Game On! The Influence of Computer Simulations on Understanding of Cancer-Based Therapies

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Abstract

Re-Mission 1, developed by HopeLab Industries, is a computer game that can be used by pediatric cancer patients to educate and prepare them for what they will experience both with cancer progression and from treatment (Tate, Haritatos, & Cole, 2009). Pediatric patients who play this game were found to have improved motivation and self-understanding of their illness (Kato, Cole, Bradlyn, & Pollack, 2008). Seeing the success of *Re-Mission 1*, HopeLab Industries developed *Re-Mission 2*, which is a series of six different games, including *Re-Mission 2: Nanobot's Revenge.* The purpose of the present study was to see if *Re-Mission 2* leads to understanding of cancer physiology in the same way as *Re-Mission 1* and assess the generalizability of the educational benefits of *Re-Mission* to other populations (i.e., college students). Furthermore, another purpose of this study was to compare the effectiveness of text-based materials and game-based materials in terms of their educational value. Fifty-five undergraduate psychology students (37 females and 18 males) were recruited from a small, liberal arts college in the Southeastern United States. The participants were divided into two conditions (text-based or game-based). Those in the game-based condition (27 total) were asked to complete 5 levels of *Re-Mission 2: Nanobot's Revenge*. They were also given a packet containing instructions on how to play the game as well as descriptions of each character and what they represented in terms of cancer physiology. Those in the text-based condition (28 total) were only given a text passage to read, which had the same information that was included in the game-based condition packet, excluding the game instructions. All the participants completed a test for understanding of cancer physiology and treatments before and after they were exposed to an experimental condition. The test included seven multiple choice questions and five short answer questions related to cancer physiology and treatment. The short answer questions were

scored from zero to three (zero being “A completely incorrect answer with no description” to three “An accurate answer that is clearly supported with ample description”). According to the results, there was not a significant difference in pre-test scores between the text-based and game-based conditions ($p > 0.05$) regardless of the question type (multiple choice or short answer). Furthermore, the post-test scores were significantly higher than the pre-test scores, regardless of condition and for both types of questions ($p < 0.05$). Also, the text-based condition was approaching significance in terms of being more effective than then game-based condition, regardless of question type ($p < 0.06$). In conclusion, while both the text-based and game-based methods were effective educational tools for teaching participants about cancer physiology and treatment, text-based method was approaching significance in terms of being more effective than the game-based method.

Game On! The Influence of Computer Simulations on Understanding of Cancer-Based Therapies

There has been extensive research on the use of metaphors as an educational tool. A person's existing knowledge is used as a metaphorical vehicle to convey new knowledge (Carter & Pitcher, 2010). For instance, Carter and Pitcher (2010) explained that water, which is a concept that everyone is familiar with, can be used to help a student understand electrical theory by making the comparison between water flowing through a pipe and current flowing through a wire. This metaphor can be further extended, which makes the connection stronger. Charteris-Black (2004) argued that "the act of stretching the resources of language involved in metaphor is a way of forging a stronger interpersonal bond between speaker and hearer" (p. 12).

Metaphors have been found to be particularly helpful in understanding scientific concepts. By making connections using existing knowledge, metaphors can make new concepts more exciting and understandable (Low, 2008). Niebert and colleagues (2012) analyzed 200 instructional metaphors and found that conceptual metaphors, understanding a concept in terms of another, is most helpful when learning scientific concepts Furthermore, in order to be effective, metaphors must be grounded in real experience, meaning that the student must understand the concept that the new scientific concept is being compared to (Niebert, Marsch, & Treagust. 2012).

Although the topic of cancer is commonly acknowledged within the popular community, the actual awareness of how cancer spreads (and how cancer treatment works) is less understood. In 2013, Gleeson and colleagues surveyed 22 women with ovarian cancer about their thoughts on genetic testing and concluded that the patients have a strong desire for education about the testing and its benefits (Gleeson et al., 2013). They found that the participants preferred a verbal education from their oncologist or a genetic specialist as opposed to text materials (Gleeson, et

al., 2013). Furthermore, a systematic review of 32 papers found that adult caregivers of cancer patients have unmet needs for treatment-related information and, thus, should be an important part of future medical educational programs (Adams, Boulton, & Watson, 2009). Lastly, following an experiment, which looked at the effectiveness of a discharge-planning program for pediatric cancer patients, it was concluded that information about illness process, diagnosis, and treatment is important to the family members of these pediatric patients (Yilmaz & Ozsoy, 2010). This research provides ample support for the idea that cancer patients and their family caregivers have a strong desire to understand this illness.

