) and verbatim idea units (i.e., ideas corresponding only to the specific wet-cell battery example in the game and not wet-cell batteries in general, such as “you must use copper and aluminum” or “the voltage difference must be greater than 2”; 5 possible). Participant responses were scored by a scorer blind to experimental condition. A second independent rater scored a subset of the tests. Inter-rater agreement on scores was high for conceptual idea units (r = 0.89) and verbatim idea units (r = 0.88). Analyses are based on the first rater’s scores.

If the worksheets help learners process the academic material about wet-cell batteries more deeply, we expect the worksheet group to outperform the control group on producing conceptual idea units but not on producing verbatim idea units. The top two lines in Table 2 show the means and standard deviations for each group on the conceptual and verbatim parts of the explanation, respectively. Conceptual and verbatim scores were converted to percentages by dividing by the total possible score (15 for conceptual, 5 for verbatim) in order to compare the scores in a single analysis. A one-way repeated measures ANOVA revealed a significant interaction between condition (worksheet or control) and response type (conceptual or verbatim), $F(1,49) = 12.01$, $p = .001$. There was a significant main effect of response type, $F(1,49) = 88.32$, $p < .001$, but no significant main effect of condition, $F(1,49) = 0.17$, $p = .680$. As predicted, the worksheet group generated significantly more conceptual idea units than the control group, $t(49) = 3.25$, $p = .002$, $d = 0.92$; and the worksheet group generated significantly fewer verbatim idea units than the control group, $t(40.76) = -2.49$, $p = 0.02$, $d = -0.68$. Overall, the worksheet group recalled more of the conceptual information regarding wet-cell batteries than the control group, whereas the control group recalled more of the game-specific information regarding wet-cell batteries than the worksheet group.

2.2.5 Does adding worksheets affect performance on the comprehension test? Students received one point for each correct answer on the comprehension test. Comprehension performance was divided into two scores: one for the 8 multiple choice questions about wet-cell batteries (i.e., intentional learning) and another for the 9 multiple choice questions about electrical generators and series and parallel circuits (i.e., incidental learning). If the worksheets help learners process the academic material about wet-cell batteries more deeply, we expect the worksheet group to outperform the control group on intentional items but not incidental learning. The next two lines of Table 2 show the means and standard deviations for each group on the intentional items and the incidental items of the comprehension test. As predicted, the worksheet group performed significantly better on the intentional items, $t(49) = 2.32$, $p = .025$, $d = 0.67$, and there was no difference between the two groups on incidental items (i.e., those referring to electric generators or series and parallel circuits), $t(49) = -0.20$, $p = .840$, $d = -0.07$. We conclude that the worksheets improved comprehension performance for the targeted learning material but did not affect comprehension performance for the other material in the game.

2.2.6 Does adding worksheets affect transfer performance? Students received one point for each acceptable answer on each of the four transfer questions, based on a rubric listing possible answers. Participants who produced multiple acceptable answers for a question could earn more than one point. Transfer test score was determining by combining the points from all four transfer questions. Participant responses were scored by a scorer blind to experimental condition. A second independent rater scored a subset of the tests. Inter-rater agreement on scores was high, $r = 0.91$. Analyses are based on the first rater's scores.

If the worksheets cause learners to process the academic content about wet-cell batteries more deeply, then the worksheet group should outperform the control group on generating creative answers on the transfer test. The bottom line in Table 2 shows the mean and standard deviation for each group on the transfer test. As predicted, the worksheet group performed significantly better than the control group on transfer, $t(49) = 2.36$, $p = .022$, $d = 0.74$. We conclude that completing the worksheets led to significantly better performance on a problem-solving transfer test.

Each of the significant differences for dependent variables in Table 2 (explanation-conceptual, explanation- verbatim, comprehension-intentional, and transfer) remained significant when ANCOVAs were conducted with condition (worksheet vs. control) as a fixed factor and time to finish the game as a covariate.

