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The Effect of Delayed Feedback and Visual Hints Within a Gaming Environment to Facilitate Achievement of Different Learning Objectives

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THE EFFECT OF DELAYED FEEDBACK AND VISUAL HINTS WITHIN A GAMING ENVIRONMENT TO FACILITATE ACHIEVEMENT OF DIFFERENT LEARNING OBJECTIVES

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Title: The Effect of Delayed Feedback and Visual Hints Within a Gaming Environment to Facilitate the Achievement of Different Learning Objectives

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Online education has become a mission critical investment for educational organizations, however ensuring the same or higher quality experienced in face-to-face courses is challenging. Incorporation of serious educational games into an online course can provide flexibility and effectiveness in conjunction with other pedagogical strategies. Much of the literature on the use of games in education focuses on the engagement or motivation value opposed to achievement of learning objectives. The study in this dissertation investigates effectiveness of two learning strategies embedded within a serious educational gaming environment. Under the theoretical framework of Information Processing, research incorporated a study where participants read an instructional module on the parts and functions of the human heart and played one of three games reinforcing content from the instructional module. All games were a quest style game having participants answer questions to earn badges. One of the game versions provided elaborate feedback to game questions, another version provided the same elaborate feedback plus offered a visual hint along with the question, and a third version provided neither feedback or a visual hint. Three post-tests (comprehension, identification, and drawing) were given to measure the transfer of information from working memory to long-term memory. Results found a significant difference between the game versions for one of the post-tests (identification) and while the other tests did not produce a significant finding, the mean scores on the comprehension and a comprehensive score did indicate participants exposed to the elaborate feedback and visual hints performed better than the control group. Demographic variables (age, gender, academic standing (GPA), credits earned, and digital gaming experience) combined with game versions were also tested to determine any effect on achievement of learning objectives. As with the results of the comprehension test and comprehensive scores, there were no statically significant findings however comparison of the means indicated participants exposed to elaborate feedback and visual hints score higher than participants not provide either. Future recommendations include the examination of different learning strategies within a gaming environment, a longitudinal study over the course of a longer term, and replication when technological advances warrant.

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INTRODUCTION

The Lumina Foundation's 2014 report, "A Stronger Nation through Higher Education" noted that the United States is at risk of having an unprecedented shortage of a college-educated workforce. In fact, this risk has created a national imperative to increase degree attainment across the United States to 60% by 2025 (Lumina, 2014). The nation's post-secondary education institutions have developed many solutions to meet his challenge. An essential strategy identified by the Lumina Foundation to help realize this goal is the use of online education. Online education is not just for distance learners; online technology can be used to augment existing face-to-face classes or for campus-based students to manage their course load and increase student engagement (Sarıtepeci & Çakır, 2015).

In 2013, 2,831 higher education institutions, representing 81% of all higher education enrollments in the United States, were surveyed on their current and future online education efforts. The number of students taking at least one online course was 33.5%. Additionally, 90% of the academic leaders surveyed indicated that it is likely or very likely that every student will be taking at least one online course within five years. Of these same academic leaders, 90.3% reported that online education is essential to their long-term institutional strategy (I. E. Allen & Seaman, 2014). Growth in online education impacts all education sectors; for instance, online enrollments at community colleges have experienced more growth than traditional face-to-face enrollments, and the outlook predicts an increase in demand (Hirner & Kochtanek, 2012).

A barrier to the widespread use of online education is the concern that the quality of online education needs to be at or exceed the quality of traditional face-to-face courses (R. L. G.

Mitchell, 2010). Various educational strategies/pedagogies can be utilized to ensure a high quality learning experience, and, if applied using game environments, these strategies can lead to advancement and quality in higher education (Christie & Jurado, 2009). Hirner and Kochtanek (2012) identified eight quality indicators for online education:

1. Conduct departmental reviews of online courses for quality and link to desired student learning outcomes;
2. Regularly evaluate courses to ensure instructors are using sound pedagogical methods, instructional philosophy, and technology;
3. Conduct regular satisfaction surveys targeting student and faculty perceptions and preferences toward the online courses and the programs;
4. Utilize accrediting body's accepted assessment methods;
5. Regularly compare student learning outcomes of online courses with student learning outcomes of courses delivered via other formats;
6. Conduct program reviews to assist in program development;
7. Conduct periodic review of all courses delivered online;
8. Student persistence and retention rates for online classes is monitored and compared to university rates.

The study in this dissertation focuses on addressing the second quality indicator: evaluating the use of pedagogical methods and technology by studying the impact of selected learning strategies within a gaming environment.

The utilization of games in online instruction in support of student learning outcomes has the potential to expand the toolset for instructors, increase the quality of online instruction, and provide another learning pedagogy for learners (Holmes, 2012). However, such a strategy needs to be designed and deployed in such a way to support the overall student learning outcomes (Johnston, Boyle, MacArthur, & Fernandez Manion, 2013). Two such learning strategies that can be incorporated into games found to support education in the absence of a gaming environment are elaborate feedback and visual hints. Learning strategies such as these have been shown to increase retention of information in traditional classroom settings through rehearsal techniques (Beck & Lindsey, 1979; Kazi, Haddawy, & Suebnukarn, 2012).

A significant factor why gaming as a pedagogical approach is gaining momentum is the attitudes, expectations, and discourse that gaming has on current students. Millennials have adopted a discourse with digital media and gaming as a result of daily use and increased access (Considine, Horton, & Moorman, 2009). Consequently, game-based learning seems to be an appropriate instructional strategy to teach today's college students (Bekebrede, Warmelink, & Mayer, 2011). In addition to student needs, other variables impacting research on the use of gaming in education include the rapid pace of technological change and audience use. While research in one area may find no significant differences in the use of some learning strategies, technological change or the change in the use of a specific technology may have shifted enough to justify revisiting research (Ross, Morrison, & Lowther, 2010).

In order to understand the expectations of millennials regarding the use of gaming in online education and the use of effective learning strategies in traditional education, this study evaluated the effect of specific learning strategies (delayed elaborate feedback and visual hints) for the achievement of learning objectives within a gaming environment. The instructional material used for this study is composed of the parts and functions of the human heart and the study measured information transferred to long-term memory by the application of these learning strategies within a serious educational game.

Research Background

This section provides an introduction of the study, the independent variables for this study, and an overview of the use of gaming in education. The general theories of cognition and learning guided the reasoning for this study as well as the overview below.

Introduction

Educational institutions continue to utilize online learning environments and, as a subset, digital gaming at an increasing level. As such, traditional learning strategies and pedagogy need to be investigated to ensure maximum efficiency and effectiveness within a digital gaming environment. This study is aimed at identifying the effectiveness of two such traditional learning strategies. The findings of this study may provide institutions, faculty, and instructional designers with additional information on how to most efficiently and effectively design learning strategies within digital gaming environments to foster the transfer of information from working memory to long-term memory. As explained later in this dissertation, working memory processes information for a few seconds before making a determination to either discard or transfer the information to long-term memory. Transfer of information to long-term memory is not synonymous with long-term retention of information. Investigation of whether specific learning strategies within a gaming environment contribute to long-term retention would be the focus of a more longitudinal study where subjects are assessed over a period of weeks or months. While not a focus of the study, the type and extent of feedback and visual hints provided to the subjects may provide further guidance to instructors, instructional designers, and gaming environment creators.

The popularity of online learning and the use of gaming for the achievement of educational objectives combined with unceasing advancements in technology require complex and continuous research directed toward their effective use in education (Bekebrede et al., 2011). Research in online gaming needs to go beyond the entertainment and motivation by studying the cognitive, emotional, motivational, and volitional processes of learning within a gaming environment (Filsecker & Kerres, 2014). The findings of this study may assist instructors and instructional designers in the use of elaborate feedback and visual hints within an instructional gaming environment for the achievement of learning objectives.

Inclusion of Feedback in Instruction

Feedback has been used in the teaching and learning process for decades. In fact, the inclusion of feedback in the practice of teaching was one of the first learning strategies experimental psychologists studied. Instructors have regarded feedback as an essential learning strategy that impacts learners' behavior (Vollmeyer & Rheinberg, 2005). The importance and success of feedback in instruction is the motivating factor for this study, and understanding the use and impact in a gaming environment should increase the quality and effectiveness of online instruction.

Raymond Kulhavy (1977) identified three types of feedback used in instruction. These three types of feedback are typical of most instructor feedback. Future research expanded up on Kulhavy's identification by studying the effectiveness of each type.

- Knowledge of Response (KR) – learners are only informed if their answer is correct or incorrect.
- Knowledge of the Correct Response (KCR) – learners are informed of the correct answer.
- Correctional Review (CR) – learners are informed if their answer is correct or incorrect and advised as to why their answer was correct or incorrect.

Future studies expanded on these notions and labeled KR feedback as verification and CR as elaborate. This study is concerned with the impact of learners when they are provided with only verification or elaborate feedback.

There are three ways in which the dynamics of feedback impact the instructor and learner: feedback can serve as a motivator to increase learner performance, learners can use feedback to validate or change their response, or feedback can satisfy a learner's need for positive reinforcement (Kulhavy, White, & Topp, 1985). Underlying these factors is the cogitative process that occurs in the learner that transfers knowledge from working memory to long-term memory, thus facilitating an understanding of the material for future retrieval (Buchwald & Rapp, 2009).

Feedback during the teaching and learning process can be delivered in a variety of forms. The most common types of feedback in instruction are verification and elaborative feedback. Verification feedback informs the learner if he or she is correct or incorrect and provides no further information. Elaborative feedback can be delivered in many forms, but, in general, it is more complex than verification feedback (Pashler, Cepeda, Wixted, & Rohrer, 2005). Most research conducted on feedback in instruction has found that verification feedback had no conclusive impact on the learner's ability to retain information. In fact, providing no feedback and providing verification seem to have the same impact on learner behavior (Fazio, Huelser, Johnson, & Marsh, 2010; Pashler et al., 2005) Additionally, much of the research has also found that providing the correct answer and more elaborative feedback does not have a significant impact on information retention (Elder & Brooks, 2008). However, this research assessed information retention relative to correct responses to previously presented questions rather than an actual understanding of the material. More recent studies have found that the more complex or elaborate the feedback is, the more the learner obtained a deeper understanding of the material (Butler, Godbole, & Marsh, 2013). Assumptions can be made that providing complex and elaborative feedback in instruction can be more productive for the learner. Early studies found this assumption to be incorrect, but, as more research is conducted on the role feedback plays, the more it looks like a deeper understanding of information can be transferred to long-term memory with the use of elaborative feedback (Chase & Houmanfar, 2009).

Inclusion of Visual Hints in Instruction

Hints are clues, prompts, or facilitators that are used as a learning strategy to enable learners to better solve problems and to promote cognitive development (Jo, 1993). Primarily, hints during the teaching and learning process provide additional information to the learner but they also promote critical thinking and problem-solving skills by helping to identify major elements identified by the instructor. In this manner, hints allow students to disregard unnecessary information and focus on the most important concepts (Harskamp & Suhre, 2007; Jo, 1993).

First impressions are very important in the transfer of information from working memory to long-term memory (Brown, Illinois Univ, Bolt, & Newman, 1977). When additional information supports a learner’s first impression, he or she is more likely to reclassify the information from declarative knowledge to procedural knowledge; hence, learners are converting “knowing what” to “knowing how” (Glaser & Bassok, 1989). Becoming a better problem solver and moving beyond rote memorization of information to actual knowledge can be a process of trial and error wherein hints are a critical learning strategy (Derry & Murphy, 1986). The use of prompts such as hints in instruction not only provides an opportunity for additional information rehearsal, but they can also provide a confidence and stimulus to more efficiently transfer information to long-term memory (Wolfe & Hom, 1993).

Gaming in Instruction

Games as a form of engaging play have been part of human behavior since the dawn of humanity. Advancements in technology have increased the complexity of games and their deep-rooted use in our culture (Glenn, 2011). Modern video games in the 21st century is a billion dollar industry that has been moving beyond the entertainment industry and can be used to facilitate knowledge acquisition (Almeida, 2012). For a long time, games faced the misconception of irrelevancy in formal or informal learning (Rieber, 1996). However, as more research is conducted on the psychological and instructional benefits of games, researchers and game developers are rapidly finding processes and solutions to the potential within a learning environment (Hannafin, 1992). In fact, studies just a few years ago on the use of games for instruction focused on stand-alone solutions that utilized various technologies. The development of gaming functionality has now entered modern learning management systems (Minović, Milovanović, Jelena, & Dušan, 2012). This acknowledgement and adoption of gamification by industry-leading learning management systems is another validation of why this and similar studies are needed.

Learner engagement can be an essential strategy for the successful achievement of student learning outcomes (Blanc, Benlloch-Dualde, & Benet, 2015). The more motivation a learner can realize, the better chance of a high level of engagement. As such, learners need to be motivated by instructional activities they find interesting (Kinzie, 1990). Games inherently can offer the necessary characteristics to motivate and engage learners (Eseryel, Law, Ifenthaler, Ge, & Miller, 2014). Game developers need to create games that challenge the learner, create a sense of curiosity, allow the learner to use their imagination by including a fantasy element, and allow the learner to have an awareness of control to optimize the motivation and engagement that permit games to be an instructional tool (Lepper & Malone, 1987). Commitments to gaming functionality used within a modern learning management system combined with a higher level of use by faculty will fundamentally lead to a natural progression toward the characteristics identified by Lepper and Malone. As such, this study provides additional empirical evidence to support commercial development efforts and faculty adoption.

Advancements in technology will create a cyclical environment for research and application of games for instruction. Changes in technology will inherently drive the manner in which society uses technology and games. For instance, the introduction of smaller mobile devices has launched an entire gaming industry for these devices. This alone has opened a new area of research focused on the application of games for instruction (Bartel & Hagel, 2014). As the gaming industry continues to grow and its application in education is better understood, the need for empirical research will need to keep pace.

Research Background Summary

Research has provided a foundational understanding of the use of learning strategies targeted for this study. Overall, these learning strategies have had a positive impact on information retention and storage in long-term memory during the teaching and learning process. In addition, the use of games as a rehearsal activity in education has been evolving and is becoming more prevalent as a pedagogy in online education. However, the impact of traditional learning strategies on instruction in a gaming environment has not been fully researched. The sections below describes how studying these learning strategies through the lens of learning theories goes beyond an introduction of these strategies.

Theoretical Framework

Learners are presented with an abundance of information through many different media and are expected to comprehend, store, and retrieve this information from their long-term memory. However, while learners retain information in progressive and predictable ways (Gagne, 1985), when learners encounter too much material or information peripheral to the student learning outcomes, student achievement may be negatively impacted. The use of learning strategies as rehearsal strategies can diminish the impact of cognitive overload (Seery & Donnelly, 2012).

This study proposes to focus on how traditional learning strategies impact a learner's ability to process information for storage in long-term memory within a gaming environment. Information processing theory and the overall theory of cognition provided a theoretical framework for this study.

As a development of learning theories, cognitive theories such as information processing theory focuses not on the learner's behavior as does learning theories. But rather concentrates on how human memory works to process information from working memory to long-term memory. Cognitive theories examine learning through the lens of mental processes rather than learner behavior (Strauss, 2000).

General Description of Information Processing

Information processing theory uses concepts of computer processing to understand the cognitive activities that help explain or predict what takes place in the human mind during learning (Ruiji, 2012). During the learning process, information is stored in working memory before the mind decides to remove the information (information decay) or move it to long-term memory (Ricker & Cowan, 2010). While the working memory makes this decision, information from long-term memory may be recalled to help construct meaning for the new information

(Holton & Edmondson, 2012). When this theory is applied to an educational environment, rehearsal strategies such as those being studied in this research can aid in the moving of information from working memory to long-term memory (Goodwin, 2014).

At a high level, information from the environment is collected from the senses and passed to sensory memory. After this information is briefly stored in sensory memory, a decision is made to either disregard the information or pass it to working memory (Sreenivasan, Gratton, Vytlacil, & D'Esposito, 2014). Working memory is further defined below; however, in brief, information received from visual and/or auditory senses is processed and a decision is made to either disregard the information, i.e., information decay, or transfer the information to long-term memory. While working memory is processing information, it may recall additional information from long-term memory to help construct meaning from the newly acquired information. (Zhang, Verhaeghen, & Cerella, 2012). Information is typically stored in working memory for about thirty seconds before the brain discards the information or transfers it to long-term memory (Paas & Ayres, 2014). A visual diagram of the information processing model can be found in Figure 1.

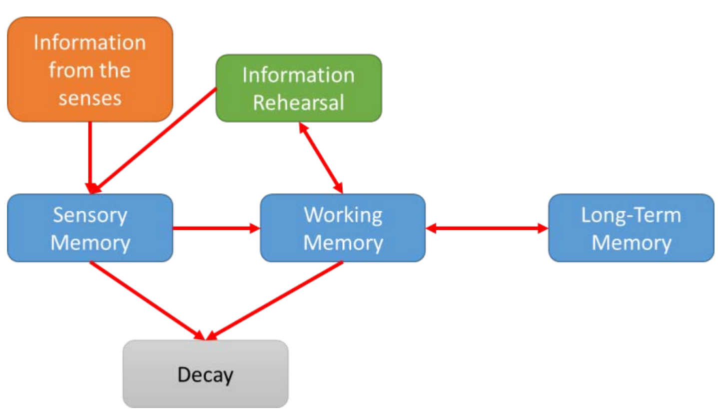

Figure 1. Information processing model.

Additionally, combinations of specific media received either visually or auditory can have a greater impact on the retention of information through the process of information rehearsal (Swann, 2013). Swann's (2013) focus of research on general eLearning demonstrates how the application of media or learning strategies applied as rehearsal strategies of instructional materials can help working memory construct meaning of the new information and the decision to transfer to long-term memory more efficiently.

Working Memory

Working memory is an information processing system comprising several components that encode, process, and maintain information (Burnham, Sabia, & Langan, 2014). In 1974, Alan, Baddeley and Hitch proposed an alternative memory model for the short-term memory model: working memory. In this model, they proposed that working memory is not a unitary system but a central control system (central executive) and two subsystems (the phonological loop and the visuospatial sketchpad) (R. J. Allen, Baddeley, & Hitch, 2014) This three-component system explained with more specificity how the human brain processes information into long-term memory for future retrieval. After further research, Baddeley added a fourth component to his model, the episodic buffer (Baddeley, 2000). Figure 2 below represents the four components that work together in storing information in long-term memory.