Although common physiological mechanisms are not easily grasped by everyone, new technology-based strategies have been developed to better familiarize one with the science behind cancer technology. HopeLab industries (see Tate, Haritatos, & Cole, 2009) developed *Re-Mission*, a video game that has been used by cancer patients to educate and prepare them (via knowledge-based content from the game) for what they will experience both with cancer progression and from treatment. *Re-Mission* gives players the opportunity to destroy cancer cells, manage treatment side effects, and stop metastases in teenage cancer patients as a nanobot named Roxxi (Tate, Haritatos, & Cole, 2009). Tate and colleagues (2009) found that even cancer patients who played *Re-Mission* for less than one hour per week were more likely be compliant with their medication. One participant explained that "it feels like you have control over your own destiny" and others agreed that playing Re-Mission gave them a sense of revenge while destroying the cancer (Tate, Haritatos, & Cole, 2009). Furthermore, in a randomized trial with 375 cancer patients (ages 13 to 29), Kato, Cole, Bradlyn, and Pollack (2008) showed that *Re-Mission* improved both motivation and self-understanding of cancer in patients with such a condition. A study by Beale and colleagues (2007) further demonstrated the educational benefits of Re-

Mission by comparing a control video-game and *Re-Mission* using pediatric and young adult cancer patients over a 3-month period. They found that while the game scores in both groups increased over time, the scores of the *Re-Mission* group increased significantly more than the control group. This shows that *Re-Mission* play has a specific effect on health education in cancer patients that cannot be attributed to the patients' expectations (Beale, Kato, Marin-Bowling, Guthrie, & Cole, 2007).

Due to the success of *Re-Mission*, HopeLab industries developed *Re-Mission 2*, which is a set of six short, interactive games (http://www.re-mission2.org/wp-content/uploads/2013/03/Re-Mission2_GameDescriptions_FINAL2.pdf). In *Nanobot's Revenge*, the player is a nanobot trying to destroy the cancerous forces of the "Nuclear Tyrant" using different types of treatment. In *Leukemia*, players fight the Leukemia Monster by fighting cancer and saving the white blood cells. In *Nano Dropbot*, players fight cancer by destroying the cancer cells that are holding the healthy cells hostage. *Stem Cell Defender* also features a nanobot to be used to grow healthy cells and fight off bacterial infection. Players also fight off bacteria and cancer cells in *Feeding Frenzy*. Lastly, *Special Ops* is the final game that is unlocked after playing five levels of each of the other five games. While the educational benefits of *Re-Mission* have been well-established (Kato, Cole, Bradlyn, & Pollack, 2008; Beale, Kato, Marin-Bowling, Guthrie, & Cole, 2007), there has been no research to assess the educational benefits of *Re-Mission 2*. Furthermore, although these products have been designed specifically for cancer patients, it is possible that it could facilitate the learning about cancer physiology in a general population who is not directly linked to a cancer experience. Thus, another purpose of this study is to assess the generalizability of the educational benefits of this game to other populations (i.e., college students). The final purpose of the present study is to explore whether the *Re-Mission 2* product may be effective in characterizing cancer progression and

therapy when compared to text-based literature that is commonly used for educational purposes. In particular, the educational effects of *Nanobot's Revenge* will be evaluated because it is most similar to the original *Re-Mission* game.

Based on previous research on *Re-Mission* (Kato, Cole, Bradlyn, and Pollack, 2008), it is hypothesized that playing *Re-Mission 2: Nanobot's Revenge* will lead to a significant understanding of cancer physiology and treatments. While previous research has indicated that different types of questions (e.g., free recall and multiple choice) utilize different methods of retrieval (Leonard & Whitten, 1983), there does not appear to be a difference in performance on each type of test. Because of this, it is hypothesized that post-test scores will be significantly higher than pre-test scores regardless of question type. Because learning with *Re-Mission 2: Nanobot's Revenge* involves the use of a metaphor while the text condition does not include a metaphor, it is hypothesized that participants in the game-based condition will have significantly higher post-test scores than those in the text-based condition due to previous research on the benefits of metaphor use in education (Carter & Pitcher, 2010; Niebert, Marsch, & Treagust, 2012).

Method

Participants

A total of 55 undergraduate students recruited through the psychology department at a small, liberal arts college in southeastern United States participated in this study. The participants were divided in to two conditions based on type of supplement material: a text-based format and game-based format. There were 28 participants (20 females, 8 males) in the text-based condition and 27 participants (17 females, 10 males) in the game-based condition. The participants' ages ranged from 18-22 years old (M = 19.8, SD = 1.04).