2.3 Discussion

Adding pre-game and in-game worksheets to *Cache 17*, a narrative game for learning, enhanced key learning outcomes—writing explanations of how wet-cell batteries work, answering multiple-choice comprehension test of the topic targeted by the worksheets, and solving transfer problems. The benefits of the worksheets were limited to targeted material (i.e., to intentional comprehension questions), however, we did not predict the benefits of the worksheets to extend beyond the targeted material. Importantly, this intervention improved learning outcomes without affecting students' reported enjoyment of the game.

3. Experiment 2

Experiment 1 demonstrated that adding a pre-game and in-game worksheet to *Cache 17* can significantly improve several learning outcomes. Experiment 2 was designed to extend the results of Experiment 1 to determine whether the in-game or pre-game worksheet alone could affect learning. As a result, one group in the experiment was given only the pre-game worksheet, one group was given only the in-game worksheet, and a control group did not receive either worksheet.

The results of this experiment can help clarify the results found in Experiment 1. Instructions and goals can influence the type of information a learner attends to in a learning situation (Erhel & Jamet, 2013; Flavell, 1979; van den Broek, Lorch, Linderholm, & Gustafson, 2001). The pre-game worksheet asks participants to reflect on their prior knowledge, and tells them that they should pay attention to information in the game that will help them write a better explanation after the game. These instructions are intended to prime appropriate cognitive processes such as selecting information relevant to wet-cell batteries, organizing that information into an explanation, and integrating that information with what they knew before the game. If instructions and goal-setting before the game helps participants select, organize, and integrate information learned in the game, then the pre-game worksheet group will outperform the control group on transfer and retention tests. This is the pre-game worksheet hypothesis.

However, learners have limited cognitive capacity. Front-loading a game with instructions and goals to be remembered throughout the game may exceed the limits of the learner's cognitive system. Previous research shows that under conditions of high cognitive load, presenting a learning prompt too early may be as helpful as not providing a prompt at all (Helsdingen, van Gog, & van Merriënboer, 2011). In contrast, having a worksheet available during game-play may be more practical for focusing the learner's attention during the appropriate parts of game playing (van Merriënboer, Kirschner, & Kester, 2003). The in-game worksheet asks participants several questions about how wet-cell batteries work. These questions are intended to prime appropriate cognitive processes such as selecting information relevant to wet-cell batteries, reorganizing that information into relevant responses, and integrating the information with prior knowledge. If the simple in-game worksheet questions help participants select, organize, and integrate information learned in the game, then the in-game worksheet will outperform the control group on transfer and retention tests. This is the in-game worksheet hypothesis.

3.1 Method

3.1.1 Participants and design. One hundred sixty-one undergraduates from the University of California, Santa Barbara participated in the experiment. There were 53 men, 105 women, and 3 participants who declined to state a gender. The mean age was 19.4 (*SD* = 2.7). The majority of participants reported playing video games for less than 1 hour per week and 10 participants played more than 10 hours per week. The mean score on a self-report scale of prior knowledge of electricity was 2.3 out of 5 (SD = 1.0), which is considered low. Fifty-six participants served in the pre-game worksheet condition, fifty participants served in the in-game worksheet condition, and fifty-five participants served in the control condition.

3.1.2 Materials. The materials in this experiment were identical to the materials used in Experiment 1.

3.1.3 Procedure. The procedure in this experiment was the same as Experiment 1, with the following exceptions: participants in the pre-game worksheet group received only the pre-game worksheet and did not receive the in-game worksheet; participants in the in-game worksheet group received only the in-game worksheet and did not receive the pre-game worksheet. The control group procedure was the same as Experiment 1.

3.2 Results

3.2.1 Data source. Participants who did not complete all three tasks in the game within the allotted time were eliminated from the analysis. As a result, 43 participants remain in the pre-game worksheet group, 42 participants remain in the in-game worksheet group, and 40 participants remain in the control group. There was not a significant difference be among the groups in the number of eliminated participants, X^2(N = 161) = 1.28, p = 0.529. All analyses reported in the results section refer to this subset of the participants.