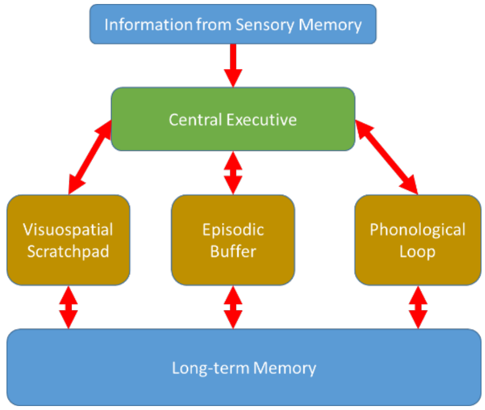

Figure 2. Model of working memory with episodic buffer

Information is received from external stimuli via the senses and quickly processed in sensory memory. This allows humans to retain information from the stimulus that has already passed (Vandenbroucke et al., 2014). Information is then sent to the central executive component of working memory. The central executive component is responsible for activities concerning planning and decision making, managing situations where communications between the other components are having conflict, complex or difficult problems, and issues where strong habitual or temptation responses are involved. While Baddeley developed the responsibilities of the central executive, it is still the least understood component of working memory (Bayliss & Roodenrys, 2000).

The visuospatial sketchpad stores and processes information arriving from the eyes. Static information such as an object's shape, color, orientation to other objects as well as the movement of the object is passed from the central executive to the visuospatial sketchpad (Frick, 1988). Breaking this down into smaller units, Baddeley concluded that the visuospatial sketchpad is composed of three components: visual, spatial and movement areas (Baddeley, 2000).

Focusing on auditory information, the phonological loop stores and processes information humans hear or verbal information and can account for the interactions between the modality of information presented, the concurrent articulation (the same information read and heard) and other auditory information. The phonological loop can be separated into areas: the passive phonological store and an active articulatory rehearsal loop (Spurgeon, Ward, & Matthews, 2014b). When written words are processed, they enter working memory and are given to the phonological store for a decision. If the information being received is also auditory, the visual representations are assumed to decay and are removed from working memory (Aboitiz, Aboitiz, & García, 2010). However, if the articulatory rehearsal loop is not occupied, the information is allowed to remain in the phonological store and be processed for possible long-term memory storage (Spurgeon, Ward, & Matthews, 2014a).

The fourth component of working memory was not added to the model until 2000, when Baddeley introduced the episodic buffer to explain the processing and maintenance of multimodal information. Multimodal information is information collected from more than one sense (Barricelli, Mussio, Padula, & Scala, 2011). The episodic buffer is able to maintain verbal and visual or spatial associations (Langerock, Vergauwe, & Barrouillet, 2014). This helps explain how working memory processes information that is seen and heard. As previously defined, the phonological store allows non-verbal information, i.e., written word, to be processed in the phonological loop even when the material is read visually. The episodic buffer controls this level of management in cross-domain associations. If a written word is also received verbally, the phonological store allows the visual information, the written word, to decay and only processes the auditory information for possible long-term memory storage (Buchsbaum & D'Esposito, 2008).

Cognitive Load Theory

In simple terms, cognitive load theory suggests that working memory has limited capacity, and, if the instructional material or learning activity exceeds the limits of working memory, learning will be hindered (Chandler & Sweller, 1991). Breaking this down further, there are three contributions to cognitive load: intrinsic cognitive load, extraneous load, and germane cognitive load (Cierniak, Scheiter, & Gerjets, 2009). Each of these components impacts cognitive load and should be understood in order to present material and design instructional activities to help promote information from working memory to long-term memory (Sweller, 2010).

Intrinsic cognitive load refers to the instructional material, more directly, the difficulty of the material. Additionally, intrinsic load cannot be transformed by instructional treatments, meaning the material is either intrinsically simple or intrinsically difficult (Kalyuga, 2011). While instructional treatments do not impact the intrinsic cognitive load, the learner's prior knowledge is also a factor in calculating intrinsic load (Bannert, 2002). One technique that can be used that will impact the difficulty of the instructional material is sequencing. When designing an instructional module, sequencing the material from simple information to more complex will help control a learner's intrinsic load (Van Merriënboer & Sweller, 2005).

Extraneous cognitive load are the activities, processes, or content a learner experiences that does not directly contribute to learning. This refers to the time and resources learners spend during the learning process that are not relevant for learning (Vandewaetere & Clarebout, 2013). Utilization of familiar instructional multimedia components to present material can reduce extraneous cognitive load, allowing students to focus on the material and not load working memory with unnecessary information (Huang, 2007). This study proposes that gaming could be considered an extraneous load for a learner who does not play a game or if the game is too complex. In these instances, learners will spend an unnecessary amount of their limited working memory to learn and understand the game. A strategy to offset the extraneous load is the presentation of redundant material to the learner (R. E. Mayer & Johnson, 2008). In the study in this dissertation, the researcher employed this strategy by the use of rehearsal instructional strategies within the gaming environment. The material presented within the game was redundant to the Dwyer heart module, thus giving the learner additional rehearsal opportunities. Compounding this strategy was the use of the delayed elaborate feedback and visual hints to further present redundant material.

Germane cognitive load is most impacted by the design or schema of the content. This includes processes such as interpreting, illustrating, categorizing, inferring, distinguishing, and organizing the instructional material. The cognitive load imposed upon the learner by these processes makes up the germane load (Debue & van de Leemput, 2014). Not to be confused with the suggestion that a gaming environment can contribute to extraneous load, a gaming environment can also contribute to germane load by reducing the overall cognitive load for the learner and positively support learning. If the game is designed to be engaging and contributes to the learner's motivation, the game schema can contribute to the learner's schema and affect learning (Cheon & Grant, 2012).

Theoretical Framework Summary

Too often, technology is used for the sake of technology without a greater understanding of its effects. When technology is applied during the teaching and learning process, faculty or instructional designers should have a understanding of how the human brain processes information and design their pedagogical approach to aid in the transfer of information to long-term memory. This section introduced the theoretical understanding of how humans process information and why the instructional material combined with the pedagogy and learning strategies needs to be aligned with the cogitative processes of the human mind. This research helps understand the impact a thoughtful application of rehearsal learning strategies within a gaming environment has on the theoretical foundations above.

Statement of the Problem

Use of instructional techniques within a gaming environment can be limited or at least designed differently than they would be in traditionally delivered face-to-face interaction. When designing a game that contributes to the desired student learning outcomes, instructors should incorporate games to provide meaningful play (Dickey, 2005). Faculty and instructional designers may find it difficult to create an online course if they are not familiar with best practices and effective learning strategies for an online gaming environment. Instructors transitioning from a traditional face-to-face setting will benefit from an understanding of the best practices of teaching online. This will help improve their pedagogical approach in an online environment such as gaming (McMurtry, 2013).

Serious educational games have been emerging from the gaming industry as the benefits are more fully understood and as the use of technology become more pervasive in society (Girard, Ecalle, & Magnan, 2013). Educational organizations have begun to accept and adapt the entertainment value of video games and repurpose these efforts for use in serious educational video games (Drugas, 2014). The problem is that advances in technology have outpaced the research on game design, effectiveness for learning, and proper strategies to promote learning (Hirumi, 2010). This problem, combined with the growing demand for online learning, has created a need for targeted research on best practices for game design for educational use. Unlike a traditional physical classroom where technology changes can occur but pedagogical approaches can remain the same, advances in technology can create a virtuous cycle of research to continually ensure the most appropriate application of gaming technology and its strategic application within an online environment.

The use of gaming for educational objectives can create an interactive environment for students to become active learners (Kriz, 2009). However to be most effective, games need to be designed and implemented using three main strategies. First, the game's goal must be to achieve some learning objective and present instructional material in an entertaining game-like manner. In doing this, the use of learning strategies needs to be concealed within the game as to not negatively impact the entertaining aspect. Secondly, the instructional material and learning strategies should be easy to understand. Lastly, the game must flow well and be challenging to the learner (Ismail, Ghafar, & Diah, 2013). All three of these strategies help frame the problem facing faculty, instructional designers, and students in today's changing educational landscape. There needs to be a state of equilibrium between the entertainment value and educational value of an instructional game that promotes effective learning strategies without negatively impacting a student's cognitive load.

Research Summary

Materials used in this research study have been adapted from Dr. Francis Dwyer's human heart model instructional material. Initially developed as a tool to examine the instructional effects of visualization and instructional training environments on student information acquisition and retrieval, this instructional material and associated assessments were developed to assist other researchers in empirical studies (Dwyer, 1982). The instructional module and assessments have been adapted to be used in a modern learning management system (Desire2Learn).

After being presented with the adapted human heart instructional module, subjects were asked to play one of three versions of the Human University Game. The first version played by the control group used avatars to progress through a fictional university campus, stopping at each building to answer a series of questions related to the instructional module. A second version is identical to the control group, however subjects that played the second version were given elaborate feedback to their answers at each university building. Finally, a third version is identical to the second (feedback) with the addition of a visual hint as to the correct answer when the question was presented. Subjects were recruited for this study from undergraduate students at Indiana University of Pennsylvania. This university is a regionally accredited doctoral and research university with approximately 15,000 students, of which 85% are undergraduate.

Research Objectives

The following research questions provide the empirically testable queries studied in this research.

RQ1: What impact will delayed elaborate feedback only or delayed elaborate feedback with visual hints in activities within a gaming environment have on a learner's ability to retain information?

RQ2: Will demographic factors interact with delayed elaborate feedback or delayed elaborate feedback with visual hints as learning strategies employed within a gaming environment for achievement of information retention?

Research Hypotheses

H_o1: There will be a statistically significant difference between the control group, the elaborate feedback treatment only group and the delayed elaborate feedback with visual hint treatment group in subject achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores).

H_o2: There will be a statistically significant difference between subjects' age and achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores) between the control group, the elaborate feedback treatment only group and the delayed elaborate feedback with visual hint treatment group.

H_o3: There will be a statistically significant difference between subjects' gender and achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores) between the control group, the elaborate feedback treatment only group and the delayed elaborate feedback with visual hint treatment group.

H_o4: There will be a statistically significant difference between subjects' academic standing (GPA) and achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores) between the control group, the elaborate feedback treatment only group and the delayed elaborate feedback with visual hint treatment group.

H_o5: There will be a statistically significant difference between the number of credits (class ranking) subjects' have earned and achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores) between the control group, the elaborate feedback treatment only group and the delayed elaborate feedback with visual hint treatment group.

H_o6: There will be a statistically significant difference between the subjects' digital gaming experience and achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores) between the control group, the elaborate feedback treatment only group and the delayed elaborate feedback with visual hint treatment group.

Definition of Terms

Active learning – Active learning is a process where the learner takes partial ownership in the teaching and learning process. Learners use their instructors as a resource as they become less dependent on the instructor to provide all of the information. Active learning can lead to a higher level of student engagement and learner motivation (Petress, 2008).

Cognition – Cognition is the mental processes and components that are used to acquire knowledge and understanding. Cognition includes components and processes such as sensory memory, working memory, long-term memory, problem solving, and decision making (Gagne, 1977).

Cognitive Load – Cognitive load is the total quantity of information the human brain can store and process in working memory before disregarding the information or transferring it to long-term memory. Working memory is limited to about four new elements of information for a duration of about thirty seconds. However, long-term memory does not have the same restrictions as working memory (Paas & Ayres, 2014).

Cognitive Overload – Cognitive overload occurs when the boundaries of working memory have been reached. When the limits of working memory have been exceeded, information is no longer transferred to long-term memory, and information loss occurs (Susanne et al., 2007). Working memory is limited to about four new elements from sensory memory and has a time duration of about thirty seconds (Paas & Ayres, 2014).

Conceptual Knowledge – The most common definition of conceptual knowledge identifies this as the understanding of associations and networks of information: that is, the understanding or framing of information based on what is known about the relationship and connections with similar information, processes or domain (Crooks & Alibali, 2014).

Declarative Knowledge – Knowledge of facts is commonly defined as declarative knowledge. Declarative knowledge is usually assumed to be useful in the initial stage of learning and must be stored in long-term memory before conceptual knowledge can be acquired (Roberts & Ashton, 2003).

Extraneous Cognitive Load – Stresses placed on an individual's working memory generated by the instructional material, pedagogy, or learning environment that shifts focus from the learning objectives. (Bunch, 2009).

Formative Feedback - Information communicated to the learner that is intended to modify his or her thinking or behavior to improve learning (Shute, 2008).

Gamification – Application of game mechanics and game thinking to non-game fields or environments. This leverages such game strategies as competition, achievement, and status in settings were gaming is not typically used (Park & Bae, 2014).

Information Decay – Loss of information from working memory prior to transfer to long-term memory. The loss of information can occur either from time-based decay or from interference-based decay (Souza & Oberauer, 2015). Working memory can store information for about thirty seconds before a decision is made to disregard the information or transfer it to long-term memory (Paas & Ayres, 2014).

Multimedia Learning – Presentation and organization of words or pictures in a manner as to elicit the use of sensory memory by using media artifacts such as animation, video, narration, audio stimuli (Pastore & Ritzhaupt, 2015).

Multimodal Interaction – Combining the use of varied multimedia artifacts (text, audio, and video) in technology-enhanced learning environments (synchronous or synchronous) to utilize multiple human senses with the goal of helping the learner focus on the instructional material (Hampel & Stickler, 2012).

Online Education – A course in which at least 80% of the instructional material and interaction is delivered via online technologies (I. E. Allen & Seaman, 2014).

Procedural Knowledge – Procedural knowledge is defined as an individual's knowledge of problem solving and the application of this knowledge to apply this information in working memory (Schneider, Rittle-Johnson, & Star, 2011).

Rehearsal Strategies – Strategies that present instructional material through multiple iterations for the benefit of information transfer from working memory to long-term memory (Couch & Moore, 1992).

Serious Education Game – Game designed and used for the primary goal of education that engages and motivates students while striving to achieve the desired student learning outcomes. Serious educational games are used to promote a learner's interest and put him or her at ease in an environment that is familiar (Borji & Khaldi, 2014).

CHAPTER TWO

LITERATURE REVIEW

Introduction

The focus of this literature review is to investigate literature related to the variables used in this study, the theory the researcher applied, and the use of digital games in education. This review is not intended to be an exhaustive review; however, it will focus on the published literature most relevant to this study. After the literature review for each section, the researcher has provided a summary that serves to connect the literature to this study.

As stated in chapter 1, information processing is the theoretical framework guiding this dissertation. However, the complex relationship between information processing, cognitive overload, and cognitive theory require the theoretical foundation examined in chapter 1. The literature review for information processing theory maintains a focus on information processing. However where appropriate the relationship with cognitive overload and cognitive theory are presented.

Literature on Feedback

A literature review by Black and William (1998) observed that one of the most influential teaching and learning strategies on student performance is informative feedback. A study on the impact of feedback used in an asynchronous learning environment determined that learner's performance improved by providing elaborate feedback that combined an expansion of the content as well as learners requests for clarification from the instructor (Guasch, Espasa, Alvarez, & Kirschner, 2013). When using a computer-based learning environment, learners who are presented with environments familiar to their cognitive abilities prefer to have feedback presented in textual form (Rieber, Smith, & Al-Ghafry, 1996). While feedback as an instructional strategy has been used in the teaching and learning process for a very long time, these studies provide empirical research as to the use of automated feedback in an online environment.

Erhel and Jamet (2013) studied the effects of user performance on entertainment video games when feedback was provided. They found that elaborative feedback combined with instruction on video game play for entertainment value can enhance information processing, promote learning, and increase the users' motivation. While Erhel and Jamet's study helped to understand the influence of feedback in a gaming environment, the methodology only considered the impact on the entertainment aspects of learning, without considering if the user's performance in the game improved from the in-game feedback. Erhel and Jamet's findings also support the research that adding feedback during the educational process can improve information processing and improve learning (Sweller, van Merrienboer, & Paas, 1998). The gap in research between the use of feedback in entertainment video games and the notion that feedback used in the teaching and learning process is underscored by the juxtaposition of these two studies. Studies on the cogitative aspect of learning such as the one conducted by Sweller, van Merrienboer, and Paas (1998) combined with the findings of Erhel and Jamet (2013) promotes the need for additional research on the impact of feedback used in serious educational games.

The use of elaborative feedback combined with a motivational goal or a reward-obtainment environment can lead to an increase in learner performance, as opposed to just verification feedback in the same environment (Higgins, 1987; Valdez, 2012). The methodology in the Valdez study included the treatment of different variations of elaborate and verification feedback accompanied by achievement goals pertaining to their scores on the post-test assessments. The study in this dissertation builds upon Valdez's study by providing elaborate feedback and adding a goal reward system; however, the gaming environment combined with the badging reward system will augment these findings. Providing feedback in online environments where the instructor and learner are not face-to-face plays a critical role in the learning process. Adding feedback in the form of answer keys can improve learner performance (White, 2003). Hurd (2006) was more direct in characterizing the role of feedback, stating that, in online education, feedback is the most critical factor in achieving the desired student learning outcomes. Independent learning environments where learners can control the use of feedback will increase engagement and assist learners with processing information more efficiently (Fernández-Toro & Hurd, 2014).

Adams and Strickland (2012) conducted a study to understand the possible impact computer-assisted feedback had on achievement of student learning outcomes. Their study participants showed a significant increase in achievement in learning outcomes when feedback was provided in a multimedia instructional system. The findings of these studies are important because of their focus on the geographical and temporal separation of the instructor and learner. In an online gaming environment, such as the focus of this study, the intent is to understand how the use of feedback in a gaming environment impacts student learning when the instructor is not present to utilize this learning strategy.

Van den Bergh, Ros, and Beijaard (2013) studied the impact of feedback on active learning environments where learners actively use resources beyond the instructor for achievement of student learning outcomes. The researchers found that students utilizing feedback in such an environments played a pivotal role in learner achievement. This research methodology did not include computer-assisted or online learning; rather, the focus was placed on the use of feedback when active learning was occurring.

Active learning can take place when the instructor and learner are engaged in synchronous and asynchronous learning; however, while the study by van den Bergh et al (2013). focused on synchronous learning, the focus of this study is on asynchronous learning. Using feedback juxtaposed with instructional content at the process level (when learners are actively learning) helps to focus the learners' processing of the information, which can be more effective for the student (Hattie & Timperley, 2007). Via a systematic review of studies researching the use of feedback, Hattie and Timperley (2007) identified several major themes, one being the most effective timing of feedback to promote learning. Building upon this research and methodology, the approach used in this study will place elaborate feedback in the instructional module as opposed to providing feedback in the formal assessment.