Materials

Pre/Post Test. Participants completed a test for understanding of cancer physiology and treatments at the beginning and end of their participation (i.e., as a pre-test and a post-test). The test consisted of seven multiple-choice questions and five short-answer questions. The multiple-choice questions each had four possible answers with only one correct answer. and the short-answer questions were graded using a rubric that was validated prior to data collection using 16 undergraduate students recruited through the psychology department at a small, liberal arts college in southeastern United States. Each question addressed material regarding cancer physiology and treatment, which was covered in both the text-based condition and game-based condition (see Appendix A). The participants were asked to rate the qualitative effectiveness of the answer. Participants were given the complete rubric of possible ratings, after which they were shown the possible answers that fit each rubric description (see Appendix B). A score of 0 denoted "a completely incorrect answer", 1 denoted "a correct answer that is not supported with any description", 2 denoted "a correct answer that is supported by moderate description", and 3 denoted "a completely correct answer that was supported by ample description". Ratings for all questions were analyzed using a 5 X 3 (Question x Rubric Response) repeated measures ANOVA, in which a significant main effect for the type of image was found, F (2, 58) = 2,129.50, p = 0.00. Post-hoc Tukey Honest Significant Difference (HSD) tests revealed that participants demonstrated clear differences between the quality of answers. More specifically, higher ratings for correct, more descriptive answers were significant across rubric rating (ps < 0.01). These results validated the rubric dimensions for which further participant responding were measured.

Game Condition. Participants in the game-based condition played five levels of *Re-Mission 2: Nanobot's Revenge* (http://www.re-mission2.org/games/#/nanobots_revenge). The game was created by HopeLab and developed by Nerdook Productions. Participants were also given a text supplement, which included instructions on how to play the game and what each character represented across five levels of game play (see Appendix D). The goal of *Nanobot's Revenge* is to kill cancer cells that are combining to form a tumor by using a variety of treatments to prevent the tumor reaching the bloodstream and metastasizing. The protagonist of the game is the Nanobot and the antagonist is the Nuclear Tyrant. The player sees the interaction between these two in between each level. As the player completes each level, the Nanobot introduces a new treatment to use, but also the Nuclear Tyrant introduces a new "enemy" to fight.

In level one, the player fights the LeukeMutants using ChemoBlast. As stated in the text supplement, the LeukeMutant represents a mutated leukocyte, which causes Leukemia. This is treated by chemotherapy (i.e., the ChemoBlast). In level two, the new enemy is the LeukemAccelerator, which also refers to a mutated Leukocyte, however the LeukemAccelerators form the tumor at a faster pace than the LeukeMutants. The new enemy in level two is the WBC Worm, which refers to a healthy white blood cell that can be used to fight infection. In level three, the Lymphoma Warrior is the enemy that is introduced and it represents Lymphoma. The new treatment is the PredniSoldier, which refers to the steroid, Prednisone. Prednisone can be used to treat Leukemia and Lymphoma. The ChemoResistor is the new enemy in level four and it refers to cells that cannot be destroyed by chemotherapy. Because of this, the Radiation Beam is the new treatment that is introduced, which is a common form of cancer treatment. Finally, in level five, the Reed Sternberg Overseer is the final enemy that is introduced in this study. This

refers to the Reed Sternberg Cell, which indicates Hodgkin's Lymphoma. The final treatment that is introduced is the Energy Vortex and the real-life correlate is not known.

Text Condition. The participants in the text condition received a series of text passages that mirrored the content of the text supplement in the game condition (see Appendix C). The text was organized to explain the content in the same order as the game.

Procedure

Participants in both conditions completed a pre-test for prior understanding of cancer physiology and treatment options (see Appendix A). Those in the game-based conditions then were given a packet of instructions that described how to play *Re-Mission 2* and what each character in the game symbolized (see Appendix D). After they finished reading, the participants played 5 levels of *Re-Mission 2: Nanobot's Revenge*. After the pre-test, those in the text-based condition read a text passage that mirrored the concepts covered in the game instruction packet and the game itself (see Appendix C). After that, the participants in both conditions completed a post-test, which was the same as the pre-test, to assess what the participants had learned (see Appendix A). Participation took less than one hour.

Results

Multiple Choice

A 2 X 2 Factorial ANOVA with repeated measure (material type, pre-post) was conducted with material type (text-based and game-based) as the between-subjects factor and test type (pre or post) as the repeated measure. The post-test multiple choice scores for the text-based condition (M = 5.57, SE=0.31) and the game-based condition (M = 4.85, SE = 0.25) were significantly higher than the pre-test multiple choice res for the text-based (M=2.21, SE= 0.29) and game-based (M = 2.85, SE = 0.21) conditions, $F(1, 53) = 9.16$, $p < 0.004$ (see Figure 1).

Furthermore, there was no significant difference in pre-test multiple choice scores between the text-based and game-based conditions ($p > 0.05$). However, the text-based condition post-test scores approached significance in terms of being higher than the game-based condition post-test scores ($p = 0.06$).