3.2.2 Are the groups equivalent on basic characteristics? A preliminary step is to determine whether the groups are equivalent on basic demographic characteristics. Individual ANOVAs revealed no significant differences (at $p < .05$) among the groups on age, $F(2,121)$ = 0.99, p = 0.375, or prior knowledge of electricity, $F(2,121)$ = 0.38, p = 0.682. A chi-square test found no significant differences between the groups on proportion of men and women, X^2(N = 124) = 6.64, p = 0.156. A Kruskall-Wallis test revealed no significant difference between groups on time spent playing video games per week, X^2(N = 124) = 0.32, p = .851. We conclude that the groups were not different on basic characteristics.

3.2.3 Does adding worksheets affect in-game experience? Time to finish the game was based on the number of minutes it took players to reach the end of the game; time to finish was set at 75 minutes for students who completed all three tasks but did not complete the game within the 75-minute deadline. Unlike Experiment 1 there was no effect of worksheets on play time (in minutes), with no significant difference between the pre-game worksheet group (M = 51.88, SD = 14.67), the in-game worksheet group (M = 52.24, SD = 14.71), and the control group (M = 50.70, SD = 13.36), $F(2,121)$ = 0.13, p = 0.879.

There was no significant difference between the groups on post-game rating of difficulty, $F(2,121)$ = 2.18, p = 0.117. There was a marginally significant difference between groups on liking the game, $F(2,121) = 2.66$, $p = 0.074$. A Tukey's HSD post hoc test revealed that the in-game worksheet group ($M = 4.39$, $SD = 1.60$) liked the game marginally more than the pre-game worksheet group ($M = 3.49$, $SD = 1.99$). Neither group differed from the control group ($M = 4.08$, $SD = 1.85$). There was a significant difference between groups on thinking the game was fun $F(2,121) = 3.12$, $p = 0.048$. A Tukey's HSD post hoc test revealed that the in-game worksheet group ($M = 4.71$, $SD = 1.59$) rated the game as significantly more fun than the pre-game worksheet group did ($M = 3.81$, $SD = 1.79$). Neither group differed significantly from the control group ($M = 4.25$, $SD = 1.52$). We conclude that asking students to complete a worksheet before or during the game did not affect game play time or perceived difficulty. However, participants who completed an in-game worksheet liked the game marginally more than participants who completed a pre-game worksheet. Participants who completed an in-game worksheet also thought the game was significantly more fun than participants who completed a pre-game worksheet did. There is no evidence that adding worksheets diminished players' enjoyment of the game.

3.2.4 Does adding worksheets affect the quality of explanations? The participants' explanation of the wet-cell battery on the post-game worksheet was scored in the same manner as Experiment 1. Participant responses were scored by a scorer blind to experimental condition. A second independent rater scored a subset of the tests. Inter-rater agreement on scores was high for conceptual idea units ($r = 0.87$) and verbatim idea units ($r = 0.83$). Analyses are based on the first rater's scores.

The top two lines in Table 3 shows the means and standard deviations for each group on the conceptual and verbatim parts of the explanation, respectively. The groups performed significantly differently on the number of conceptual idea units generated, $F(2,121) = 3.24$, $p =$

0.043. A Tukey's HSD post hoc test revealed that the in-game worksheet group significantly outperformed the control group on writing conceptual idea units, $p = 0.035$. No other group differences were significant. There was no significant difference between the groups on number of verbatim idea units generated. Overall, the in-game worksheet group recalled more of the conceptual information regarding wet-cell batteries than the control group, and no other group differences were significant.

3.2.5 Does adding worksheets affect performance on the comprehension test? The comprehension test was separated in to intentional questions and incidental questions and scored in the same manner as Experiment 1. The next two lines of Table 3 show the means and standard deviations for each group on the intentional items and the incidental items of the comprehension test, respectively. There were no significant differences between groups on intentional items $F(2,121) = 1.08$, $p = 0.343$, or incidental items, $F(2,121) = 0.69$, $p = 0.505$. We conclude that the worksheets did not affect comprehension performance for the targeted learning material or for the other material in the game.