Elaborate feedback that scaffolds information from an entire online learning module has been found to increase student test scores as compared to verification feedback and isolated or single unit elaborate feedback (Lin et al., 2014). The methodology used in this study will build upon these findings by using a gaming environment with questions and associated elaborate feedback by grouping the material according to the progression of the instructional material. Segedy, Kinnebrew, and Biswas (2013) conducted a study to find if contextualized and conversational format feedback in a computer simulation had any impact on student achievement. They found that by contextualizing the feedback toward the goal of the simulation and providing feedback in a conversational format resulted in a significant increase in the students' ability to understand the material. The findings of this study support the concept that elaborate feedback that is not verbal or face-to-face can be effective in the teaching and learning process.

In a study using post-graduate students participating in an online course, Coll, Rochera, and Gispert (2014) found that elaborate feedback tended to promote knowledge building when varying the complexity of the feedback. The researchers targeted post-graduate students, who would have more declarative and conceptual knowledge than the subjects of the study in this dissertation: traditional undergraduate students in their first year or two of post-secondary education. As such, these participants might benefit more from the use of a gaming environment to deliver the instructional material and elaborate feedback.

Use of feedback in an online environment can be influenced by intermediary variables such as self-regulations. When instructional designers include feedback as a learning strategy to assist with reducing detrimental variables, learning can be enhanced (Lee, Lim, & Grabowski, 2010). The study by Lee, Lim, and Grabowski (2010) speaks to one of the foundational aspects of this study by understanding the impact of learning strategies by course developers.

The use of elaborative feedback given after a student failed a question can yield more positive results in desired behavior opposed to allowing students to repeat the task while only providing verification feedback (Narciss et al., 2014). The methodology used by Narciss et al. (2014) tests the impact of elaborate feedback; however, this was assessed with the impact of repeated attempts by subjects that received only verification feedback. Effects of such feedback ripple beyond the positive impact to student learning. A study conducted by Espasa and Meneses (2010) found that improvement in student achievement was also accompanied by increased levels of overall satisfaction with the course. While not measured in the current study, the gamification of the instructional module should also increase student engagement and satisfaction.

Time has an impact on the effectiveness of formative feedback. Feedback can be categorized as either immediate feedback (IF) that provides the learner with information immediately after a question or delayed feedback (DF) which gives the learner information a few minutes after a question (Shute, 2008). The literature review by Shute (2008) helps define and understand the relationship between immediate and delayed feedback, part of the parameters of the study in this dissertation.

Research results have been mixed on the effectiveness of immediate feedback compared to delayed feedback. A study on the use of feedback for the instruction of foreign languages produced varied results, and, in analyzing the data further, the researchers found that the cognitive level of the question determined the feedback timing for optimal results (Ferreira, Moore, & Mellish, 2007). While the content of the instructional module and learning environment (gaming environment) is different, the study by Ferreira et al. (2007) provides an understanding of how the composition of the elaborative feedback in relation to the material impacts the effects of feedback.

Some research has focused on feedback given to gamers in a gaming environment; however, these studies have not explored any impact feedback has on learning. Tsai, Tsai, and Lin (2015) conducted a study to examine knowledge acquired and retained in a single-player game, multiplayer game, and feedback within the game. They found that the game mode (single or multiplayer) had no significant effect on knowledge retention. However, feedback provided in either game mode showed a significant increase in user performance.

These findings contribute to gaming in general, but not to the use of gaming for achievement of learning objectives. This shows that feedback within a gaming environment does have an impact on individuals. Feedback in games also impacts play motivation. Positive feedback increases confidence, and long-term game play boosts intrinsic motivation (Burgers, Eden, van Engelenburg, & Buningh, 2015). The focus of the Burgers et al.'s (2015) study was on the entertainment value and resulting motivation of the gaming environment, but this could provide evidence toward the level of student engagement with the use of games in the teaching and learning environment.

In a mixed-method study, Scoles, Huxham, and McArthur (2013) found that providing elaborate feedback in the form of student exemplars during the presentation of instructional material resulted in better student exam scores. Additionally, the students surveyed on their attitudes toward this type of feedback indicated that it was received positively, and they also indicated deeper understanding of the material. Moreover, the use of elaborate feedback that is less specific or individualized forces active learning on the student, thus promoting critical thinking, increasing student engagement, and promoting achievement of student learning outcomes (Jonsson, 2013). Both of these studies emphasize the importance of the content of the feedback. Elaborate feedback written to elicit critical thinking can have a more positive effect on achievement of learning objectives than other types of feedback.

Summary on Feedback

The literature on the use of feedback suggests that elaborate feedback has a greater impact on knowledge retention than other forms of feedback. Additionally, research on the timing of feedback (immediate or delayed) has produced mixed results, suggesting that further testing in different environments such as gaming could provide greater clarity. Research on the use and effect of feedback in a gaming environment has been limited to achievement or motivation associated to the entertainment value. This literature review indicates that further research on the effects of feedback toward achievement of learning objectives in a gaming environment is needed to help instructional designers and course developers negatively impact cognitive overload and thus maximize learning.

Literature on Visual Hints

A study revising a 1931 study by experimental psychologist Norman Maier exploring incidental learning using visual hints found that a treatment group exposed to visual hints outperformed the control group. Subjects were presented with a geospatial problem to solve where the treatment group was given a visual hit on the most effective solution. The treatment group was able to complete 50% more tasks required to solve the program than the control group (Bröderbauer, Huemer, & Riffert, 2013). This study affirms the results of previous studies demonstrating that human minds, when trying to solve problems, processing visual hints perform better than subjects who are not exposed to the hints.

Chalfoun and Frasson (2008) posed a research question to determine if information processing could be enhanced if a visual hint was introduced during the learning process. This had been studied in a non-technology enhanced environment, but Chalfoun and Frasson studied this pedagogical strategy in a computerized tutoring environment. They found that overall, the subjects exposed to the visual hints in the tutoring system were 2.6 times more efficient, producing 44% less mistakes than the control group. Chalfon and Frasson's study was similar to the research conducted in this dissertation, however the visual hints provided in their study were given prior to the presentation of the instructional material. It was observed that subjects receiving the hints prior to the instructional material did not read the entire instructional lesson and were able to move through the material at a faster pace than the control group. The study conducted for this research presented the visual hint along with the instructional material in the environment of a digital game.

Transferring information from working memory to long-term memory requires individuals to discard irrelevant material. There are different strategies for assisting in the information processing activities. A study conducted by Mitchell et al. (2002) tested the effectiveness of information retention using visuals. Subjects were presented with names on a computer screen to remember, the treatment group was also presented with a color they were required to name aloud. Immediately after being presented with 60 names and colors, all subjects were given a post-test comprising the original 60 names and 60 new names. The subjects were asked to identify if each name was a new name or one presented from the original list. This study concluded that there was a significant difference between the treatment group and control group in the retention of information by using visual cues to help the mind process information. Similar to the Chalfon and Frasson study, this study did not present the visual hints to the subjects during the presentation of the instructional material or problem solving task. Rather this study used unintentional visual hints to determine if working memory could unconsciously use the additional information to help process information into long-term memory.

While studying several independent variables on the effectiveness of face-to-face instruction and blended (face-to-face and online) instruction for information scaffolding, Chin and Lee (2014) posed the research question "To what extent does a hint-based teaching-learning strategy result in multi-dimensional critical thinking?" (p. 44). In a pre and post-test experiment, the researchers found mixed results when analyzing data. Two groups were studied to determine if there was any significant difference between hint-based and non-hint based learning. Researchers established a baseline mean by providing both groups an assessment not utilizing visual hints. The same groups were tested again utilizing visual hints during the assessment. Group A had a lower mean score for the hint-based assessment while group B saw an increase in their mean scores for the hint-based assessment. The authors noted that there were several intervening variables that could have impacted the results. Two of note were the instructors, both groups had different instructors present the instructional module and secondly, the group showing an increase in post-test scores had less time for the assessment. Although the study by Chin and Lee showed mixed results most likely because of the intervening variables, the environment used was a digital one where the material was presented on a computer. These findings indicate that further research should be conducted to understand the impact of visual hints in a digital environment.

When the use of digital technologies such as computers started to be more prevalent in the teaching and learning process, Ikeda (1999) conducted a study on the effectiveness of sound hints. Ikeda's study observed the impact of hints of 21 non-Japanese speaking subjects learning how to speak Japanese over a four month period. The independent variable being studied was the subject's Japanese language skills determined by a pre-tests. After dividing the subjects into two groups based on test scores (lower and higher) and four months of the same computer based instruction, Ikeda observed that the students with a lower pre-test score had a more significant increase on the post-test scores than the group with higher pre-test scores. This study is relevant because of the use of hints in a digital environment where learning strategies such as hints have not been studied enough to determine their effectiveness. Although Ikeda did not separate the subjects into a hint and non-hint groups, he observed that students, especially with overall lower ability, might be more receptive to hints as a learning strategy in a digital environment.

Jia-sheng, Jyh-cheng, Shao-chun and Maiga (2008) studied high school students using a virtual lab digital environment to understand if visual hints within the virtual environment had any effect on learning compared to students conducting the same experiments in a real-life lab. Group A conducted science experiments in a real-life lab, group B used the virtual environment with assistance of a virtual tutor, and group C use the same virtual environment but was presented with visual hints while conducting experiments. Analyzing results from a pre and post-test study, students in the real-life lab had higher overall scores, however, group C had a higher increase in their post-test scores then the other two groups. Further investigation might reveal any intervening variables on why group A outperformed the treatment groups in both the pre-test and post-test scores. The increase in post-test scores by group C, however, indicates that visual hints might have a positive impact for learning.

Summary on Visual Hints

Most of the literature on the use of hints to promote learning is focused on hints not designed to draw learner attention. These hints were important to the studies and were intended to help the learner. However their use and placement was designed to lead the learner to believe they were unintentional, meaning the hints were presented to the subjects without their knowledge that the hints were part of the instructional module. These studies observed that hints in instruction can help the human mind process information more effectively for long-term storage and retrieval as well as problem solving. Interestingly, Chalfoun and Frasson (2008) observed that the group exposed to the hints performed better than the control group even though many of the subjects did not thoroughly read the instructional material. This indicates that visual hints may provide more instructional support then hypothesized and had the potential to positively impact information processing in a gaming environment.

Literature on Information Processing Theory

Cognition necessitates the processing of information, information processing theory helps model and predict how humans receive, interpret, and store information. As a theory of cognitive architecture, information processing theory is similar to and contributes to models of communication theory. Communication theory identifies a sender, a message over a specified medium, and a receiver. Within this process the message is encoded and decoded by the respective participant. During the process, noise can impact the message or the decoding of the message. Information processing theory helps us understand and predict how the receiver processes the information, bridging the gap between communication theory and cognition (Piccinini & Scarantino, 2011).

Designing digital teaching materials for use in modern online enhanced courses can be challenging. Perspective alone is not adequate, individuals designing a course using multimedia resources need to understand how the human mind processes information. According to Li Riuji (2012) only under the guidance of information processing theory and learning theories can online teaching resources be developed for maximum efficiency and effectiveness.

Li and Kettinger (2006) expand upon information processing theory. Their expansion focuses on the mind’s need to recall previously learned information from long-term memory into working memory to aid in the construct for the new information. New information is created by using a series of ‘elementary information processes’ (EIPs) retrieved from long-term memory similar to how a computer processes information. Use of EIPs indicate that the existing information stored in long-term memory is needed for the construct of new information processed by working memory.

Applying information processing theory to a commercial marketing campaign, researchers found that the information stored into long-term memory can be influenced to produce a desired outcome when future information is presented. Sixty-four subjects presented with information intended to form a negative impression about a corporation were asked questions during a study that required the subjects to invoke previously stored positive information with the goal of replacing the negative information. Subjects were unknowingly exposed to a rumor that linked the use of worms to McDonald's food by a researcher posing as a subject. Subjects were then asked questions attempting to invoke positive information from long-term memory about McDonalds. Questions such as "Where was the closest McDonalds to your house growing up?" The intent was to transfer information such as a positive childhood memory from long-term memory to working memory to replace the construct of McDonalds using worms. This noise was created to influence what information the subject stored in long-term memory. During a follow up session, these same subjects were asked questions to invoke responses associated with the negative information. Because many of the subjects did not recall the rumor, the researchers found that the storage and retrieval strategies used in the experiment yielded a significant finding, concluding that the strategies were effective (Tybout, Calder, & Sternthal, 1981). This study demonstrates how information presented in a strategic manner can impact the cognition process by using information processing theory to predict how individuals acquire information.

Closely linked to information processing theory is the mind's ability to process a finite amount of new information or cognitive load (Paas & Ayres, 2014). Working memory processes new information with a capacity of about 3-5 units of new information for about 30 seconds. During this time, working memory accesses long-term memory to provide additional information for processing assistance. If the new information is not processed into long-term information within these limitations, the new information will succumb to information decay, thus losing the new information. Digital materials presented in online learning environments can enrich learning, but they can also obstruct the processing of information by appropriating the learners working memory and contributing to cogitative overload. Instructional material design must consider cognitive overload by reducing the amount of noise when communicating information, thereby making the most efficient use of learning strategies (Kalyuga, 2012).

Information is processed though visual and auditory senses or both the visual and audio channels. According to Taylor (2013), instructional designers incorporating both visual aids and text in the same instructional module should integrate the two artifacts. This averts the learner from being required to use the text to acquire information from the image, thus avoiding unwanted noise that contributes to cognitive overload. Additionally, materials should not be designed to address multiple learning styles within the same module. Research has shown that combining text, visuals, and audio within the same module increases cognitive load (Clark & Mayer, 2011).

Summary of Information Processing Theory

As a young branch of cognitive science, information processing theory has not been the focus of much literature. Advancements in computer technology allowed researchers to draw similarities between how computers and the human mind processes information. Common throughout the literature was a focus on cognition and cognitive load. Given the uncertain nature of the psychology behind how the mind processes information, one possible option would be to consider human information processing similarity to how a computer processes information.

Literature on Gaming in Education

Bellotti, Kapralos, Lee, Moreno-Ger, and Berta (2013) identified three requirements for a serious educational game. First, a game needs to be fun and entertaining. Secondly, the game needs to be educational. And lastly, the game must include the ability for students to be assessed on the instructional material incorporated in the game. The researchers' assessment of serious game research also suggests that, as hardware and software advance, further research should be conducted to keep pace with changing possibilities.

Pløhn (2014) hypothesized that, if designed well, an education game can motivate students to spend time outside of the classroom to work on the instructional material. He used a mixed-methodology approach to further understand students' interaction with an education quest game called *Nuclear Mayhem*. Findings supported his hypothesis: 87% of the logins occurred outside of the classroom when no formal class activity was taking place. Student interviews identified the storyline, plot, and realistic nature of the game as their main motivation for playing the game outside of the formal teaching environment. This study supports an earlier study on the effects an education game had on public high school students studying mathematics. Students who played a mathematics video game scored significantly higher on district-wide exams than students who did not play the game. Qualitative findings from teacher interviews indicated that the game motivated the students, reduced their fears of mathematics, and motivated, and challenged the students in an entertaining manner (Kebritchi, Hirumi, & Bai, 2010).

Games can function as a motivational rehearsal technique to increase a student's interaction with the instructional material. To achieve this outcome, games must be sustainable, meaning they must be designed to challenge and entertain students, allowing them to remain motivated and focused on the material (Eseryel, Law, Ifenthaler, Xun, & Miller, 2014). Similarly, Burguillo (2010) concluded that aspects such as quests, fantasies, and challenges in an educational computer game had a positive impact on students' learning abilities and construct knowledge. A study conducted with high school-aged students used a video game to teach how household electrical appliances use electricity, how to calculate energy consumption, and basic energy conservation. The study found that students playing the game significantly outperformed the students who did not play the game (Dorji, Panjaburee, & Srisawasdi, 2015).

A mixed-methods approach conducted to study the effects of the use of a game-based course on American history found that students using the game spent more time reviewing the course material compared to the control group that used a non-game-based online course. The increase in time spent with the course material led to a significant performance difference between the group using the game and the group not using the game. Qualitative findings indicated that the story and presentation of the instructional material contributed to student motivation (Hess & Gunter, 2013).

Students using a serious educational game to learn British literature performed better than students learning the same material without the use of the game (Mansour & El-Said, 2009). The researchers observed the game increasing the social interaction among the students by game play outside of the formal classroom. They concluded that this increase in social interaction about the instructional material contributed to the performance differentiation compared to students not playing the game (Mansour & El-Said, 2009).

Serious educational games have also proven to be effective in achieving targeted behavior beyond classroom instructional material. The use of games to teach adolescents the negative impact of alcohol and drug use has been shown to be effective in reducing usage. This research also provides evidence that, not only can learning outcomes be increased by the use of games, but attitudes and behaviors can change as the result of serious educational games (Rodriguez, Teesson, & Newton, 2014).

Researchers and designers are also adding social elements to serious educational games to positively increase students' motivation. A survey of high school students asked to play a game designed within Facebook found that students were more inclined to play the educational game after school without being constrained by the time limitations of the school setting. The researchers concluded that adding social interaction elements to a serious educational game can increase motivation and encourage students to explore the game in unexpected ways (Chien-Hung, Yu-Chang, Bin-Shyan, & Yen-Teh, 2014).

Moreover, the use of gaming in education has also been studied from a cultural perspective. A study of Latino children's (aged 10-13) knowledge of the food pyramid assessed the knowledge, skills, attitudes, and behavior of students who played a serious educational game compared to a control group that did not play the game. Findings indicated that the treatment group that played the digital game had an overall increase in the areas measured. Additionally, the study found no cultural difference between the age groups measured by acculturation level (Serrano & Anderson, 2004).

Papastergiou (2009) conducted a study of 88 high school students to understand if achievements of specific learning objectives were impacted by the use of a serious educational game. This study used the same instructional material but split the participants into two groups: the treatment group played a game using the instructional material and the control group read the material from a computer-based learning module. The results demonstrated that the treatment group achieved higher scores on a post-test and observations of both groups during the experiment indicated that the treatment group were more enthusiastic and motivated.

Demographic variables used for study in this dissertation have also undergone empirical research to determine their effect toward digital game play. One such variable, gender, does have an impact. A study of engineering students using a car race simulation game found that males played digital games significantly longer than females, however there were no significant differences in the level of engagement or motivation between genders (Joiner et al., 2011). A review of literature on the use of educational games for females found many commonalities between features in female-focused games and attributes found in constructivist learning environments (Dickey, 2006).