[Insert Figure 1]

Short Answer

A 2 X 2 Factorial ANOVA with repeated measures (material type, pre-post) was conducted with material type (text-based and game-based) as the between-subjects factor and test type (pre or post) as the repeated measure. The post-test, short-answer question scores for the text-based condition ($M = 8.54$, $SE = 0.49$) and the game-based condition ($M = 7.67$, $SE = 0.55$) were significantly higher than the pre-test short answer question scores for the text-based ($M = 2.50$, $SE = 0.20$) and game-based ($M = 1.59$, $SE = 0.34$) conditions, $F(1, 53) = 265.22$, $p < 0.0001$ (see Figure 2). Furthermore, there was no significant difference in pre-test short answer scores between the text-based and game-based conditions ($p > 0.05$). However, the text-based condition post-test scores approached significance in terms of being higher than the game-based condition post-test scores ($p = 0.06$).

[Insert Figure 2]

Discussion

The first hypothesis, which stated that playing *Re-Mission 2: Nanobot's Revenge* would lead to a significant understanding of cancer physiology and treatments, was supported. There was not a significant difference in pre-test scores between the text-based and game-based conditions regardless of the question type (multiple choice or short answer). This shows that the participants' base knowledge was relatively the same prior to their participation in either

condition. Furthermore, the post-test scores were significantly higher than the pre-test scores showing that the participants gained an understanding of cancer physiology and treatments. This supports previous research on the first version of *Re-Mission*, which found that *Re-Mission* can be an effective tool for cancer education ((Kato, Cole, Bradlyn, & Pollack, 2008; Beale, Kato, Marin-Bowling, Guthrie, & Cole, 2007). The second hypothesis, post-test scores will be significantly higher than pre-test scores regardless of question type, was also supported. The post-test scores were significantly higher than the pre-test scores, regardless of condition and for both types of questions. This provides support for the idea that while the game-based condition was shown to be effective, it was not more effective than the text-based condition.

However, the final hypothesis, which said that participants in the game-based condition would have significantly higher post-test scores than those in the text-based condition, was not supported by the results. In fact, the text-based condition was approaching significance in terms of being more effective than then game-based condition, regardless of question type. Based on previous research, which has shown that the use of a metaphor, such as a video game in this case, is beneficial for learning it was expected that the game-condition, which included a metaphor, would perform better than those in the text-based condition (Carter & Pitcher, 2010; Niebert, Marsch, & Treagust, 2012). A possible explanation for this discrepancy is that the participants may not have fully understood the metaphor because there was not a large incentive (e.g., a class grade) to effortfully focus on the connection between cancer physiology and *Re-Mission 2: Nanobot's Revenge*. Despite this, those who played Re-Mission 2: Nanobot's Revenge still learned a significant amount between the pre- and post-test. Overall, while both the text-based and game-based methods were effective educational tools for teaching participants about cancer

physiology and treatment, text-based method was approaching significance in terms of being more effective than the game-based method.

There were some limitations to this study. There were less than 30 participants in each condition and while we were able to achieve significance with a small sample, it is likely that we would have achieved a higher power with a larger sample size. Furthermore, this study did not have a large enough sample or males to compare the learning styles of males and females. Similarly, there was not a large enough variety of majors to include major as a potential variable involved in pre-test/post-test performance. If this study were to be replicated, it would be helpful to obtain a larger sample size with a more equal ratio of males to females. Similarly, other factors should be included to investigate whether there are certain variables that help a person perform better on the post-test. Lastly, future studies should include a test for long-term learning by testing the participants using the same post-test 2-3 weeks after their original participation in the study. It is possible that one of the educational methods (text or game) or a certain question type (multiple choice or short answer) is more effective in terms of long-term learning.

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Figure 1. Mean Multiple Choice Score as a Function of Test Type