3.2.6 Does adding worksheets affect transfer performance? Transfer questions were scored in the same manner as Experiment 1. Participant responses were scored by a scorer blind to experimental condition. A second independent rater scored a subset of the tests. Inter-rater agreement on scores was high, $r = 0.80$. Analyses are based on the first rater's scores. The bottom line in Table 3 shows the mean and standard deviation for each group on the transfer test. An ANOVA revealed a significant difference between groups on transfer performance, $F(2,121) = 4.42$ $p = 0.014$. A Tukey's HSD post hoc test revealed that the in-game worksheet group scored significant higher than the control group on the transfer test, $p = 0.010$. No other group differences were significant. We conclude that completing an in-game worksheet led to significantly better performance on a problem-solving transfer test compared to the control group.

3.3 Discussion

This experiment helps tease out the results found in Experiment 1. In Experiment 1, participants who received a pre-game and in-game worksheet and played *Cache 17* outperformed a group that played *Cache 17* alone on an explanation, comprehension questions, and a transfer test. In Experiment 2, participants who completed only the in-game worksheet performed better than the control group on an explanation and a transfer test. Therefore, the in-game worksheet hypothesis was supported for those learning outcomes. Participants who completed only the pre-game worksheet did not differ significantly from either group on any of the learning outcomes. Therefore, the pre-game worksheet hypothesis was not supported.

The performance of the pre-game worksheet group suggests that attempting to write an explanation of how a wet-cell battery works and setting the goal of being able to write a better explanation after playing the game does not significantly improve learning when done in the absence of an in-game intervention. It is interesting to note that even though this group was explicitly informed of, and given practice on, the explanation test, they still did not outperform the control group. This result is consistent with the idea of *just-in-time information presentation* laid out by van Merriënboer, Kester, and Kirschner (2003), although it involves prompting to attend to conceptual information rather than procedural information. Information such as learning goals can overwhelm a learner's cognitive capacity when presented too early. Instead, giving learners just-in-time information, such as a worksheet they complete during the game, can help them direct their limited cognitive resources to the goal without causing cognitive overload. The post-game survey also helps explain this effect. Participants in the pre-game worksheet group found the game significantly less fun and liked the game marginally less than participants in the in-game worksheet group. It is possible that having a goal in mind (i.e., learning how wet-cell batteries work), but being prevented from working toward that goal by the fast-paced game mechanics, led to a less enjoyable in-game experience.

The results of this experiment have theoretical significance. Research on metacognition and goal-setting emphasizes the importance of knowing what you intend to learn (i.e., setting goals) when engaging with a learning environment. However, goal-setting may be limited in immersive environments such as narrative games, when there is nothing in the game explicitly reminding you to be working toward your goal. Research on cognitive load, on the other hand, suggests that providing just-in-time prompts to learners can help encourage appropriate cognitive processing. The results of the current experiment support this latter view.

One limitation of this experiment is that there was no condition that included both the pre-game worksheet and the in-game worksheet. This decision was made largely for efficiency and power. Experiment 1 addressed the effect of adding both in-game and pre-game worksheets, and the primary question in Experiment 2 was to see how the worksheets affect learning independently. In order to maximize power to address this primary question, we limited the second experiment to three groups.

4. General Discussion

This study demonstrates the value of applying psychological science to the domain of educational games, which has been the subject of strong claims based on weak evidence (Mayer, 2014, National Research Council, 2011, O'Neil & Perez, 2008; Tobias & Fletcher, 2011). In Experiment 1, participants who received pre-game and in-game worksheets that focused on the educational aspect of Cache 17 performed better than a control group on a written explanation, a comprehension test, and a transfer test. In Experiment 2, participants who received only the in-game worksheet performed better on a written explanation and a transfer test than a control group, although the effect was neither as large nor as nuanced (i.e., no effect for comprehension test; no effect for verbatim information on explanations) as the combination of pre-game and in-game worksheets in Experiment 1. Participants who received the pre-game worksheet only did not differ significantly from either group on any learning outcomes. In both experiments learning outcomes were improved without affecting enjoyment of the game.