Age does not have a strong impact on the use of serious educational games. Younger students may have a higher comfort level with the digital environment, however their attitude and ability does not seem to be impacted by age (I. Mayer, Warmelink, & Bekebrede, 2013). A study linking gender and age found that while males tend to actually play video games more frequently and for a longer period of time, there was no difference between the attitudes toward game play. Females found the use of educational games just as motivating and rewarding. This same study also investigated the impact of age in relationship to gender and found no differences between female attitude regardless of age (Toro-Troconis & Mellström, 2010).

Extensive game play does have an effect on student achievement. A survey conducted at five post-secondary institutions in New York asked student about their daily gaming habits. Analysis found a significant impact between the amount of time spent on gaming for entertainment and student achievement (GPA). This study did not find a significant impact on the length (years) and student achievement, indicating that regardless of when a student is exposed to digital games the more time spent playing games will negatively impact their GPA (Anand, 2007). Elementary aged children who play educational video games were surveyed to examine their attitudes and strategies used during digital game play. While the sample size was small, a significant effect did occur between the strategies used for a video game and academic achievement (GPA). Students who used the in-game help and sought help from peers were higher achievers in school (Hamlen, 2014).

Games can also benefit upper-division undergraduate students when used in online instruction. A study conducted with upper-division medical students find that using a games based learning module performed significantly better on cognitive knowledge testes than students who were not exposed to the games based learning module (Boeker, Andel, Vach, & Frankenschmidt, 2013).

Summary of Gaming in Education

A comparative study by Borji and Khaldi (2015) analyzed the literature on the use of games in education and developed an instrument to assess the quality of serious educational games. However, in conducting their study, Borji and Khaldi (2015) concluded that there are not enough empirical studies of the use of serious games in education and solicited an open call for additional research in varying contexts to broaden understanding.

Chapter Summary

With the exception of gaming in education, much of the available literature is focused on research in a non-digital real-life environment. Only in the last few years has a focus been on research in a digital environment. Additionally, the literature lacks standards in common terms or independent variables. Some of this can be attributed to the views of various researchers in the area of cognition. Additionally, many of the studies in the area of visual hints had small samples sizes and were not focused on the use of aids in instruction rather on hints designed to be in the background and not the subjects' focus. Some literature focused on multimedia or cognition does address the use of visual aids in instructional modules though the focus was on the areas such as placement, relationship to the text, and accompaniment with auditory aids. Research on the use of visual aids during an assessment activity is limited to problem solving and not information retention.

Literature on gaming is just beginning to shift focus from motivation, engagement, and entertainment based games to serious educational games. Not surprisingly, early in the application of gaming in education, existing games were researched on their value in education. As gaming in education became more prevalent, serious educational games were developed and the research has been shifting toward games developed purposefully for education. Still much of the research is focused on the merits of games in education and not on any impact the game design has on achieving desired learning outcomes. The research in this dissertation does not presume to address all the gaps in the research. However, it does attempt to shift focus from gaming's motivational and entertainment qualities to its capacity to promote learning. The research in this dissertation intends to advance the field by unifying traditional learning strategies and digital gaming environments.

CHAPTER THREE

RESEARCH METHODOLOGY

Introduction

The purpose of this study was to identify if exposure to specific learning strategies during game play had any effect on an individual's ability to retain information. Providing delayed elaborate feedback or visual hints to students for rehearsal during the teaching and learning process are not new learning strategies; both have been researched in the context of more traditional learning environments. However, neither has had empirical research conducted on how these learning strategies might affect learning within a gaming environment.

Overview

This chapter identifies the selection and description of the instructional material used for this study along with the assessment method accompanying the instructional module. The process of how materials were evaluated and refined is also discussed in detail. Drawing from the instructional materials the creation of content for the game and treatments applied during gameplay are presented. Finally, this chapter provides details of how the subjects were selected and the procedure in which the study was conducted.

Selection of Content

Materials used in this study were adapted from the outgrowth of the Program of Systematic Evaluation (PSE) printed resources (Experimental Instructional Materials) initially developed by Francis Dwyer and later modified by Richard Lamberski to include visual images to reinforce the textual components (Dwyer, 1982). Items from the Experimental Instructional Materials were adapted for use within a modern learning management system. Placement of the materials—both text and images—were not the focus of this study and thus were not addressed.

Hundreds of studies have been conducted using Dwyer's instructional module where independent variables such as the addition and placement of visuals, the addition of audio narration, animated visuals, static visuals and many other variables were used as treatments to study their effects on information retention (Dwyer, 1982). This study builds upon this prior research by making the use and placement of images (visual hints) at appropriate places within the content and game.

In 1965, Francis Dwyer developed a method for empirical research that became known as the Program of Systematic Evaluation (PSE). It was initially developed as a tool to examine the instructional effects of visualization and instructional training environments on student information acquisition and retrieval (Dwyer, 1982). As an outgrowth of the PSE, a set of materials known as the Experimental Instructional Materials (EIM) were developed to assist researchers. Numerous researchers have adopted the Program of Systematic Evaluation and associated EIM materials to study various independent variables. The use of the Experimental Instructional Materials in different contexts have contributed to findings in many fields (Dwyer, 1987).

At its core, the EIM has three components:

- An instructional module containing approximately 2000 words describing the parts of the human heart, the location of each part, and their functions during the diastolic and systolic phases of the heart;
- Images containing different degrees of realistic detail of the human heart;
- Three criterion measures to evaluate the educational objectives of the instructional module.

Application of independent variables against these materials have demonstrated a "high degree of predictability in facilitating the achievement of specific education objectives" (Canelos, 1987) . With the application of unique experimental and control conditions, the EIM materials can be effective in studying the impact of learning, learner behavior, instructional design strategies, and presentation materials (Dwyer, 1987).

Assessment Method

Three original post-test assessments developed as part of the Experimental Instructional Materials were used as designed for three of this study's criterion measures. A subject's comprehensive score on the identification, drawing, and comprehension assessments was used as a fourth criterion measure. Each assessment consists of 20 items, measuring the subject's knowledge of the presented material. The three evaluation materials used for this study were divided into the following areas: drawing, comprehension, and identification. Following the Program of Systematic Evaluation, each instrument was designed to measure a different educational objective based on the instructional material. The multiple choice (comprehension and identification) and the drawing criterion instruments are provided in Appendices A, B and C.

A description of each of the evaluation assessments as presented by Dwyer (1987, p. 248) can be found in Table 1 below

Table 1.

Description of Original Experimental Instructional Material Assessments

Drawing Test	The objective of the drawing test was to evaluate a subject's ability to construct and/or reproduce items in their appropriate context. The drawing test (20 items) provided the subjects with a numbered list of terms corresponding to the parts of the heart presented in the instructional module. The students were required to draw a representation diagram of the heart and place the numbers of the listed parts in their respective positions. For this test, the emphasis was on the correct positioning of the symbols with respect to one another and in respect to their concrete referents.
Identification Test	The objective of the identification test was to evaluate a subject's ability to identify parts or positions of an object. This multiple-choice test (20 items) required students to identify the numbered parts on a detailed drawing of a heart. Each part of the heart, which had been discussed in the instructional material, was numbered on a drawing. The objective of this test was to measure the ability of the student to use visual cues to discriminate one structure of the heart from another and to associate specific parts of the heart with their proper names.
Comprehension Test	The comprehension test consisted of 20 multiple-choice items. Given the location of certain parts of the heart at a particular moment of its functioning, the student was asked to determine the position of other specified parts of the heart at the same time. This test required that the students have a thorough understanding of the heart, its parts, its internal functioning, and the simultaneous processes occurring during the systolic and diastolic phases. The comprehension test was designed to measure a type of understanding in which the individual can use the information being received to explain some other phenomenon.
Comprehensive Test Score	The items contained in the three criterion tests (identification, drawing, and comprehension) were combined into a 60-item

	composite test score. The purpose was to measure achievement of the varied levels of objectives presented in the instructional unit.

Reliability of Criterion Measures

"A random sample of previous studies were selected to determine the reliability of each criterion test as it related to information retention. A statistical analysis was conducted on the random sample and measured using the Kuder-Richardson Formula 20 Reliability Method. The results of the analysis showed, on average, reliability coefficients of .81 for the identification test, .77 for the comprehension test, and .92 for the overall criterion total" (Dwyer, 1987, p. xi). Because the criterion measures were used in many previous studies and have been determined to be reliable, the researcher is confident these criterion measures will provide the reliability and validity necessary to show if there is any statistical difference between the control and treatment groups.

Development of Instructional Material

Questions developed for the *Heart University* game were based on the EIM instructional module developed by Dwyer with Lamberski's visual additions. A total of fifty-five (55) questions were developed to reinforce the heart parts and processes material presented in the instructional material. The researcher developed materials similar to the EIM assessment criterion but purposefully avoided the duplication of questions found on the assessments. All new content was derived from the adapted instructional material; no new information about the human heart's parts or functions was presented to the subjects. As such, all new material was designed to reinforce the instructional material and aid in rehearsal opportunities for the subjects.

Creating the Stimulus

The Experimental Instructional Materials comprising the original text developed by Dwyer and the visual images created by Lamberski evolved into twenty learning modules within the Desire2Learn (D2L) Learning Environment. To minimize the study's technical needs and reduce their extraneous cognitive load, each learning module and associated image was adapted to be displayed within the D2L environment. The alternative was to utilize a presentation application such as Microsoft's PowerPoint or a newly developed Adobe Flash environment. However, the researcher determined that having subjects leave the D2L course might lead to subject confusion and confound the results of the study.

In addition to the original instructional module, the researcher utilized D2L's Gamification module to study the effects of learner behavior within a gaming environment. The original EIM instructional unit, the newly developed game, a demographic survey, and the associated EIM assessments were combined to form a course within the D2L Learning Environment. By changing only the game within the course to apply the experimental treatments, the research utilized a total of three courses for this study: course one for the control group, course two for treatment one, and course three for treatment two. Examples of the original Dwyer content and Lamberski visuals that were adapted for use in the D2L course can be seen in Figures 3, 4, and 5. All twenty instructional modules that were presented in the Desire2Learn (D2L) Learning Management System (LMS) can be found in Appendix D.

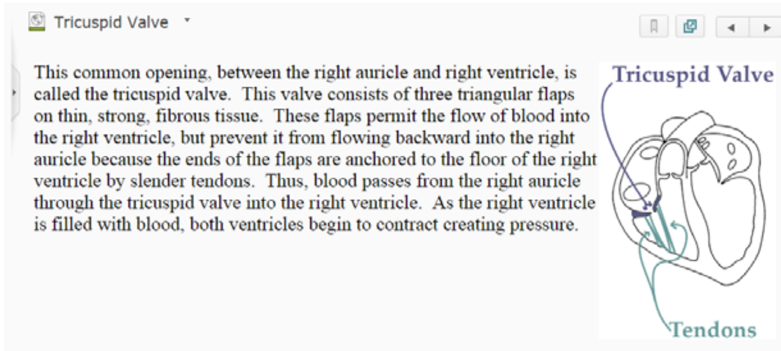

Figure 3. Adapted LMS instructional unit.

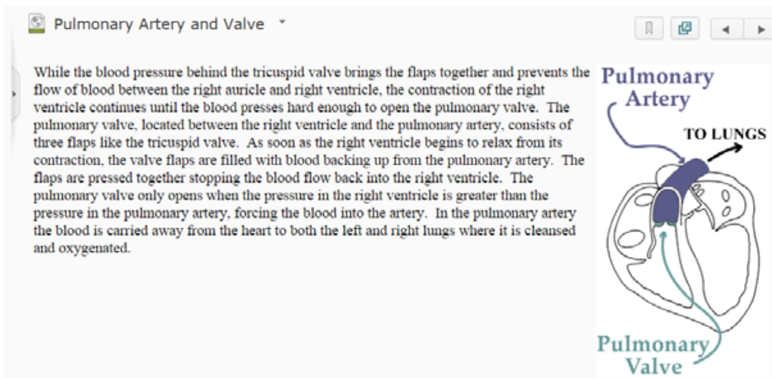

Figure 4. Adapted LMS instructional unit.

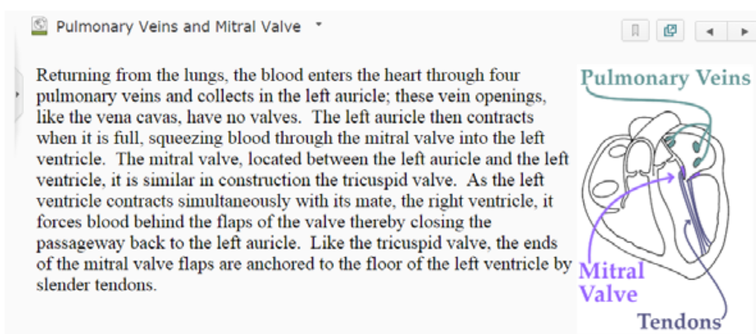

Figure 5. Adapted LMS instructional unit.

The gaming environment used for this study was Desire2Learn's (D2L) Gamification Module. Designed as a serious learning game, D2L's Gamification Module is a single-player quest-type video gaming environment that includes a motivational reward system within the game course. Players represented by customizable avatars journey through an instructor-designed map, stopping at waypoints to complete tasks (activities comprising one or many questions) designed by the instructor. As players answer questions correctly, they receive points that allow them to earn badges toward an overall goal or game objective. The Gamification Module also utilizes additional functionality such as a leaderboards, level advancements, and team challenges. While these features create competition among students in a class, they are not the focus of the study in this dissertation and will not be variables in the analysis. The short duration of this study combined with the nature of the instructional material cause these features to be inconsequential to the study. Future research studying the effects of competition among groups of subjects may impact the design of serious learning games.

Using the D2L Gamification module, the researcher created a quest game called Heart University. Subjects use a predesigned avatar to travel in a fictitious university campus setting, stopping at campus buildings (the defined waypoints) to complete activities defined as a series of questions. For each question the subject answers correctly they are awarded 1 point toward specific badges. After earning seven badges, the subject will be awarded a diploma from Heart University. Figure 6 below shows the opening screen when a student begins their Heart University experience and Figure 7 shows the campus map from the student/subject's role in the course.

Figure 6. Heart University opening screen.

Figure 7. The campus map.

After selecting the activity at each campus building, the subject is presented with an activity where they are required to answer a specific number of questions as designated by the researcher. The D2L Gamification module uses four activity types that are described in Table 2.

Table 2

D2L Gamification Activities

Activity Type	**Activity Description**
Matching	An activity that presents students with several images containing pictures or text and challenges them to categorize these images.
Hotspot	An activity that challenges students to identify an area of an image and answer questions about the area.
Question and Answer	A typical multiple choice type activity that requires students to choose one or all answers that apply.
Sorting	An activity that challenges students to order or prioritize a set of images or words.
Branching Scenario	An activity that challenges students to navigate a conversation or procedure, choosing the best response.

These activity types demonstrate how technological advancements can impact the tools having an effect within serious educational games. Future studies should explore the impact, if any, the use of different question types for information rehearsal has on retention. Since activity type was not the focus of this study, the researcher utilized only the question-and-answer activity type. The researcher deemed these types were closest to the objectives of Dwyer's Program of Systematic Evaluation.

Figure 8 is an example of a question and answer activity given to the Control Group and Treatment Group 1. Treatment Group 2 will receive a visual hint in addition to the question; an example of an activity for Treatment Group 2 can been found in Figure 9.

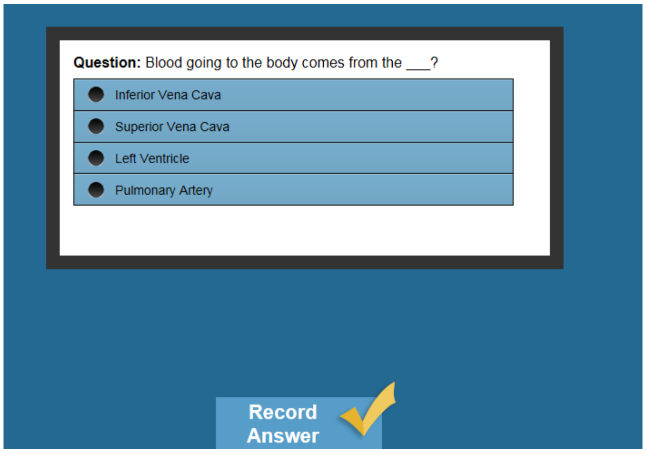

Figure 8. Activity as seen by Control Group and Treatment 1 groups.

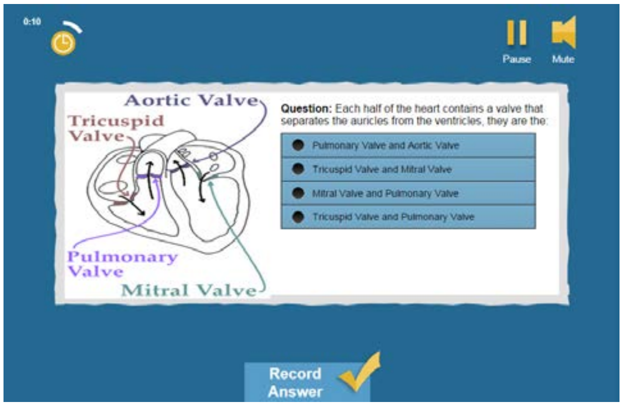

Figure 9. Activity as seen by Treatment Group 2.

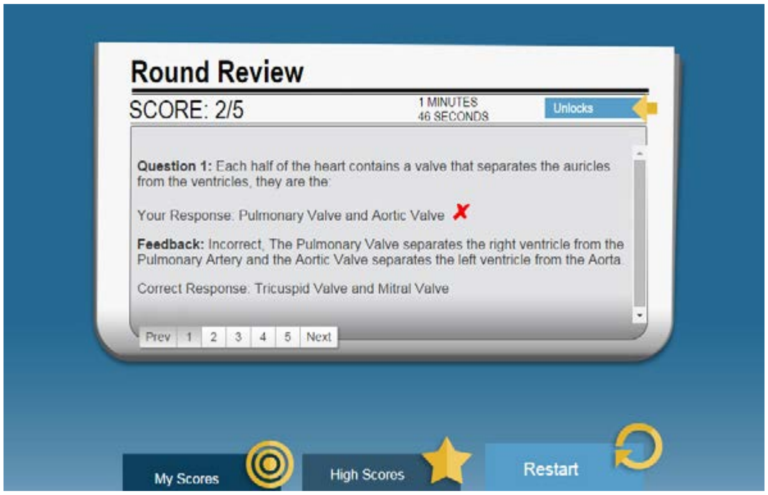

Figure 10. Elaborate feedback as seen by Treatment Group 1 and 2.