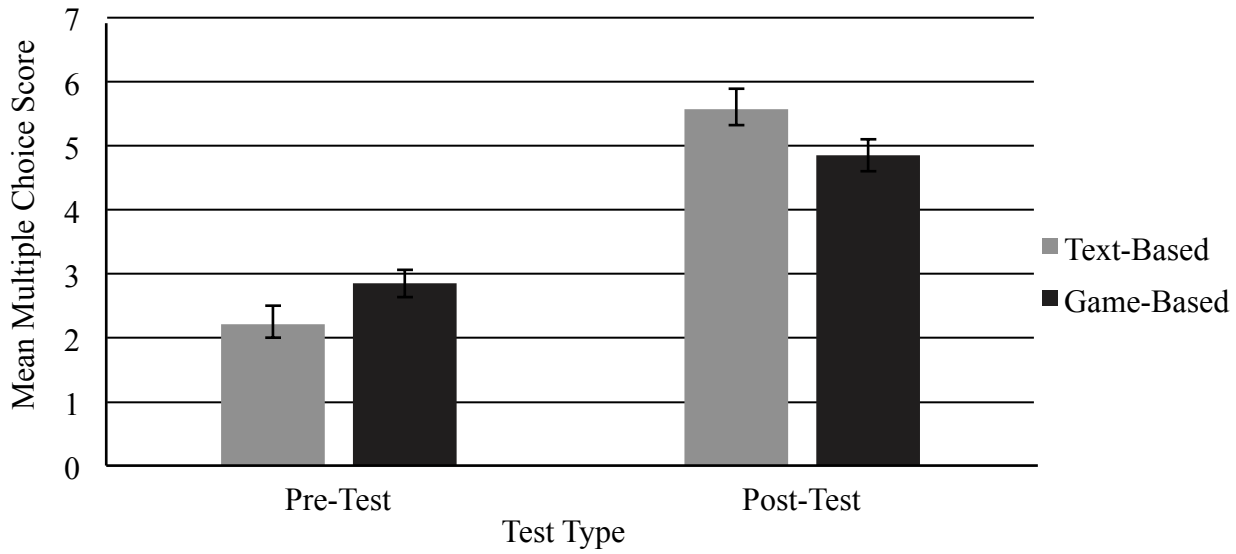
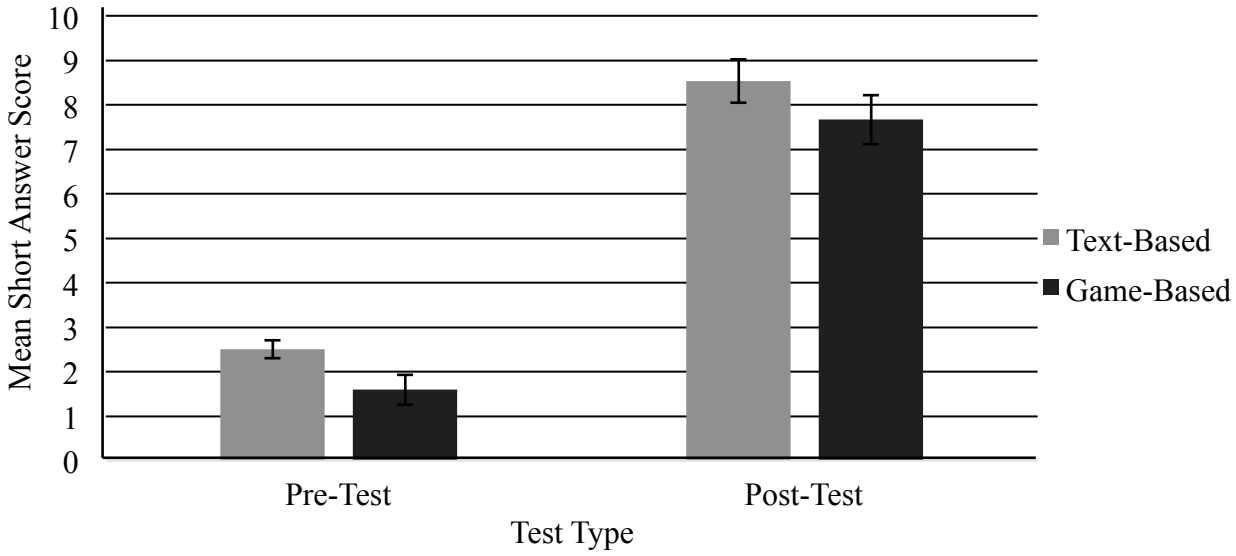


Figure 2. Mean Short Answer Score as a Function of Test Type



Appendix A

Directions: Please read each question carefully and respond to the best of your ability. Make sure to clearly mark your answer so that there is no confusion about which answer you have chosen.

Multiple Choice

1. What is the common substance is used in nanobot prototypes to reduce rejection?
    a. DNA
    b. Amino Acids
    c. Lipids
    d. Carbohydrates

2. Chemotherapy is designed to kill
    a. Cells that are undergoing a mutation process
    b. Cells with cancer DNA
    c. Cells that rapidly divide
    d. Cells with excess protein chains

3. Prednisone is a
    a. Antibiotic
    b. Steroid
    c. Radiation treatment
    d. All of the above

4. There are ___ types of Lymphoma
    a. 3
    b. 4
    c. 2
    d. 1

5. All of the following are common sites of Lymphoma except:
    a. Ankle
    b. Neck
    c. Groin
    d. Armpit

6. If a Reed Sternberg Cell is present, then the patient has:
    a. Leukemia
    b. Non-Hodgkin's Lymphoma
    c. Lung Cancer
    d. Hodgkin's Lymphoma

7. What substance is used in internal radiation?
    a. X rays
    b. Radium
    c. Gamma rays
    d. All of the above

Directions: Read each question carefully and provide a detailed response that shows your knowledge of the subject matter. Please write as neatly as possible.