These results are consistent with the idea, based on the Cognitive Theory of Multimedia Learning and Cognitive Load Theory, that the worksheets helped students focus their limited cognitive resources on the educational aspect of *Cache 17*. Evidence that the worksheets reduce extraneous processing and encourage essential processing is reflected in enhanced conceptual explanations (in both experiments) with reduced verbatim intrusions (in Experiment 1) and enhanced comprehension performance (in Experiment 1). Evidence that the worksheets helped learners engage in generative processing is reflected in enhanced transfer performance (in both experiments).

A practical implication of this study is that simple materials added to games can enhance learning without requiring modifications to the game itself. Our results suggest that learning from an educational narrative game can be enhanced by adding worksheets that focus on the educational aspect of the game both before and during game play. Further, while worksheets during game play can enhance learning outcomes on their own, this study does not support adding pre-game worksheets only.

An important limitation of these experiments is that only participants who completed all three tasks in Cache 17 were included in the analysis. This was necessary because the comprehension test includes questions from all three tasks, so participants who were not exposed to all of the learning material in the game had to be excluded. In Experiment 1, 11 out of 62 participants (18%) did not finish the required tasks. In Experiment 2, 37 out of 161 participants (23%) did not finish the required tasks. Chi-square analyses revealed that participants who did not finish the game were significantly more likely to be women than participants who did finish the game in both experiments, and they were more likely have less video game experience than participants who did finish the game in Experiment 2. There was no significant difference in prior knowledge of electricity. Low video game experience could slow a player down in Cache 17 as the mechanics of navigation (i.e., coordinating between the mouse, which rotates the player's perspective, and keyboard buttons, which move the player through space) can be difficult to learn for inexperienced players. Negative affect toward video games and low video game self-efficacy could also be contributing factors, although they were not measured in the current experiments. Therefore, students who are not able to perform well in an educational game may need additional or alternative instruction in order to be exposed to all of the learning material the game provides.

Future work is needed to identify which aspects of worksheets encourage students to attend to and reflect on the target educational information in narrative games. For example, the in-game worksheet in this study was designed to be as simple as possible in order to encourage completion, but further work is needed to investigate whether asking questions that are more conceptual could facilitate beneficial forward transfer or test expectancy effects (Sagerman & Mayer, 1987; Thiede, Wiley & Griffin, 2011). Future research is also needed to investigate the effect of adding educational worksheets to other computer games, as well as investigating the effects of instructional worksheets in ill-structured problem-solving tasks and far transfer tests.

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Table 1

Two Competing Goals of Narrative Games for Learning

Game feature	Goal	Mechanism
Narrative theme	Recover stolen artwork	Motivational processes
Instructional material	Build a wet-cell battery	Cognitive processes

Table 2

Experiment 1: Performance on Post-game Tests of Learning Outcome

Measure of learning outcome	Worksheet group		Control group		Effect size
(Total possible)	*M*	*SD*	*M*	*SD*	*d*
Explanation: Conceptual (15)	6.30*	1.82	4.64	1.81	0.92
Explanation: Verbatim (5)	0.22*	0.42	0.68	0.86	-0.68
Comprehension: Intentional (8)	7.61*	0.58	7.07	0.98	0.67
Comprehension: Incidental (9)	4.61	2.04	4.71	1.67	-0.07
Transfer	4.59*	1.50	3.43	1.64	0.74

Note. Asterisk (*) indicates significant difference from control group at $p < .05$ (independent samples t-test). There were four transfer questions with no defined limit to the number of correct solutions possible.