Subject Selection

Recruitment of Subjects

Prior to the recruitment of any subjects, this study received approval by the Indiana University of Pennsylvania's Institutional Review Board (IRB) for the use of human research subjects. Subjects were recruited from among undergraduate students at Indiana University of Pennsylvania (IUP), making the sample a convenience sample. IUP is a regionally accredited doctoral and research university with approximately 15,000 students, of which 85% are undergraduate. Emails were sent to the instructors of the targeted classes seeking approval for subject recruitment. To encourage participation the researcher purchased VISA gift cards to be awarded from a random drawing from all subjects. The researcher or designee attended a regularly scheduled class session and gave a brief overview of the study, the study's procedures, the list of available sessions, the expectations of each subject, and an explanation of the incentives. All students agreeing to participate signed a consent agreement, all further communication pertaining to the session times were provided via email provide on the consent agreement.

The Participants

In total, 15 classes enrolling 415 students were approached for participants. From these visits, 123 students indicated a willingness to participate by submitting a sign-up sheet and 65 completed the study. There were 22 students in both the Control Group and Treatment Group 2 and 21 students in Treatment Group 2, for a total of 65 subjects. Students agreeing to participate were asked to visit a website to sign up for one of eight designed sessions. Each subject was randomly assigned to either the Control Group, Treatment Group 1, or Treatment Group 2 upon entering the computer lab. In the experiment, a limiting factor was the timeframe in which the gaming environment was available. While the emphasis on acquiring subjects targeted at least 30 per group, only 21-22 subjects per group were able to participate in the timeframe available. Because of the small sample size there are limits as to the inferences that can be made as a result of the statistical analysis. In particular, it is possible that some significant differences may not be seen because of the smaller sample size. Some of the findings contained in chapter four in particular the lack of significance, might not be representative of the effect delayed elaborative feedback, visual hints and selected demographic variables have on transfer of information from working memory to long-term memory. However, the findings here were in line with other studies examining demographics and games. Expanding the timeframe of the study to collect additional subjects was problematic because of time constraints related to access for the gaming environment.

To not bias the results, all subjects were asked about their knowledge of the parts and functions of the human heart. The demographic survey asked subjects about courses they might have taken that would include knowledge of the human heart. No subject indicated that they had prior knowledge of the human heart from their university coursework.

Procedure

Subjects in the study were permitted to control the time it took to review the module, on average it took about 20 minutes to review the instructional material. Most subjects completed the experiment in about 45 minutes. They had the ability to review all material to their satisfaction prior to beginning the game with experimental treatments. Additionally, before being presented with the instructional module, each subject read an introduction that explained the purpose of the study, the controls used within the learning management system to navigate the module, a brief introduction to the game, and the criterion tests they should expect upon completion of the game.

The study was conducted in September 2015 at Indiana University of Pennsylvania. This section contains information about the recruitment of subjects, an overview of the study's participants, a review of the research design to include a description of the gaming environment and treatments, the experimental procedures used for the major study, and the statistical analysis procedures.

All three groups were presented with the same instructional module adapted from the Dwyer EIM material on the parts and function of the human heart via the D2L Learning Environment. Additionally, after all subjects had sufficient time to review the instructional module, all subjects across the three groups (control, treatment 1 and treatment 2) was presented with the same 34 questions developed. The presentation materials presented to all three groups were displayed within the D2L Gamification environment as activities on the Heart University campus map. The only difference between the materials presented to the three study groups was the application of the treatments within the Heart University game. A description of each treatment follows below in Table 3.

Table 3.

Treatments Applied in Heart University

Treatment	**Brief Description**	**Full description**
Control Group	Instructional Game with No Learning Strategies Applied	The Control Group will play the Heart University game with no treatments applied. They will be presented with the same newly developed material, providing an opportunity for rehearsal of the material in the EIM instructional material. Subjects will not be informed of the correctness or incorrectness of their answers; however, they will earn badges toward their diploma and have knowledge of their overall achievement within the game.
Treatment Group 1	Instructional Game with Elaborate Feedback	Subjects in Treatment Group 1 will play the Heart University game and be provided with elaborate feedback during the review after each game activity. Each game activity contains 1-5 questions and after completing an activity the subjects will review each question with the knowledge of the correctness or incorrectness of their answer and elaborate feedback as to why their answer was correct or incorrect. Subjects will have knowledge of why they did or did not earn their badges toward their Heart University diploma. This group will be provided an opportunity for rehearsal of

		the EIM instructional material with the additional reinforcement of elaborate feedback.
Treatment Group 2	Instructional Game with Visual Hints and Elaborate Feedback	Subjects in Treatment Group 2 will play the Heart University game and as with treatment group 1, they were provided with elaborate feedback during the review after each game activity. However, during game play, when presented with a question, this group will be presented with a visual hint as to the correct answer. Figure 3.7 above provides an example of a visual hint. Subjects had knowledge of the correct answer before they answer the question in addition to the same elaborate feedback as Treatment Group 1. This group will be given reinforcement of the EIM instructional material during game play and be provide with an opportunity for rehearsal in the form of elaborate feedback during the activity review.

Research Design

The researcher employed a post-test only experimental design to investigate the effect delayed elaborate feedback and visual hints have on the achievement of learning objectives within a gaming environment. The study examined the effect of several independent variables, the learning strategies (delayed elaborate feedback and visual hints) within the game and any interaction specific demographic variables (age, gender, class standing, gaming experience and credits earned) had with the game version. The study's dependent variables were achievement of learning objectives of each group based on performance on the identified three criterion measures and comprehensive score. A subject's achievement on the learning objectives was measured by the individual and total scores of three assessments: an identification assessment, a drawing assessment, and a comprehension assessment along with a fourth criterion measure that was the total of all three assessments (a comprehensive score). For statistical analysis the alpha level was set to *p*=.05 and a two-way analysis of variance (ANOVA) with a Turkey's HSD extension was used for the statistical test.

As previously stated, all subjects were instructed to review the adapted EIM instructional material based on the parts and functions of the human heart. After a review of the instructional material, each subject played the Heart University game and was presented with the same questions within the game. Depending on which group each subject was randomly assigned, the game would present either no treatment (Control Group), delayed elaborate feedback during the activity review (Treatment Group 1), or visual hints during the game activity and delayed elaborate feedback during the activity review (Treatment Group 2). Immediately after playing the Heart University game, every subject took the three EIM assessments (identification, terminology, and comprehension). Each subject was allowed to review the material and play the game at his or her own pace. On average, the entire study lasted approximately one hour. The individual scores on these assessments as well as the combined total for each subject was analyzed using two-way ANOVA test with a Turkey's HSD extension in SPSS.

Experimental Procedures

The experiment was conducted in two computer labs in Stouffer Hall on the main campus of Indiana University of Pennsylvania. Daily sessions over a three-day period (Monday, Tuesday, and Wednesday) were offered to subjects to participate. The researcher monitored the labs from 8am to 6pm each day, allowing the subjects to arrive any time most convenient to them. Upon entering the computer lab, students were given a sheet of paper with a unique username and password, brief instructions, and the drawing assessment (on the back of the sheet). The specific username corresponded to the version of the game presented to the subject. The Control Group was provided usernames to course one, Treatment Group 1 subjects were provided usernames to course two, and subjects in Treatment Group 2 were given usernames for course three. Each of the respective courses was identical in content and functionality except for the version of the treatments applied in the Heart University game. The version of the game contained the same activities; however, each Treatment Group received a unique treatment, and the Control Group did not.

As the subjects entered the computer lab, they were asked to print their first and last name along with their signature. After signing in, the subjects were handed a sheet of paper and asked to sit at any available computer. Web browsers were already launched and the course site was already loaded on each computer. The subjects were instructed to use the username and password provided on the paper and to begin the experiment when ready. No identifiable information was collected to connect the subjects and unique username, providing for anonymous data collection.

After successfully signing in using the provided unique username and password, each subject was presented with an informed consent screen, verified that they were eighteen years of age or older and asked for permission to proceed. Upon receiving permission to proceed, all subjects were presented with a short demographic survey. The demographic survey can be found in Appendix E. If any subject was under the age of eighteen, the subject would not have been permitted to proceed, thanked for his or her participation and excused. No subjects under the age of eighteen participated in the survey.

When the subjects finished the demographic survey, all groups were asked to read the twenty D2L units containing instructional content adapted from the EIM materials on the parts and functions of the human heart. Upon review of all the instructional material, the subjects launched the Heart University game which presented the subject with one to five questions in each game activity. Each multiple choice question had four or five possible answers with only one answer being the correct answer.

After a subject selected an answer, he or she would hit the record answer button and, depending on the answer, may or may not receive points toward a badge. Treatment Groups 1 and 2 were allowed to review their answers and received elaborate feedback after the entire activity (1-5 questions) had been completed. There was no minimum or maximum time limit imposed during the experiment, and the researcher was present in the room to answer any questions and to ensure there were no disturbances.

Chapter Summary

This chapter described why the Dwyer EIM instructional module was selected and how it was adapted for this study. An in-depth description for the criterion measures and associated reliability as well as described the development of instructional material was provided. Finally, this chapter provided a detailed description of how the subjects were recruited and the experimental procedures used by the researcher.

CHAPTER FOUR

FINDINGS

Introduction

The study in this dissertation investigated the effects that delayed elaborate feedback and visual hints have on the immediate retention of information. After reading the same instructional material, subjects played one of three quest-type serious education games: a control group that did not receive any feedback or visual hint, a group that received elaborate feedback, and a group that received both elaborate feedback and visual hints. Guiding this study was a theoretical derivative of cognitive science, Information Processing Theory. This theory and investigating how cognitive overload interacts with it served as the foundation for this study. To test the effects of learning objective achievement, a post-test only experiment was developed which employed three assessments and a comprehensive score.

The Treatments

The established Dwyer Experimental Instructional Materials were chosen for the instructional material because of the recognized validity and reliability of the content and associated assessments. Dwyer's instructional module, as well as Lamberski's visual adaptations, were modified to utilize in the Desire2Learn Learning Environment. Additionally, the Desire2Learn Games Based Learning module was employed for the gaming environment where the treatments were applied. As depicted in Table 4, the control group played the game with no feedback to their answers or visual hints, Treatment 1 applied the use of elaborate feedback after each game activity, and Treatment 2 used the same elaborate feedback as Treatment 1 with the addition of a visual hint within the game activity.

Table 4

Description of Game Treatments

Subject Group	Treatment	Number of Subjects
Control Group	No treatment	22
Treatment 1	Delayed Elaborate Feedback	21
Treatment 2	Delayed Elaborate Feedback and Visual Hints	22

Profile of the Sample

Undergraduate students from Communications Media, Business, Education, and Safety Science courses were invited to participate in this study. This convenience sample avoided the selection of students who might have prior knowledge of the instructional material. There were 22 students in the control group, 21 in treatment 1 group, and 22 in treatment group 2, for a total of 65 subjects. Recruitment began with permission from instructors to visit their respective classes and solicit participants. From class visits, 123 students signed the letter of invitation agreeing to join the study. Students agreeing to participate were asked to visit a website to sign up for a designed timeslot. Of these 123 initial commitments, 48 students selected a designated time to participate and 65 students actually participated. Email reminders sent to all participants prompted many students who did not select a designated timeslot to join the study. Each subject was randomly assigned to either the control group, treatment group 1, or treatment group 2 upon entering the computer lab.

Overall gender distribution was close to even, with 10% more males participating than females. The control group and treatment group 2 saw the same 10% disparity, while treatment group 1 was slightly closer to a more equitable split. Table 5 illustrates the gender division among groups. Hypothesis 3 examined how gender effected achievement on the criterion tests across all three groups.

Table 5

Gender and Game Treatment

Gender		Control Group	Treatment Group 1	Treatment Group 2	Total
Female	#	10	9	10	29
	%	45%	43%	45%	45%
Male	#	12	12	12	36
	%	55%	57%	55%	55%
Total	#	22	21	22	65
	%	100%	100%	100%	100%

As the focus of hypothesis 4, subjects' academic standing (GPA) was examined to determine if it has any interactive effect on the type of game a student played and their ability to transfer information to long-term memory. Table 6 below illustrates the division of a student's academic standing across all groups. Ten subjects did not report their GPA: either they did not wish to report, or more than likely they were first-semester freshman or freshman transfers and had not earned enough credits to have a GPA.

Table 6

Class Standing (GPA) and Game Treatment

GPA		Control Group	Treatment Group 1	Treatment Group 2	Total
2.0 – 2.5	#	2	0	0	2
	%	11%	0%	0%	4%
2.6 – 3.0	#	5	2	5	12
	%	26%	11%	28%	22%
3.1 – 3.5	#	6	7	10	23
	%	32%	39%	56%	42%
3.6 – 4.0	#	6	9	3	18
	%	32%	50%	17%	33%
Total	#	19	18	18	55
	%	100%	100%	100%	100%

The distribution of age across the game groups was evenly distributed—both the control group and treatment group 2 had 22 subjects, while treatment group 1 had 21. No student under the age of 18 participated in the study, and only eight subjects report their age as 23 years of age or older. Hypothesis 2 examined the effect a subject age and the game they played to determine if there was any effect on their achievement on the criterion tests. Table 7 illustrates the division of age across all groups.

Table 7

Age and Game Treatment

Age		Control Group	Treatment Group 1	Treatment Group 2	Total
18	#	3	4	4	11
	%	14%	19%	18%	17%
19	#	5	3	4	12
	%	23%	14%	18%	18%
20	#	3	5	4	12
	%	14%	24%	18%	18%
21	#	4	2	5	11
	%	18%	10%	23%	17%
22	#	5	3	3	11
	%	23%	14%	14%	17%
23+	#	2	4	2	8
	%	9%	19%	9%	12%
Total	#	22	21	22	65
	%	100%	100%	100%	100%

Very few freshman participated in the study; however, 11 subjects reported their age was 18. This may indicate that a number of the subjects may have earned college credit prior to the start of their first fall semester. Or some may have started their post-secondary education at age 17, beginning their sophomore year at age 18 and participating in the study prior to their 19th birthday. Hypothesis 5 examined if there was any effect on the number of credits a student earned, the game they played, and their achievement on the criterion tests. Table 8 illustrates the distribution of the amount of credits across the groups.

Table 8

Credits Earned and Game Treatment

Class Ranking		Control Group	Treatment Group 1	Treatment Group 2	Total
Freshman	#	2	0	0	2
	%	11%	0%	0%	4%
Sophomore	#	5	2	5	12
	%	26%	11%	28%	22%
Junior	#	6	7	10	23
	%	32%	39%	56%	42%
Senior	#	6	9	3	18
	%	32%	50%	17%	33%
Total	#	19	18	18	55
	%	100%	100%	100%	100%

Measured in terms of number of years, subjects were asked their experience playing digital video games. Table 9 illustrates the subjects' gaming experience across the groups. Subjects participating in the study mostly fell in the outer ranges of gaming experience. Fifteen percent of all subjects reported as having no gaming experience, while 55% reported has having 8 or more years of gaming experience. Hypothesis 6 examined the effect a subjects gaming experience and their achievement on the criterion tests.

Table 9

Gaming Experience and Game Treatment

Gaming Experience		Control Group	Treatment Group 1	Treatment Group 2	Total
None	#	3	3	4	10
	%	14%	14%	18%	15%
0-2 Years	#	0	1	1	2
	%	0%	5%	5%	3%
2-4 Years	#	2	2	1	5
	%	9%	10%	5%	8%
4-6 Years	#	2	1	2	5
	%	9%	5%	9%	8%
6-8 Years	#	3	0	4	7
	%	14%	0%	18%	11%
8-10 Years	#	5	3	4	12
	%	23%	14%	18%	18%
10+ Years	#	7	11	6	24
	%	32%	52%	27%	37%
Total	#	22	21	22	65
	%	100%	100%	100%	100%

Statistical Techniques

Focusing on the first research question—the effect that delayed elaborate feedback and visual hints have on information retention in long-term memory—the researcher examined the individual and comprehensive scores on the post-tests between the control and treatment groups. The first hypothesis tested the achievement scores on each of the criterion tests, as well as the overall comprehensive score.

The second research question examined how demographic factors affected the ability of the subjects to retain information in long-term memory. Five hypothesis were tested to understand the impact that five independent demographic variables have on the transfer of information into long-term memory.

A one-way ANOVA test was conducted on the dependent variables (drawing test, identification test, comprehension test, and comprehensive scores) in H_o1 for examination of RQ1. All of the variables were measured using ratio level data. Each test was 20 points, while the comprehensive score was a based on 60 points. As a result of the ANOVA's assumption of homogeneity of variance between the groups, Levene's test was used to assess if the groups have similar variances. If the results of Levene's test are not significant, there is an assumption of equality of variances and an ANOVA test was used.

Because all hypotheses for RQ2 investigated the effects of demographic combinations with learning strategies and their effect on transferring information to long-term member, the researcher utilized a two-way ANOVA. Inclusion of the results for Levene's test is for information purposes only. Since SPSS was employed for all analysis, an automatic adjustment was made for any issues of homogeneity of variances.

Results

RQ1: What impact will delayed elaborate feedback only or delayed elaborate feedback with visual hints in activities within a gaming environment have on a learner's ability to retain information?

Research question one investigated the effect exposure to delayed elaborate feedback and visual hints have on transfer of information from working to long-term memory. Other variables, such as demographic information analyzed for RQ2, were not taken into consideration for the analysis of RQ1. Achievement on three 20-point assessments and a comprehensive score combining all three scores were used for this analysis.

H_o1: There will be a statistically significant difference between the control group, the elaborate feedback treatment only group, and the delayed elaborate feedback with visual hint treatment group in subject achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores).

To test this hypothesis, scores on each of the three criterion tests, as well as a comprehensive score, were analyzed for each treatment group. All statistical tests conducted were one-way ANOVA tests. The results from the SPSS analysis are in Tables 10 – 13

This first test for hypothesis 1 examined the scores on the comprehension test across the treatment groups. Levene's test was not significant (2.228); thus, an F-test was used for the ANOVA. Results of the test did not show a significant difference between the groups, indicating that the use of feedback or visual hints along with feedback does not significantly impact comprehension. However, the mean score (m=11.32) of the group exposed to elaborate feedback and visual hints was higher than the other two groups. A larger subject size might find a greater disparity in the means and a significant finding.