Short Answer

1. How does cancer spread to other parts of the body?

2. Describe how white blood cells (i.e., Leukocytes) lead to Leukemia.

3. What are the purposes of Prednisone?

4. Describe the two types of radiation therapies for cancer.

5. What are some of the differences between Hodgkin's lymphoma and non-Hodgkin's lymphoma?

Appendix B

Directions: On the following pages, you will see 5 free-response questions with sample answers. All of the sample answers are correct but they vary in quality (i.e., clarity, amount of description provided, etc.). The responses can be graded on a scale from 0-3, with 3 being the best answer. Below is a more detailed explanation of how to characterize each score. Using the descriptions below, please read each question and then match each response to the score (1-3) that you believe best fits that response. Please note that each score will only be used once for each question.

Note: You do not need to know the answer to the question in order to grade the responses. Your goal is only to distinguish between "no description", "moderate description", and "ample description".

Rubric Dimension	**0**	**1**	**2**	**3**
Theoretical/Application Explanation(s)	A completely incorrect answer with no description	A correct answer that is not supported with any description	An accurate answer is supported by moderate description	An accurate answer that is clearly supported with ample description

Question 1: How does cancer spread to other parts of the body?	
	Cancer is designed to spread throughout the body, and when it gets to certain places in the body, it will create more tumors.
	Regardless of the severity of the cancer, the main goal of treatment is to avoid metastasis, which is when localized cancer spreads to other parts of the body. Metastasis occurs when some cancer cells break away from the primary tumor and enter the blood stream or lymphatic system and form a new, secondary tumor in another part of the body.
	Cancer spreads throughout the body and forms more tumors.

Question 2: Describe how white blood cells (i.e., Leukocytes) lead to Leukemia.

	Leukemia is a type of blood cancer.
	Leukemia can develop in blood cells or blood-forming tissue in places such as bone marrow and the spleen. Otherwise known as "white blood," leukemia occurs when abnormally mutated white blood cells are formed. The purpose of white blood cells, otherwise known as leukocytes, is to fight infections, but a large number of leukocytes can be a sign of leukemia.
	Leukemia is a type of blood cancer that relates to abnormal amounts of white blood cells. The number of these cells can be detected in leukemia.

Question 3: What are the purposes of Prednisone?	
	Prednisone can be used to treat cancer in different ways, such as aiding digestion and helping with inflammation within the body. It may be combined with chemotherapy treatment to have additional effects against cancer spread.
	Prednisone is a medicine that helps with the treatment of cancer in a number of different ways.
	Prednisone is often used to help treat leukemia and lymphoma. This steroid has several uses, such as treating nausea in cancer patients, stimulating appetite, and as an anti-inflammatory. Doctors have also found that chemotherapy is more effective in lymphoma patients when the chemotherapy is used in combination with Prednisone, which prevents white blood cells from going to parts of the body where swelling (i.e., tumors) are located.

Question 4: Describe the two types of radiation therapies for cancer.	
	There are two different kinds of radiation therapy; external radiation and internal radiation. External radiation uses X rays or gamma rays, which are administered using several different kinds of machines that are outside of the body. Internal radiation involves radium or other radioactive materials being placed directly in the tumor. External radiation is much more common than internal radiation because it is a much less invasive process.
	There are two types of radiation therapy. One is external, and one is internal.
	The two types of radiation therapy are external and internal radiation. External radiation is named so because it takes place outside the body. Internal radiation, instead, is administered into the body and thus works from inside.

Question 5: What are some of the differences between Hodgkin's lymphoma and non-Hodgkin's lymphoma?	
	The presence of Reed Sternberg cells is what determines the type of lymphoma. If Reed Sternberg cells are present, then it is Hodgkin's lymphoma. Aside from the presence of the Reed Sternberg cell, there are few differences between non-Hodgkin's and Hodgkin's lymphoma. The symptoms are very similar (e.g., swelling of the lymph nodes, weight loss, etc.). Non-Hodgkin's lymphoma can be found anywhere in the body, though Hodgkin's lymphoma is more likely to be found in the lymph nodes in the upper body.
	These two cancers are made of different cells.

	OR These cancers are found in different parts of the body.
	Hodgkin's and non-Hodgkins lymphoma are different in a couple of ways. Hodgkin's lymphoma conditions have different cells than non-Hodgkin's lymphoma conditions. Also, these different types of cancer are located in different parts of the body.