Table 3

Experiment 2: Performance on Post-game Tests of Learning Outcome

Measure of learning outcome (total possible)	Pre-game WS group	In-game WS group	Control group	Pre-game vs. in-game	Pre-game vs. control	In-game vs. control
Explanation: Conceptual (15)	*M* = 4.84 *SD* = 2.16	*M* = 5.54 *SD* = 2.07	*M* = 4.43 *SD* = 1.69	*d* = -0.33	*d* = 0.21	*d* = 0.59*
Explanation: Verbatim (5)	*M* = 0.49 *SD* = 0.86	*M* = 0.51 *SD* = 0.78	*M* = 0.73 *SD* = 0.85	*d* = -0.03	*d* = -0.26	*d* = -0.28
Comprehension: Intentional (8)	*M* = 7.00 *SD* = 1.31	*M* = 7.37 *SD* = 0.83	*M* = 7.18 *SD* = 1.22	*d* = -0.33	*d* = -0.14	*d* = 0.18
Comprehension: Incidental (9)	*M* = 4.44 *SD* = 1.72	*M* = 4.46 *SD* = 1.40	*M* = 4.80 *SD* = 1.49	*d* = -0.01	*d* = -0.22	*d* = -0.23
Transfer	*M* = 3.79 *SD* = 1.71	*M* = 4.32 *SD* = 1.62	*M* = 3.23 *SD* = 1.62	*d* = -0.32	*d* = 0.34	*d* = 0.67*

Note. Asterisk (*) indicates significant difference at $p < .05$ (Tukey's HSD post hoc test). There were four transfer questions with no defined limit to the number of correct solutions possible.

Figure 1. Screenshots from *Cache 17*. Clockwise from top left: Kate and Alex arrive at the bunker during the introductory cut scene; Alex in front of the barrel of brine for the wet-cell battery task; Viewing the PDA; Viewing the map of the bunker.

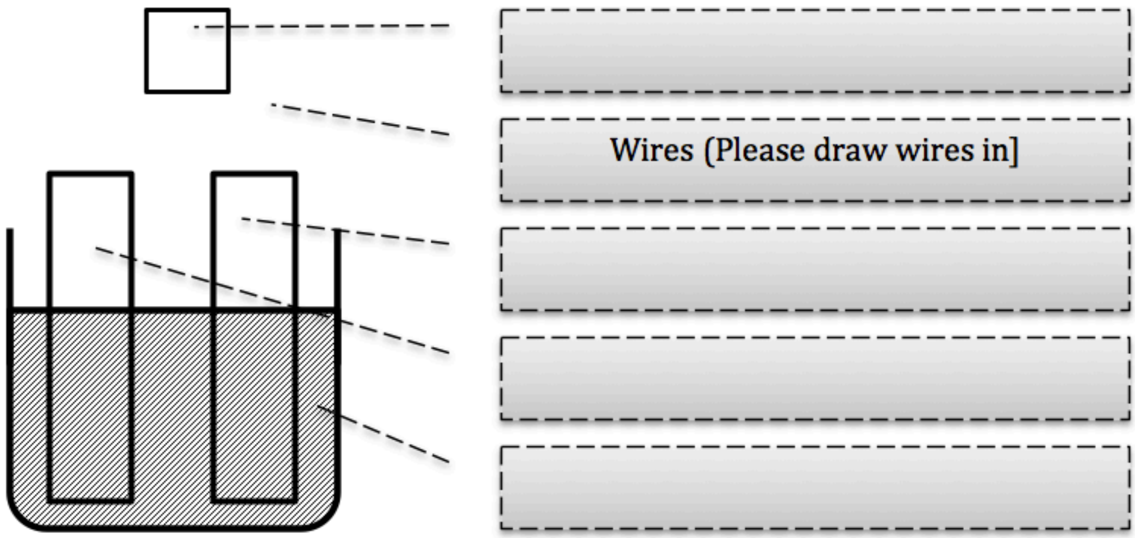

Figure 2. Fill-in-the-blank diagram on the pre- and post-game explanation worksheets.