Table 10

One-Way Analysis of Variance for Comprehension Scores

Treatment Group	N	Mean	Std. Dev.	Std. Error	F-value	Sig.
Control	22	9.59	3.838	.818	.966	.386
Feedback Only	21	9.76	4.392	.958	df=2,62	
Feedback & Visual Hints	22	11.32	5.241	1.117		
Total	65	10.23	4.527	.561		

Note. Levene's = 2.228 (df= 2,62) p = .116

The second statistical test for hypothesis 1 investigated the scores on the identification test across the treatment groups. Just as in the test for the comprehension scores, the Levene's test was not significant (.613); thus, an F-test was used for the ANOVA. However, as shown in Table 11, there is a significant difference between the three groups, revealing that the learning strategies used in the game did affect the transfer of information from working memory to long-term memory. Students who were given a visual hint and elaborate feedback scored significantly higher than students in the control group who were given neither elaborate feedback nor visual hints.

Table 11

One-Way Analysis of Variance for Identification Scores

Treatment Group	N	Mean	Std. Dev.	Std. Error	F-value	Sig.
Control	22	9.50	3.827	.816	3.724	.030
Feedback Only	21	10.00	3.347	.730		
Feedback & Visual Hints	22	12.55	4.585	.978	df=2,62	
Total	65	10.69	4.127	.512		

Note. Levene's = .613 (df= 2,62) p = .545

Table 12 shows that, similar to the comprehension test, there is no significance difference between the groups and the drawing test. However, unlike the results from the comprehension test, the control group actually has the highest mean score. Still, the difference in the mean score between the control group and the group getting elaborate feedback and visual hints is not as great as the difference from the comprehension test.

Table 12

One-Way Analysis of Variance for Drawing Scores

Treatment Group	N	Mean	Std. Dev.	Std. Error	F-value	Sig.
Control	21	14.43	3.749	.818	1.585	.213
Feedback Only	21	12.33	4.608	1.006	df=2,61	
Feedback & Visual Hints	22	14.27	4.377	.933		
Total	65	13.69	4.302	.538		

Note. Levene's = .788 (df= 2,61) p = .459

As with the comprehensive and drawing tests, Table 13 shows no significant difference among the groups. However, the means of the control group and feedback group are close, and the group exposed to the feedback and visual hints (group 3) has a much higher mean score. This could indicate that the effect of using elaborate feedback and visual hints in a gaming environment may have an impact on transfer of information from working memory to long-term memory. With the significance level shown in Table 13, a larger sample size might yield a significant finding.

Table 13

One-Way Analysis of Variance for Comprehensive Scores

Treatment Group	N	Mean	Std. Dev.	Std. Error	F-value	Sig.
Control	22	32.86	9.548	2.036	1.839	.168
Feedback Only	21	32.10	11.045	2.410	df=2,62	
Feedback & Visual Hints	22	38.14	13.058	2.784		
Total	65	34.40	11.460	1.421		

Note. Levene's = .788 (df= 2,61) p = .459

Taking the small sample size into consideration, the statistical analysis for RQ1 indicates that the addition of elaborate feedback and visual hints within a serious education game may foster the processing of information from working memory to long-term memory. While only the identification test had a statistically significant finding, the mean scores for the comprehension could also indicate the use of learning strategies had a positive effect. A larger sample size could result in a more definitive analysis. Limitations discussed in chapter five regarding the drawing test may have had an adverse effect on the overall comprehensive score. A larger sample size and the discounting of the drawing test could be objectives for a future research.

RQ2: Will demographic factors interact with delayed elaborate feedback or delayed elaborate feedback with visual hints as learning strategies employed within a gaming environment for achievement of information retention?

The second research question examines the effect that demographic variables have on the transfer of information to long-term memory. In the literature review, a range of studies examining demographic factors and games were considered. As the results below show, the findings here were essentially consistent with other studies of demographics and games. Similar to the testing of the first hypothesis, each hypothesis tested for this research question analyzed scores for each of the 3 criterion tests and a comprehensive score. As previously stated, because a two-way ANOVA was used for these hypotheses, SPSS made an automatic adjustment for any issues of homogeneity of variances. Inclusion of the results from the Levene's test is only informational.

H_o2: There will be a statistically significant difference between subjects' age and achievement on the criterion tests (drawing, identification, comprehension, comprehensive

test scores) among the control group, the delayed elaborate feedback treatment only group, and the delayed elaborate feedback with visual hint treatment group.

Scores from the comprehension, identification, and drawing tests were tested to determine the effect that age and game group had on achievement. A 6 x 3 two-way ANOVA was conducted to determine if age, the first factor (18, 19, 20, 21, 22, or 23 and over), and the second factor, game played (control, treatment 1 or treatment 2), had any effect on achievement on the scores from each posttest. Table 14 through 16 provided a summary of the results. These findings for interaction between a subject's age and use of a serious educational game is consistent with the research of Mayer, Warmelink, and Bekebrede whereby a student's age does not effect an individual's ability to play the game. Any effect age has on game play is constrained to an individual's comfort level during the actual game play (I. Mayer et al., 2013). A larger sample size might be needed to substantiate these findings, however given prior research and these findings, a qualitative approach might help understand an individual's comfort level in playing serious educational games with respect to their age.

Table 14

Two-way Analysis of Variance for Comprehension

Independent Variable	SS	df	MS	F	Sig.
Game	42.042	2	21.021	.888	.418
Age	52.176	5	10.435	.441	.818
Game x Age	93.359	10	9.336	.395	.943
Within (Error)	1112.000	47	23.660		
Total	1311.538	65			

Note. Levene's = 1.623 (df= 17,47) p = .096

Table 15

Two-way Analysis of Variance for Identification

Independent Variable	SS	df	MS	F	Sig.
Game	106.428	2	53.214	3.519	.038
Age	132.660	5	26.532	1.754	.141
Game x Age	145.744	10	14.574	.964	.487
Within (Error)	710.800	47	15.123		
Total	1089.846	65			

Note. Levene's = 2.465 (df= 17,47) p = .008

Table 16

Two-way Analysis of Variance for Drawing

Independent Variable	SS	df	MS	F	Sig.
Game	60.784	2	30.392	1.430	.250
Age	60.714	5	12.143	.571	.721
Game x Age	63.392	10	6.339	.298	.978
Within (Error)	977.450	46	21.249		
Total	1165.750	64			

Note. Levene's = 1.513 (df= 17,46) p = .133

While there was no statistically significant impact between a subject's age, the game version they played and achievement on the comprehension test, a comparison of the mean scores indicates that some age groups did perform as expected. As seen in Table 17 below, subjects 18 years old or 23 and older had mean scores that increased when exposed to additional learning strategies. Also, with the exception of the 19 year old group, mean scores were higher on the group exposed to both the visual hints and elaborate feedback. This might indicate that either the visual hints themselves or the combination with elaborate feedback yields more positive results than elaborate feedback alone.

Table 17

Mean Comprehension Scores by Age

Group and Age		Mean	Std. Dev.	N
Control	18	10.33	5.86	3
	19	11.20	5.59	5
	20	7.00	1.73	3
	21	11.50	3.11	4
	22	8.20	1.92	5
	23+	8.00	1.41	2
Feedback Only	18	11.50	6.25	4
	19	8.00	5.00	3
	20	10.40	3.78	5
	21	7.50	2.12	2
	22	8.33	4.04	3
	23+	10.75	5.19	4
Feedback & Visual Hints	18	12.25	7.59	4
	19	9.75	5.68	4
	20	10.25	6.02	4
	21	13.60	3.91	5
	22	9.67	6.35	3
	23+	11.50	2.12	2
Totals	18	11.45	6.04	11
	19	9.92	5.14	12
	20	9.50	4.23	12
	21	11.73	3.85	11
	22	8.64	3.64	11
	23+	10.25	3.81	8

Similar to the comprehension test, analysis of the identification test did not produce a statistically significant finding for specific age groups. However, in comparing the means, in general subjects who received the visual hints and elaborate feedback scored higher than the control group. The only exception were the 20 year old subjects. Like the comprehension test, this might indicate that the addition of elaborate feedback alone does not have enough of an effect as combined with visual hints. Or, the use of elaborate feedback has no effect and visual hints alone are contributing to the higher scores. The mean scores for all age groups by game group can be found in Table 18 below.

Table 18

Mean Identification Scores by Age

Group and Age		Mean	Std. Dev.	N
Control	18	13.67	4.93	3
	19	8.80	5.63	5
	20	8.33	1.53	3
	21	8.00	2.45	4
	22	9.00	2.65	5
	23+	11.00	2.83	2
Feedback Only	18	11.75	3.59	4
	19	9.33	4.04	3
	20	9.60	3.36	5
	21	7.50	6.36	2
	22	12.00	1.00	3
	23+	9.00	2.71	4
Feedback & Visual Hints	18	13.75	3.30	4
	19	11.00	5.71	4
	20	8.00	6.06	4
	21	15.20	2.17	5
	22	13.00	3.00	3
	23+	15.00	4.24	2
Totals	18	13.00	3.61	11
	19	9.67	4.94	12
	20	8.75	3.89	12
	21	11.18	4.75	11
	22	10.91	2.88	11
	23+	11.00	3.70	8

Finally, a comprehensive score from the three criterion tests were combined and tested to determine the effect that age and game group had on overall achievement. A 6 x 3 two-way ANOVA was conducted to determine if age, the first factor (18, 19, 20, 21, 22, or 23 and over), and the second factor, game played (control, treatment 1 or treatment 2), had any effect on achievement on the overall comprehensive scores. The results are summarized on Table 19. These findings signify that the game played, age, and the interaction between the two had no effect on the overall comprehensive score.

Table 19

Two-way Analysis of Variance for Comprehensive

Independent Variable	SS	df	MS	F	Sig.
Game	491.389	2	245.695	1.697	.194
Age	556.510	5	111.302	.769	.577
Game x Age	610.679	10	61.068	.422	.929
Within (Error)	6803.117	47	144.747		
Total	8405.600	65			

Note. Levene's = 1.308 (df= 17,47) p = .229

H_o3: There will be a statistically significant difference between subjects' gender and achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores) among the control group, the delayed elaborate feedback treatment only group, and the delayed elaborate feedback with visual hint treatment group.

Scores from the comprehension, identification, and drawing tests were tested to determine the effect gender and game group had on achievement. To determine if gender, the first factor (female or male), and the second factor, game played (control, treatment 1 or treatment 2), had any effect on achievement on scores from all three post-tests, a 2 x 3 two-way ANOVA was conducted. A summary of results can be found on Table 20 through Table 22. These findings indicate that the game played, gender, and the interaction between the two had no effect on achievement for any of the post-tests. Described in more detail in the limitations section of chapter five, further research with a larger sample size or a similar study conducted over a longer time period could be conducted to support these findings.

Table 20

Two-way Analysis of Variance for Comprehension

Independent Variable	SS	df	MS	F	Sig.
Game	43.543	2	21.771	1.021	.367
Gender	.254	1	.254	.012	.913
Game x Gender	13.042	2	6.521	.306	.738
Within (Error)	1258.622	59	21.333		
Total	1311.538	65			

Note. Levene’s = 1.705 (df= 5,59) p = .148

Table 21

Two-way Analysis of Variance for Identification

Independent Variable	SS	df	MS	F	Sig.
Game	113.297	2	.012	3.442	.039
Gender	.012	1	.913	.001	.978
Game x Gender	1.825	2	16.460	.055	.946
Within (Error)	971.117	59			
Total	1089.846	65			

Note. Levene's = .651 (df= 5,59) p = .662

Table 22

Two-way Analysis of Variance for Drawing

Independent Variable	SS	df	MS	F	Sig.
Game	56.497	2	28.249	1.495	.233
Gender	7.717	1	7.717	.409	.525
Game x Gender	4.813	2	2.406	.127	.881
Within (Error)	1095.727	58	18.892		
Total	1165.750	65			

Note. Levene's = 1.238 (df= 5,58) p = .303

In addition to the two-way ANOVAs not indicating any statistically significant difference between a subject's gender and achievement on the comprehension post-test, a comparison of the means also did not indicate any additional effect. Table 23 shows the distribution of males and females fairly equal for each of the three groups and mean scores for each gender were relatively close. Males in the control and feedback only groups scored slightly higher, however females scored higher in the feedback and visual hints group. As seen in table 23, results for the identification test are in conflict with the comprehension scores.

Table 23

Mean Comprehension Scores by Gender

Group and Gender		**Mean**	**Std. Dev.**	**N**
Control	Female	9.00	3.33	10
	Male	10.08	4.30	12
Feedback Only	Female	9.56	5.43	9
	Male	9.92	3.68	12
Feedback & Visual Hints	Female	11.90	4.91	10
	Male	10.83	5.67	12
Totals	Female	10.17	4.63	29
	Male	10.28	4.51	36

Similarly to the mean scores for the comprehension test, scores for the identification test did not indicate any effect caused by gender. Scores seen in table 24 below are in conflict with the results from the comprehension test above. The differences between the scores were close than the comprehension test.

Table 24

Mean Identification Scores by Gender

Group and Gender		**Mean**	**Std. Dev.**	**N**
Control	Female	9.70	4.40	10
	Male	9.33	3.47	12
Feedback Only	Female	10.00	3.64	9
	Male	10.00	3.28	12
Feedback & Visual Hints	Female	12.30	5.58	10
	Male	12.75	3.82	12
Totals	Female	10.69	4.63	29
	Male	10.69	3.74	36

Finally, a comprehensive score from the three criterion tests were combined and tested to determine the effect that gender and game group had on overall achievement. A 2 x 3 two-way ANOVA was conducted to determine if the first factor, gender (female or male), and the second factor, game played (control, treatment 1 or treatment 2), had any effect on achievement on the drawing scores. Table 25 provides a summary of the results. The results signify that the game played, gender, and the interaction between the two had no effect on achievement on the overall comprehensive score. Notwithstanding the limitation of the small sample size, these finding are consistent with the prior research of Joiner et al. Whereby males may tend to play more digital games for a longer period of time, there is no difference between the motivation and level of engagement between males and females (Joiner et al., 2011). Beyond motivation and engagement, these findings might also suggest that there is no extraneous cognitive load for females considering that males tend to play digital video games more. This is an area where future research might examine the effect further.

Table 25

Two-way Analysis of Variance for Comprehensive

Independent Variable	SS	df	MS	F	Sig.
Game	465.706	2	232.853	1.737	.185
Gender	13.751	1	13.751	.103	.750
Game x Gender	9.351	2	4.675	.035	.966
Within (Error)	7911.356	59	134.091		
Total	8405.600	65			

Note. Levene's = 1.061 (df= 5,59) p = .391

H_o4: There will be a statistically significant difference between subjects' academic standing (GPA) and achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores) among the control group, the delayed elaborate feedback treatment only group, and the delayed elaborate feedback with visual hint treatment group.

Scores from the comprehension, identification, and drawing tests were tested to determine the effect that academic standing (GPA) and game group had on achievement. A 4 x 3 two-way ANOVA was conducted to determine if GPA, the first factor (2.0-2.5, 2.6-3.0, 3.1-3.5, and 36.-4.0), and the second factor, game played (control, treatment 1 or treatment 2), had any effect on achievement on scores from all three post-tests. Tables 26 through 28 provides a summary of the results. There were no significant findings from the three tests, indicating that there is no effect between the interaction of a subject's academic standing and game version played. As discussed in the limitations section, further research with a larger sample size or over a longer period of time could be conducted to corroborate these results.

Table 26

Two-way Analysis of Variance for Comprehension

Independent Variable	SS	df	MS	F	Sig.
Game	18.432	2	9.216	.421	.659
GPA	16.514	3	5.505	.251	.860
Game x GPA	38.644	4	9.661	.441	.778
Within (Error)	985.684	45	21.904		
Total	1054.836	55			

Note. Levene's = 1.138 (df= 9,45) p = .357

Table 27

Two-way Analysis of Variance for Identification

Independent Variable	SS	df	MS	F	Sig.
Game	74.410	2	37.205	2.174	.125
GPA	12.852	3	4.284	.250	.861
Game x GPA	54.315	4	13.579	.794	.536
Within (Error)	770.013	45	17.111		
Total	917.345	55			

Note. Levene's = 1.263 (df= 9,45) p = .283

Table 28

Two-way Analysis of Variance for Drawing

Independent Variable	SS	df	MS	F	Sig.
Game	62.740	2	31.370	1.533	.227
GPA	8.664	3	2.888	.141	.935
Game x GPA	60.895	4	15.224	.744	.567
Within (Error)	900.284	4	20.461		
Total	1032.833	54			

Note. Levene's = 1.012 (df= 9,44) p = .445

Mean scores from the comprehension test might indicate that exposure to both elaborate feedback and visual hints might effect students with a higher GPA to a greater degree. As seen in Table 29, mean scores for the treatment group receiving both elaborate feedback and visual hints were higher than the control group and feedback only group. While students with less than a 3.0 actually scored higher in the control group.

Table 29

Mean Comprehension Scores by GPA

Group and GPA		**Mean**	**Std. Dev.**	**N**
Control	2.0-2.5	12.00	7.07	2
	2.6-3.0	10.00	4.18	5
	3.1-3.5	9.50	3.62	6
	3.6-4.0	7.67	1.97	6
Feedback Only	2.0-2.5	-	-	0
	2.6-3.0	9.00	4.24	2
	3.1-3.5	8.71	3.63	7
	3.6-4.0	10.78	5.26	9
Feedback & Visual Hints	2.0-2.5	-	-	0
	2.6-3.0	9.80	5.50	5
	3.1-3.5	10.60	5.54	10
	3.6-4.0	11.33	5.69	3
Totals	2.0-2.5	12.00	7.07	2
	2.6-3.0	9.75	4.37	12
	3.1-3.5	9.74	4.45	23
	3.6-4.0	9.93	4.53	18

Finally, a comprehensive score from the three criterion tests were combined and tested to determine the effect that academic standing (GPA) and game group had on overall achievement. A 4 x 3 two-way ANOVA was performed in order to determine whether GPA, the first factor (2.0-2.5, 2.6-3.0, 3.1-3.5, and 36.-4.0), and the second factor, game played (control, treatment 1, or treatment 2), had any effect on achievement on the comprehensive scores. A summary of results is in Table 30. Thus, the game played, GPA, and the interaction between the two had no effect on achievement on the comprehensive score. Even though there were no significant findings between the interaction of a subjects GPA and achievement on the post-tests the mean scores indicate that subjects with higher GPAs may have benefited more from the elaborate feedback and visual hints. This reflects research conducted by Cavanaugh and Jacquemin (2015) that found students with higher GPAs will have higher achievement rates than students with lower GPAs. Future research with a larger sample size and over a longer period of time could result in a more definitive finding as to whether students with higher GPA have higher attainment rates than lower performing students.