Appendix C

Passage 1

Cancer occurs when the body produces abnormal cells that divide exponentially and interfere with healthy cells. These abnormal cells can group together and form a mass, called a tumor. Cancer can appear almost anywhere in the body, which is why there are over 100 different kinds of cancer. Each of them are characterized by their location in the body (e.g., breast cancer originates in the breast and lung cancer originates in the lungs). Some of the major types are Leukemia and Lymphoma.

There are three action plans associated with treatment that depend on the severity of the cancer; cure, control, or comfort. The first choice would be to cure the cancer, if possible, by destroying all the abnormal tissue so that it doesn't come back. If the cancer can't be cured, then doctors hope to control it by using treatments to stop the tumor from growing or spreading to other parts of the body. Finally, if the cancer is too advanced, then treatment may be used only to reduce the patient's symptoms and help the patient feel better without trying to cure the cancer. Regardless of the severity of the cancer, the main goal of treatment is to avoid metastasis, which is when localized cancer spreads to other parts of the body. Metastasis occurs when some cancer cells break away from the primary tumor and enter the blood stream or lymphatic system and form a new, secondary tumor in another part of the body.

One of the newer treatments that is currently being investigated is known as nanotechnology. A nanobot is a tiny robot that delivers antibodies, which kill invaders of the body, to leukemia and lymphoma cells to stop the growth of the cancer. There are several different uses of nanotechnology, such as cancer detection and treatment. Instead of being made of metal, Harvard

scientists made their prototype out of DNA chains, which decreases the chances of the body rejecting the nanobot. Most these nanotechnology products are still in the clinical trial phase and are not widely available. However, scientists are optimistic that nanotechnology will be an important part of cancer treatment in the future. There are several different kinds of cancer treatment. Regardless of the treatment being used, it's important to note that it takes several treatments to shrink or eliminate cancer. These treatments must be spaced a part to give the patient time to rest and recover. This waiting period is also known as a refractory period.

Passage 2

Leukemia can develop in blood cells or blood-forming tissues, such as the bone marrow and spleen. Otherwise known as "white blood", leukemia occurs when abnormal/mutated white blood cells are formed. The purpose of white blood cells, otherwise known as Leukocytes, is to fight infections. Large amounts of leukocytes can be a sign of leukemia. Chemotherapy, which is the administration of chemical compounds into the body, is one of the major cancer treatments to treat Leukemia. While chemotherapy often successfully kills cancer cells, it can also kill rapidly dividing healthy cells (e.g., hair cells).

Passage 3

Lymphoma appears in the lymph nodes, which are generally located in the neck, armpits, and groin. There are two different kinds of lymphoma, non-Hodgkin's and Hodgkin's. Multiple treatments are often used in combination to successfully control or cure the cancer. For instance, doctors have found that chemotherapy is more effective in lymphoma patients when the chemotherapy is used in combination with Prednisone, which prevents white blood cells from going to parts of the body where swelling (i.e., tumors) are located. Prednisone, a pill often used

to help treat leukemia and lymphoma, is a steroid that has several uses, such as treating nausea in cancer patients, stimulating appetite, and as an anti-inflammatory.

Passage 4

Some cancer cells can become resistant to the effects of certain treatments, which prevents the success of that treatment. For instance, some tumors may not be receptive to chemotherapy treatment and, therefore, other treatments must be used. Radiation is a possible alternative to chemotherapy. Radiation is when gamma rays and/or X rays are directed toward the cancerous tissue. There are two different kinds of radiation therapy; external radiation and internal radiation. External radiation uses X rays or gamma rays, which are administered using several different kinds of machines that are outside of the body. Internal radiation involves radium or other radioactive materials being placed directly in the tumor. External radiation is much more common than internal radiation because it is a much less invasive process

Passage 5

There are a few differences between Hodgkin's and non-Hodgkin's Lymphoma. The main difference is the presence of Reed Sternberg cells. If Reed Sternberg cells are present, then it is Hodgkin's lymphoma. Aside from that, the symptoms are very similar (e.g., swelling of the lymph nodes, weight loss, etc.), however, while lymphoma can be found anywhere in the body, Hodgkin's lymphoma is more likely to be found in the lymph nodes in the upper body.