Table 30

Two-way Analysis of Variance for Comprehensive

Independent Variable	SS	df	MS	F	Sig.
Game	293.775	2	146.888	1.074	.350
GPA	78.750	3	26.250	.192	.901
Game x GPA	332.928	4	83.232	.608	.659
Within (Error)	6155.979	45	136.800		
Total	6831.345	55			

Note. Levene's = .989 (df= 9,45) p = .462

H_o5: There will be a statistically significant difference between the number of credits (class ranking) subjects have earned and achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores) among the control group, the delayed elaborate feedback treatment only group and the delayed elaborate feedback with visual hint treatment group.

Scores from the comprehension, identification, and drawing tests were tested to determine the effect number of credits earned (class ranking) and game group had on achievement. Three 4 x 3 two-way ANOVAs were conducted to determine if class ranking, the first factor (freshman, sophomore, junior, and senior), and the second factor, game played (control, treatment 1 or treatment 2), had any effect on achievement on the comprehension scores. Tables 31 through 33 provide a summary of the results. There were no significant findings from the three tests, indicating that there is no effect between the interaction of the number of credits a subject has earned and the game version played. As discussed in the limitations section, further research with a larger sample size or over a longer period of time could be conducted to uphold these results.

Table 31

Two-way Analysis of Variance for Comprehension

Independent Variable	SS	df	MS	F	Sig.
Game	46.850	2	23.425	1.068	.351
Earned Credits	68.119	3	22.706	1.036	.385
Game x Earned Credits	70.886	6	11.814	.539	.776
Within (Error)	1140.125	52	21.925		
Total	1311.484	63			

Note. Levene's = 2.932 (df= 11,52) p = .004

Table 32

Two-way Analysis of Variance for Identification

Independent Variable	SS	df	MS	F	Sig.
Game	130.268	2	65.134	3.766	.030
Earned Credits	38.391	3	12.797	.740	.533
Game x Earned Credits	27.390	6	4.565	.264	.951
Within (Error)	899.300	52	17.294		
Total	1088.109	63			

Note. Levene's = 1.332 (df= 11,52) p = .234

Table 33

Two-way Analysis of Variance for Drawing

Independent Variable	SS	df	MS	F	Sig.
Game	105.583	2	52.791	3.182	.050
Earned Credits	98.372	3	32.791	1.976	.129
Game x Earned Credits	168.927	6	28.154	1.697	.141
Within (Error)	846.132	51	16.591		
Total	1158.413	63			

Note. Levene's = .563 (df= 11,51) p = .849

Even though there were no significant findings in the analysis of the comprehension test between the interaction of the game version and number of credits earned, the mean comprehension scores suggest future research to understand this better. Results in Table 34 below may indicate that upper-division students (junior and seniors) benefited more from exposure to elaborate feedback and visual hints than lower-division students (freshmen and sophomores). This is consistent with the findings of Boeker, Andel, Vach, and Frankenschmidt (2013) whereby upper division students seem to perform better when exposed to games based learning.

Table 34

Mean Comprehension Scores by Credits Earned

Group and Credit Earned		Mean	Std. Dev.	N
Control	Freshman	9.67	4.13	6
	Sophomore	11.50	6.40	4
	Junior	8.75	2.06	4
	Senior	9.00	3.12	8
Feedback Only	Freshman	8.80	3.27	5
	Sophomore	13.00	6.16	5
	Junior	9.88	3.36	8
	Senior	5.67	1.53	3
Feedback & Visual Hints	Freshman	11.00	8.25	4
	Sophomore	11.40	4.51	5
	Junior	11.25	4.50	8
	Senior	12.00	6.98	4
Totals	Freshman	9.73	4.95	15
	Sophomore	12.00	5.29	14
	Junior	10.20	3.64	20
	Senior	9.13	4.53	15

Comparison of the mean scores for the identification test were somewhat similar to the comprehension test, however as seen in Table 35 below, lower-division subjects (freshman and sophomores) also performed better when exposed to elaborate feedback and visual hints. This is not in conflict with the research conducted by Boeker, Andel, Vach, and Frankenschmidt (2013), however future research possibility with a larger sample size could bring more conclusive analysis for this research.

Table 35

Mean Identification Scores by Credits Earned

Group and Credit Earned		**Mean**	**Std. Dev.**	**N**
Control	Freshman	10.83	4.58	6
	Sophomore	9.50	6.25	4
	Junior	8.50	2.38	4
	Senior	9.00	2.73	8
Feedback Only	Freshman	10.80	2.59	5
	Sophomore	11.60	3.85	5
	Junior	9.00	3.79	8
	Senior	8.67	2.08	3
Feedback & Visual Hints	Freshman	12.75	4.43	4
	Sophomore	13.20	5.36	5
	Junior	11.25	3.39	8
	Senior	14.25	3.50	4
Totals	Freshman	11.33	3.79	15
	Sophomore	11.57	4.97	14
	Junior	9.80	4.29	20
	Senior	10.33	3.60	15

Finally, a comprehensive score from the three criterion tests were combined and tested to determine the effect that number of credits earned (class ranking) and game group had on achievement. A 4 x 3 two-way ANOVA was performed in order to determine whether class ranking, the first factor (freshman, sophomore, junior, and senior), and the second factor, game played (control, treatment 1, or treatment 2) had any effect on achievement on the comprehensive score. On Table 36 is a summary of the results. This signifies that the game played, credits earned (class ranking), and interaction between the two had no effect on achievement of the comprehensive score.

The report from the Lumina Foundation referenced in chapter one found that 22% of the U.S. population ages 25-64 have some higher education coursework but no degree. This could indicates a retention issue as students progress through their undergraduate coursework. If the addition of serious educational games can benefit upper division undergraduate students, faculty and instructional designers could help more undergraduates perform better and possibility earn their undergraduate degree. Future research expanding upon Boeker, Andel, Vach, and Frankenschmidt (2013) might help understand the differences between lower-division and upper-division undergraduates as it relates to serious educational games.

Table 36

Two-way Analysis of Variance for Comprehensive

Independent Variable	SS	df	MS	F	Sig.
Game	636.287	2	318.143	2.407	.100
Earned Credits	503.928	3	167.976	1.271	.294
Game x Earned Credits	542.328	6	90.388	.684	.663
Within (Error)	6872.325	52	132.160		
Total	8403.609	63			

Note. Levene's = 1.562 (df= 11,52) p = .138

H_o6: There will be a statistically significant difference between the subjects' digital gaming experience and achievement on the criterion tests (drawing, identification, comprehension, comprehensive test scores) among the control group, the feedback treatment only group, and the delayed elaborate feedback with visual hint treatment group.

Scores from the comprehension test were tested to determine the effect that digital gaming experience and game group had on achievement. A 7 x 3 two-way ANOVA was conducted to determine if digital gaming experience, the first factor (none, 0-2 years, 2-4 years, 4-6 years, 6-8 years, 8-10 years, and more than 10 years), and the second factor, game played (control, treatment 1 or treatment 2), had any effect on achievement on the comprehension scores. Tables 37 through 39 provide a summary of the results. There were no significant findings from the three tests, indicating that there is no effect between the interaction a subjects gaming experienced (measured in years of digital games played) and the game version played. As discussed in the limitations section, further research with a larger sample size or over a longer period of time could be conducted to support these results.

Table 37

Two-way Analysis of Variance for Comprehension

Independent Variable	SS	df	MS	F	Sig.
Game	40.999	2	20.500	.919	.406
Years of Experience	70.934	6	11.822	.530	.783
Game x Years of Experience	177.012	10	17.701	.794	.635
Within (Error)	1025.942	46	22.303		
Total	1311.538	65			

Note. Levene's = 3.295 (df= 18,46) p = .001

Table 38

Two-way Analysis of Variance for Identification

Independent Variable	SS	df	MS	F	Sig.
Game	45.856	2	37.928	2.877	.067
Years of Experience	87.861	6	14.644	1.111	.371
Game x Years of Experience	309.938	10	30.994	2.351	.024
Within (Error)	606.519	46	13.185		
Total	1089.846	65			

Note. Levene's = 1.890 (df= 18,46) p = .042

Table 39

Two-way Analysis of Variance for Drawing

Independent Variable	SS	df	MS	F	Sig.
Game	60.824	2	30.412	1.528	.228
Years of Experience	76.243	6	12.707	.638	.699
Game x Years of Experience	145.406	10	14.541	.730	.692
Within (Error)	895.829	45	19.907		
Total	1165.750	64			

Note. Levene's = 1.023 (df= 18,45) p = .454

For most of all the demographic variables examined in this study, comparison of the mean scores for the comprehension test seem to indicate a trend whereby some groups benefited from the use of elaborate feedback and visual hints. However a comparison of the means found in Table 40 below does not indicate any relationship between digital game experience (measured in years playing digital games) and game version played. Anand (2007) found a correlation between the daily video game use and GPA, future research to examine the relationship between daily game use and achievement when exposed to serious educational games might determine if there is any relationship between gaming experience and use of serious educational games.

Table 40

Mean Comprehension Scores by Gaming Experience

Group and Gaming Experience		Mean	Std. Dev.	N
Control	0 Years	6.67	1.16	3
	0-2 Years	-	-	0
	2-4 Years	12.00	7.07	2
	4-6 Years	8.50	3.54	2
	6-8 Years	7.33	2.52	3
	8-10 Years	11.60	5.08	5
	More than 10 Years	10.00	2.94	7
Feedback Only	0 Years	11.00	7.00	3
	0-2 Years	7.00	-	1
	2-4 Years	4.50	.707	2
	4-6 Years	8.00	-	1
	6-8 Years	-	-	0
	8-10 Years	9.33	3.51	3
	More than 10 Years	10.91	4.21	11
Feedback & Visual Hints	0 Years	11.75	5.06	4
	0-2 Years	13.00	-	1
	2-4 Years	6.00	-	1
	4-6 Years	10.00	2.83	2
	6-8 Years	12.25	7.23	4
	8-10 Years	14.00	2.45	4
	More than 10 Years	9.67	6.83	6
Totals	0 Years	10.00	5.01	10
	0-2 Years	10.00	2.24	2
	2-4 Years	7.80	5.26	5
	4-6 Years	9.00	2.45	5
	6-8 Years	10.14	5.93	7
	8-10 Years	11.83	4.07	12
	More than 10 Years	10.33	4.52	24

Results from comparing the means for the identification test can be found in Table 41 below. Unlike the comprehension test, all put one group seemed to have a higher achievement when exposed to elaborate feedback and visual hints. The 2-4 year group had a drastic decrease in their mean scores. However as with other analysis conducted for this study, future research with a larger sample size might yield more discernable results. The subject size for each group of gaming experience was fairly low, contributing doubtful results.

Table 41

Mean Identification Scores by Gaming Experience

Group and Gaming Experience		**Mean**	**Std. Dev.**	**N**
Control	0 Years	7.00	1.00	3
	0-2 Years	-	-	0
	2-4 Years	12.50	4.95	2
	4-6 Years	9.50	2.12	2
	6-8 Years	5.00	2.65	3
	8-10 Years	10.60	3.98	5
	More than 10 Years	10.86	3.72	7
Feedback Only	0 Years	9.33	6.03	3
	0-2 Years	7.00	-	1
	2-4 Years	7.00	0.00	2
	4-6 Years	5.00	-	1
	6-8 Years	-	-	0
	8-10 Years	9.33	2.31	3
	More than 10 Years	11.64	3.35	11
Feedback & Visual Hints	0 Years	14.00	3.65	4
	0-2 Years	12.00	-	1
	2-4 Years	2.00	-	1
	4-6 Years	13.00	2.83	2
	6-8 Years	14.75	4.57	4
	8-10 Years	14.00	1.83	4
	More than 10 Years	10.83	5.57	6
Totals	0 Years	10.50	4.77	10
	0-2 Years	9.50	3.54	2
	2-4 Years	8.20	5.07	5
	4-6 Years	10.00	3.74	5
	6-8 Years	10.57	6.32	7
	8-10 Years	11.42	3.40	12
	More than 10 Years	11.21	3.60	24

Finally, a comprehensive score from the three criterion tests were combined and tested to determine the effect that digital gaming experience and game group had on achievement. A summary of the results can be found in Table 42. The intent of this analysis was to determine if students with varying experience with digital games had any discernable difference between other groups. The statistical analysis did not find any significance nor any trends in comparing the means. This might indicate that previous experience with digital games has no effect on performance for a serious educational game. However, because the same size for this study was small, this cannot be fully determined. Future research with a larger sample size may find more trends as use of serious educational games are related to digital video games.

Table 42

Two-way Analysis of Variance for Comprehensive

Independent Variable	SS	df	MS	F	Sig.
Game	374.147	2	187.073	1.471	.240
Years of Experience	592.358	6	98.726	.776	.593
Game x Years of Experience	1605.791	10	160.579	1.262	.279
Within (Error)	5851.384	46	127.204		
Total	8405.600	65			

Note. Levene's = 2.159 (df= 18,46) p = .018

Summary

The majority of the statistical tests conducted on the hypotheses resulted in findings that were not significant. However, assessments created by Dwyer as part of the Experimental Instructional Materials are intended to evaluate components of the instructional material in a diverse manner. While there were no significant findings for the statistical tests conducted on the scores for the comprehension or drawing tests, or the comprehensive score, there were significant findings on the identification assessment.

RQ1 investigated the effects the addition of delayed elaborate feedback and visual hints had within a gaming environment on resulting achievement. For the identification test, a one-way ANOVA test found a significant effect occurring. The mean score for the control group was 9.50, the mean for the group only receiving delayed elaborate feedback was 10.00, while the mean score for the group receiving both delayed elaborate feedback and visual hints was 12.55. The ANOVA test found a significance level of .030. Because a statistically significant result was found, a Turkey post hoc test was conducted. A summary of the Turkey HSD test can be found in Table 43 below. The post hoc comparisons using the Turkey HSD indicated that the mean score for the group receiving both delayed elaborate feedback and visual hints (M = 12.55, SD = 4.585) was significantly different than the group receiving neither learning strategy (M = 9.50, SD = 3.827). However, the second treatment group receiving only delayed elaborate feedback (M = 10.00, SD = 3.347) did not significantly differ from the control group or the treatment 2 group.

Table 43

Results from Turkey HSD test for RQ1

Game		Mean Difference	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Game 1	2	-.500	1.209	.910	-3.40	2.40
	3	-3.045	1.194	.035	-5.91	-.18
Game 2	1	.500	1.209	.910	-2.40	3.40
	3	-2.545	1.209	.097	-5.45	.36
Game 3	1	3.045	1.194	.035	.18	5.91
	2	2.545	1.209	.097	-.36	5.45

These results suggest that the inclusion of delayed elaborate feedback and visual hints within a gaming environment do have an effect on transfer of information from working memory to long-term memory. Specifically, these results indicate that when students are given pedagogical reinforcing techniques within a serious educational game, they are more likely to retain information and achieve the learning objectives. This same effect can be observed when achievement on the identification test interacts with some of the demographic variables. Age, gender, and credits earned all had a significant effect on achievement scores from the identification test. Additional investigation, possibly with a larger sample size, would determine if there is significant effect.

Conclusion

The purpose of this study was to examine the effect specific learning strategies (delayed elaborate feedback and visual hints) within a gaming environment have on transfer of information to long-term memory. This chapter outlined the results of this study, which were analyzed using one-way and two way Analysis of Variance (ANOVA) tests. The first research question inquired as to the direct impact of these learning strategies, regardless of demographic factors. Analysis of H_o1, performed by examining one of the post-tests from Dwyer's Experimental Instructional Materials, showed that the combined use of delayed elaborate feedback and visual hints does have a significant impact on an individual's ability to process information from working memory to long-term memory. However overall, a significant effect was not found on the other three measures.

The second research question and associated hypotheses investigated the effect that individual demographics combined with these learning strategies has on the transfer of information from working memory to long-term memory. Five demographic variables were studied: age, gender, academic standing (GPA), credits earned (class rank), and digital gaming experience. The same significant effect found for the identification test occurred when the age, gender, and credits earned interacted when applying these learning strategies within a gaming environment.

CHAPTER FIVE

DISCUSSION

Summary

The use of serious educational games and digital games in general as a pedagogical tool in the teaching and learning process has been the focus of many research studies. However, the application of embedded learning strategies within a gaming environment has not received the same attention as gaming in general. Driving forces, such as technological advancement and pressures from many private, public, and governmental sectors to increase the education attainment rate in the United States, have created an environment where post-secondary institutions are spending more resources for online learning. To meet demands for high quality academic programs and to make judicious use of resources, faculty and instructional designers need additional research in areas such as the focus of this dissertation.

Supporting the need for more empirical research, the study in this dissertation focused on the effect that delayed elaborate feedback and visual hints within a gaming environment has on information retention. Sixty-five subjects from a mid-sized public university in Western Pennsylvania were asked to review instructional material originally developed by Dr. Francis Dwyer and adapted for use in the Desire2Learn Learning Management System. After reviewing the material, the subjects played one of three games: a control game where no instructional strategies were used, treatment group 1 where delayed elaborate feedback was provided, and treatment group 2 which used both delayed elaborate feedback and visual hints. All subjects completed three post-tests, where the scores were analyzed to determine if any significant effect had occurred. Research questions examined the effect these learning strategies embedded within a serious education game had on achievement as well as the effect certain demographic variables had on achieving the learning objectives. The findings for the study in this dissertation were presented in Chapter 4.

An outgrowth of cognitive science, Information Processing Theory was the primary theoretical framework guiding this study. Cognitive load or rather overload was a contributing factor in applying information processing theory. The basic premise is that the human brain processes information similar to how a computer processes information, and, when presented with extraneous information, the human brain will use working memory and associated processing to shift focus away from the desirable educational material, thus causing cognitive overload, information loss, and the inability to transfer information to long-term memory. Both information processing and cognitive load were germane, as the learning strategies employed in the game were intended to reduce extraneous cognitive load and allow the subjects to use reinforcing rehearsal techniques to aid in the transfer of instructional material to long-term memory.

Discussion

The first hypothesis stated a significant effect would occur between achievement on the three criterion post-tests and the overall comprehensive score. This means that students exposed to delayed elaborate feedback and/or visual hints would transfer more of the instructional material to long-term memory and have significantly higher scores on the post-tests. Subjects in treatment group 3 who were given visual hints and delayed elaborate feedback in the game had higher mean scores on all posts-tests, except for drawing, which was almost the same as the control group. Achievement on the identification test was the only post-test that had a statistically significantly finding for treatment group 3. The mean scores for the comprehension test were higher, as predicted by the hypothesis, but the increase was not statistically significant.