Appendix D

Re-Mission 2: Nanobot's Revenge Characters Explained

Directions: You will be playing 5 levels of *Re-Mission 2: Nanobot's Revenge*, which illustrates how a cancerous tumor is formed as well as how it can be destroyed using different treatments. At the beginning of each level, you will be faced with a new "enemy" and you will also be given a new treatment to help fight that enemy. **Before you start each level, please read the descriptions below that correlates with each level, which explain the real-life mechanisms involved with the game.**

Background: Cancer occurs when the body produces abnormal cells that divide exponentially and interfere with healthy cells. These abnormal cells can group together and form a mass, called a tumor. Cancer can appear almost anywhere in the body, which is why there are over 100 different kinds of cancer. The main goal of this game is to use the available treatments to prevent a cancerous tumor from growing and entering the blood stream. If the tumor reaches the blood stream, then a part of the tumor will break away and spread to other parts of the body through the blood stream or the lymphatic system. This is also known as metastasis. As you continue to fight the cancer, the levels will get progressively harder in the same way that cancer can get progressively harder to treat. Cancer often cannot be eliminated with just one treatment but rather a combination of treatments over time. Therefore, at the beginning of each level, you will be given a new treatment to fight the cancer. Since cancer gets progressively harder to treat, you will also be given a new enemy to fight.

As you're playing, be sure to watch this energy icon at the bottom of the screen. You can only release a certain amount of treatment before you have to wait for a small period of time for the body to rest and recover. This is also known as a refractory period.

Protagonist: Nanobot
A nanobot is a tiny robot that delivers antibodies, which are designed to kill invaders of the body, to cancer cells to stop growth. There are several different uses of nanotechnology, such as cancer detection and treatment. Instead of being made out of metal, Harvard scientists made their prototype out of DNA chains, which decreases the chances of the body rejecting the nanobot. A majority of these nanotechnology products are still in the clinical trial phase and are not widely available. However, scientists are optimistic that nanotechnology will be an important part of cancer treatment in the future. In the game, the nanobot is the "good guy" who organizes all the treatments to fight the enemies.

Antagonist: Nuclear Tyrant
Unknown real-life correlate, essentially the personification of cancer. This character is the leader of all the enemies you will encounter and it decides which enemy will be released each level.

Re-Mission 2: Nanobot's Revenge Characters Explained

Enemy #1: LeukeMutant

Refers to a mutated leukocyte (i.e., white blood cell). Presence of mutated leukocytes leads to leukemia. Leukemia can develop in blood cells or blood-forming tissues, such as the bone marrow and spleen. Purpose of this level is to destroy these using chemotherapy.

Treatment #1: ChemoBlast

Refers to chemotherapy, which is the administration of chemical compounds to treat. While chemotherapy often successfully kills cancer cells, it can also kill rapidly dividing healthy cells (e.g., hair cells).

Enemy #2: LeukemAccelerator

Also refers to a mutated leukocyte (i.e., white blood cell). In the game, this enemy helps build the tumor faster so a second treatment is needed in combination with the chemotherapy to defeat all of the enemies.

Treatment #2: WBC Worm

Refers to a healthy white blood cell (i.e., leukocyte), which fights off infection.

Enemy #3: Lymphoma Warrior

Refers to Lymphoma. Lymphoma appears in the lymph nodes, which are generally located in the neck, armpits, and groin. There are two different kinds of lymphoma, non-Hodgkin's and Hodgkin's. Prednisone is effective in treating both kinds of lymphoma so the new treatment in the game is PredniSoldier.

Treatment #3: PredniSoldier

Refers to Prednisone, a drug that is used to treat certain cancers, like leukemia and lymphoma. This steroid has several uses, such as treating nausea in cancer patients, stimulating appetite, and as an anti-inflammatory. Doctors have also found that chemotherapy is more effective in lymphoma patients when the chemotherapy is used in combination with Prednisone.

Re-Mission 2: Nanobot's Revenge Characters Explained

Enemy #4: ChemoResistor

Refers to chemotherapy resistant cells. Some cancer cells become resistant to the effects of chemotherapy and prevent the success of the treatment. Therefore, radiation is the new treatment that is being introduced in the game.

Treatment #4: Radiation Beam

Refers to radiation, which is a common cancer treatment. There are two different kinds of radiation therapy; external radiation and internal radiation. External radiation uses X rays or gamma rays, which are administered using several different kinds of machines that are outside of the body. Internal radiation involves radium or other radioactive materials being placed directly in the tumor. External radiation is much more common than internal radiation.

Enemy #5: Reed Sternberg Overseer

Refers to a Reed Sternberg cell. The presence of Reed Sternberg cells determines whether a person has non-Hodgkin's or Hodgkin's lymphoma. If there are Reed Sternberg cells, then the person has Hodgkin's lymphoma. Aside from the presence of the Reed Sternberg cell, there are few differences between non-Hodgkin's and Hodgkin's lymphoma. The symptoms are very similar (e.g., swelling of the lymph nodes, weight loss, etc.). Lymphoma can be found anywhere in the body, though Hodgkin's lymphoma is more likely to be found in the lymph nodes in the upper body.

Treatment #5: Energy Vortex

Unknown real-life correlate.