When exposed to delayed elaborate feedback and visual hints, the data suggests subjects are likely to perform better. While there was not a statistically significant finding, it can be concluded that the learning strategies might help individuals transfer information from working memory to long-term memory. As noted in the limitations below, there were interfering variables related to the drawing post-test which could explain the unexpected mean scores. Because of this, the comprehensive scores were affected, which explains why the control group performed slightly better than treatment group 1. However the group given both feedback and hints performed much better than the other two groups. Had the interference not occurred for the drawing post-test, there might be a statistically significant finding for the overall comprehensive score.

Hypotheses two through six examined the effect that different demographic variables had on achievement of the learning objectives. Interactions among the demographic variables and the game version played did not produce any significant findings. This indicates that, regardless of which game version was played, demographic factors such as age, gender, credits earned, and academic standing showed no impact on achievement of the learning objectives. As discussed previously, one of the limiting factors was the timeframe in which the gaming environment was available for this study. This resulted in a lower than targeted participants per group. Because of the smaller than expected sample size, significant findings may be missed due to the limited number of subjects.

For reasons previously detailed and validated by Sarıtepeci and Çakır (2015), the use and growth of online technology for both supplementing face-to-face education and fully online education has provided more opportunities for faculty and leaners alike. To ensure a quality experience and education, instructional designers and faculty must design the delivery of content in manner that takes advantage of technological features and uses reliable pedagogical approaches. The study in this dissertation investigated the effect that two learning strategies, proven to be effective in the teaching and learning process without the use of technology, have when they were used in a serious education game. Results from this and similar empirical research will help faculty and instructional designers make thoughtful use of limited resources with the goal of maximizing the achievement of the learning objectives.

Cognitive overload can occur regardless of the use of technology, however faculty and instructional designers can use learner's discourse with technology, in particular games, to reduce extraneous load thus more effectively presenting instructional material. This research can aid faculty and instructional designers by helping understand how specific game elements effect the processing of information. By organizing and presenting material in an environment that is familiar, engaging, and motivating, faculty and instructional designers can optimize learning modules to provide better opportunities for information to be transferred from working memory to long-term memory. Both practitioners such as faculty and instructional designers and games based learning creators should work together to further research on the use of specific learning strategies within a serious educational game.

As mentioned above, Learning Management Systems (LMS) makers have a responsibility to continually develop game based learning modules that delivers flexibility and diversity for the inclusion of multiple learning strategies and pedagogy. One of the limitations discussed below was the ability for subjects to bypass the feedback screen. Future enhancements might include the ability for faculty decide if they want to require the use of feedback, perhaps students could not proceed in the game without first viewing the feedback. This is only one example impacting faculty and instructional designer's application of serious educational games.

This and similar research should provide LMS creators with the information necessary to focus their development efforts.

This research is in line with previous research that indicates demographic characteristics do not impact aspects such as engagement, motivation, and achievement as it related to digital game play. However, flexibility in the design of serious educational games may provide faculty and instructional designers the ability to create games which can adapt to different learning styles. For example, the use of visual hints for visual learners, use of audio hints for auditory learners, or animation hints that can be tailored toward individual learning styles.

While a significant finding occurred only on one criterion test, the means from the other tests may support the assertion that use of targeted learning strategies within a serious education game possibly have a positive impact how the human brain processes information for storage in long-term memory. Studies by Vollmeyer and Rheinberg (2005), Kulhavy, White, and Topp (1985), and several others reinforce the finding that use of elaborate feedback has a positive impact in the learning process. The use of visual hints as a pedagogical approach has been examined much less than feedback. However, the findings from the study in this dissertation agree with research conducted by Jo (1993), Harskamp and Suhre (2007), and others previously discussed in chapters 1 and 2 that the use of visual hints helps working memory disregard extraneous information and focus on the necessary information.

Limitations

Notwithstanding the one significant finding for the identification post-test and observations of mean scores from the comprehension and drawing scores, there were notable limitations of this study. One such limitation has been discussed in the proceeding section, the sample size was below the target size. As a result of this limitation, the statistical analysis conducted was impacted as the limited sample size was a compounding factor. The environment itself could have contributed to an extraneous cognitive load, thus inhibiting working memory processes for the instructional material. The study did not take into consideration the subjects' familiarity with the Desire2Learn Learning Management System, and hence did not ask them about it. While this is the same online learning environment used at the university where the study was conducted, it is reasonable to assume not all subjects have a level of experience with Desire2Learn that would reduce their extraneous cognitive load. During the experiment, some subjects needed assistance in using navigational controls in the online course.

The sample size was adequate for this experiment; however, a larger sample size could have provided a greater diversity in the subjects. It was difficult to conduct further analysis by changing the grouping of the demographic information, since some of the groupings would have resulted in clusters with a very small subset of the sample, while others would have overwhelmed the groups.

Undue extraneous cognitive load was not the only attribute of the study environment. In the Desire2Learn gaming module, it was not possible to force subjects in treatment group 1 or 2 to view the feedback. As subjects completed an activity within the game, they were presented with a screen informing them of their performance and whether they earned a badge. They could either click on a review button or bypass the review by returning to the game map and moving on to the next activity. Subjects in treatment groups 2 and 3 were given written instructions on how to access the feedback and were asked to review the feedback prior to continuing their game play, but there was no way to prohibit them from continuing if they did not review the feedback.

While two of the three assessments were assimilated into the same Desire2Learn course and provided a seamless experience for the subjects, the drawing post-test was a handwritten test.

This test required subjects to draw a human heart on a piece of paper and label 20 items on their drawing. Some subjects expressed apprehension about their drawing skills. Trepidation with being required to illustrate their drawing skills (or lack thereof) could have contributed to the subjects' germane cognitive load, causing cognitive overload, and been a contributing factor to information decay.

Conclusion and Recommendations for Future Research

Much of the research examining the use of digital games in education investigates the motivating and engagement effect such games have on learners. The research draws connections between student engagement, motivation, and the ability for students to learn. However, more research needs to be conducted, similar to the study in this dissertation, focusing on qualities of the game that directly promote learning. The underlying question asked in this dissertation is if learning occurs as a result of the design of the game. Breaking the design components of a game into smaller elements and investigating the effect each component has on the ability to promote learning provides specific information that may lead to more concrete strategies for faculty and instructional designers.

As technology changes, research similar to the study in this dissertation needs recur. Due to shifts or advancements in technology, users will naturally experience extraneous cognitive load. Specific to the study in this dissertation, the manner in which elaborate feedback and visual hints are delivered is constrained to the current technological environment. Other factors typically found in games, such as competition facets, can increase engagement and motivation, which could produce a significant effect when mixed with elaborate feedback and/or visual hints. A more longitudinal study conducted over an entire semester where other aspects, such as badging and achievements, are combined with elaborate feedback and visual hints could, over time, reduce extraneous cognitive load and have more of an effect on student achievement. As the instructional module used for the study in this dissertation was not related to the subject's university course content, future research would allow a researcher to adapt an instructional module within the game to align with the student learning outcomes from their course. The limitation related to the familiarity with the Desire2Learn environment discussed above could also be mitigated in a semester-long study. As students become more familiar with the environment, extraneous cognitive load will be reduced.

The study in this dissertation examined the effectiveness of learning strategies application within a gaming environment for the goal of transferring information from working memory to long-term memory. Not tested was the effect these learning strategies had on long-term retention of information. In addition to recommending a longitudinal study where a serious educational game is played over the course of a semester, participants should be tested several weeks or months. Testing subjects after longer period of time will examine if the addition of delayed elaborate feedback and visual hints have any effect on long-term retention of information.

As mentioned previously discussed, the small sample size was problematic for the statistical analysis. Not only would a longitudinal study be a target for a future study, but it would provide the opportunity for a larger sample size that may help reveal potentially significant differences and patterns.

In addition to studying the effect over a longer time period, the media used to deliver the elaborate feedback and visual hints could be altered to determine if delivery method has an effect. For instance, the use of audio, video, or animation as an alternative to the methods used in this study could easily be investigated and compared to the results of this study. This is another impact of not only technological advancement but students' intercourse with the technology.

As presented in Chapter 1, the use of online technology in post-secondary education is no longer an emerging strategy; it has become a mission critical component of an organization's operations. Balancing delivery methods with sound pedagogical strategies will be critical to a course's success. Under the theoretical framework of information processing theory, cognitive load, and general cognitive processes, this research contributes to the field by providing faculty and instructional designers with empirical evidence on how two specific learning strategies interact with a gaming environment to promote learning.

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Appendix A

Comprehension Test

1. Which valve is most like the tricuspid in function?
    a. PULMONARY
    b. AORTIC
    c. MITRAL
    d. SUPERIOR VENA CAVA

2. When blood is being forced out the right auricle, in which position is the tricuspid valve?
    a. BEGINNING TO OPEN
    b. BEGINNING TO CLOSE
    c. OPEN
    d. CLOSED

3. When blood is being forced out the aorta, it is also being forced out of the __.
    a. PULMONARY VEINS
    b. PULMONARY ARTERIES
    c. SUPERIOR VENA CAVA
    d. CARDIAC ARTERY

4. The contraction impulse in the heart starts in the __.
    a. THE RIGHT AURICLE
    b. BOTH VENTRICLES SIMULTANEOUSLY
    c. BOTH AURICLES SIMULTANEOUSLY
    d. THE ARTERIES

5. In the diastolic phase the ventricles are __.
    a. CONTRACTING, FULL OF BLOOD
    b. CONTRACTING, PARTIALLY FULL OF BLOOD
    c. RELAXING, FULL OF BLOOD
    d. RELAXING, PARTIALLY FULL OF BLOOD

6. During the first contraction of the systolic phase, in what position will the mitral valve be?
    a. BEGINNING TO OPEN
    b. OPEN
    c. BEGINNING TO CLOSE
    d. CLOSED

7. During the second contraction of the systolic phase, blood is being forced away from the heart through the __.
    a. PULMONARY AND AORTIC ARTERIES
    b. SUPERIOR AND INFERIOR VENA CAVAS
    c. TRICUSPID AND MITRAL VALVES

d. PULMONARY VEINS

8. When blood is entering through the vena cavas, it is also entering through the __.
    a. MITRAL VALVE
    b. PULMONARY VEINS
    c. PULMONARY ARTERY
    d. AORTA

9. When heart contracts, the __.
    a. AURICLES AND VENTRICLES CONTRACT SIMULTANEOUSLY
    b. VENTRICLES CONTRACT FIRST, THEN THE AURICLES
    c. RIGHT SIDE CONTRACTS FIRST, THEN THE LEFT SIDE
    d. AURICLES CONTRACT FIRST, THEN THE VENTRICLES

10. While blood from the body is entering the superior vena cava, blood from the body is also entering through the __.
    a. PULMONARY VEINS
    b. AORTA
    c. INFERIOR VENA CAVA
    d. PULMONARY ARTERY

11. When the blood leaves the heart through the pulmonary artery, it is also simultaneously leaving the heart through the __.
    a. TRICUSPID VALVE
    b. PULMONARY VEINS
    c. AORTA
    d. PULMONARY VALVE

12. When pressure in the right ventricle is superior to that in the pulmonary artery, in what position is the tricuspid valve?
    a. CLOSED
    b. OPEN
    c. BEGINNING TO CLOSE
    d. CONFINED BY PRESSURE FROM THE RIGHT ARTERY

13. When the ventricles contract, blood is forced out the __.
    a. SUPERIOR AND INFERIOR VENA CAVAS
    b. PULMONARY VEINS
    c. TRICUSPID AND MITRAL VALVES
    d. PULMONARY AND AORTIC VALVES

14. Blood leaving the heart through the aorta had left the heart previously through the __.
    a. VENA CAVAS
    b. PULMONARY VEINS
    c. TRICUSPID AND MITRAL VALVES
    d. PULMONARY ARTERY

15. When the blood in the aorta is exerting a superior pressure on the aortic valve, what is the position of the mitral valve?
    a. CLOSED
    b. OPEN
    c. BEGINNING TO OPEN
    d. CONFINED BY PRESSURE FROM THE RIGHT AURICLE

16. When the tricuspid and mitral vales are forced shut, in what position is the pulmonary valve?
    a. CLOSED
    b. BEGINNING TO OPEN
    c. OPEN
    d. BEGINNING TO CLOSE

17. During the second contraction of the systolic phase, in what position is the aortic valve?
    a. FULLY OPEN
    b. PARTIALLY OPEN
    c. PARTIALLY CLOSED
    d. FULLY CLOSED

18. Blood is being forced out the auricles simultaneously as blood is __.
    a. ENTERING ONLY THE VENA CAVAS
    b. BEING FORCED OUT THE PULMONARY AND AORTIC VALVES
    c. PASSING THROUGH THE TRICUSPID AND MITRAL VALVES
    d. BEING FORCED OUT THROUGH THE PULMONARY ARTERY

19. If the aortic valve is completely open, the __.
    a. SECOND CONTRACTION OF THE SYSTOLIC PHASE IS OCCURRING
    b. DIASTOLIC PHASE IS OCCURRING
    c. TRICUSPID AND MITRAL VALVES ARE COMPLETELY OPEN
    d. BLOOD IS RUSHING INTO THE RIGHT AND LEFT VENTRICLES

20. When the heart relaxes, the __.
    a. AURICLES RELAX FIRST, THEN THE VENTRICLES
    b. RIGHT SIDE RELAXES FIRST, THEN THE LEFT SIDE
    c. LEFT SIDE RELAXES FIRST, THEN THE RIGHT SIDE
    d. VENTRICLES RELAX FIRST, THEN THE AURICLES

Appendix B
Identification Test

Arrow number one (1) points to the

SEPTUM
AORTA
PULMONARY ARTERY
PULMONARY VEIN
NONE OF THESE

Arrow number two (2) points to the

SUPERIOR VENA CAVA
INFERIOR VENA CAVA
PULMONARY ARTERY
TRICUSPID VALVE
AORTA

Arrow number three (3) points to the

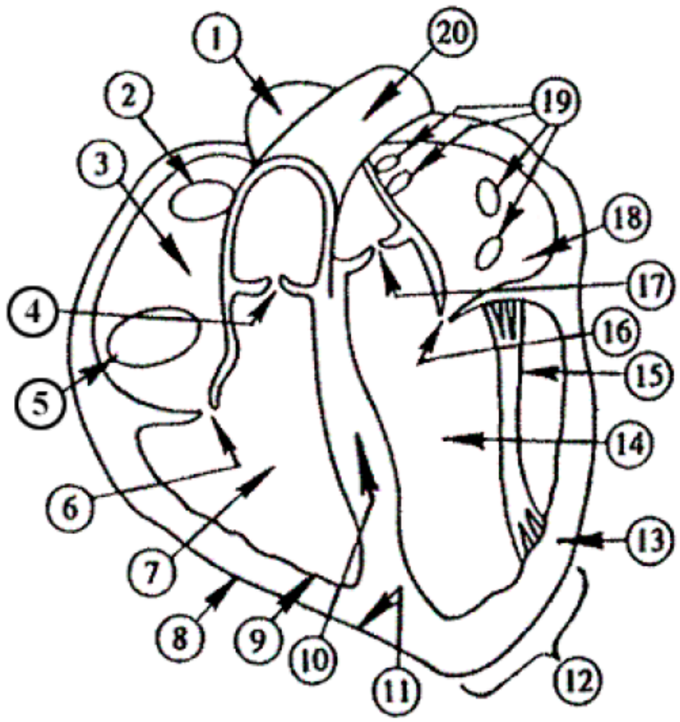
RIGHT VENTRICLE
RIGHT AURICLE
LEFT VENTRICLE
LEFT AURICLE
HEART MUSCLE

Arrow number four (4) points to the

PULMONARY VALVE
PULMONARY VEIN
AORTA VALVE
TRICUSPID VALVE
MITRAL VALVE

Arrow number five (5) points to the

AORTA
PULMONARY ARTERY
SUPERIOR VENA CAVA
INFERIOR VENA CAVA
PULMONARY VEIN



Arrow number six (6) points to the

AORTA
PULMONARY VALVE
MITRAL VALVE
TRICUSPID VALVE
SEMI-LUNAR VALVE

Arrow number seven (7) points to the

LEFT VENTRICLE
RIGHT VENTRICLE
RIGHT AURICLE
LEFT AURICLE
VASCULAR SPACE

Arrow number eight (8) points to the

MYOCARDIUM
ECTODERM
PERICARDIUM
ENDOCARDIUM
EPICARDIUM

Arrow number nine (9) points to the

ENDOCARDIUM
MYOCARDIUM
PERICARDIUM
ECTODERM
SEPTUM

Arrow number ten (10) points to the

ENDOCARDIUM
PERICARDIUM
SEPTUM
MYOCARDIUM
AORTIC BASE

Arrow number eleven (11) points to the

EPICARDIUM
PERICARDIUM
ENDOCARDIUM
MYOCARDIUM
NONE OF THESE

Arrow number twelve (12) points to the

PERICARDIUM
MYOCARDIUM
ENDOCARDIUM
ENDODERM
APEX

Arrow number thirteen (13) points to the

PERICARDIUM
ENDOCARDIUM
ECTOCARDIUM
ENDODERM
MYOCARDIUM

Arrow number fourteen (14) points to the

RIGHT VENTRICLE
LEFT VENTRICLE
LEFT AURICLE
RIGHT AURICLE
APEX

Arrow number fifteen (15) points to the

PULMONARY VEINS
TENDONS
AORTAS
PERICARDIUM
NONE OF THESE

Arrow number sixteen (16) points to the

VENIC VALVE
PULMONARY VALVE
TRICUSPID VALVE
AORTIC VALVE
MITRAL VALVE

Arrow number seventeen (17) points to the

SUPERIOR VENA CAVA
TRICUSPID VALVE
AORTIC VALVE
PULMONARY VALVE

MITRAL VALVE

Arrow number eighteen (18) points to the

RIGHT AURICLE
RIGHT VENTRICLE
LEFT AURICLE
RIGHT AURICLE
SEMI-LUNAR CHAMBER

Arrow number nineteen (19) points to the

INFERIOR VENA CAVA
SUPERIOR VENA CAVA
AORTAS
PULMONARY VEINS
PULMONARY ARTERIES

Arrow number twenty (20) points to the

INFERIOR VENA CAVA
AORTA
PULMONARY ARTERY
SEPTUM
SUPERIOR VENA CAVA

Appendix C
Drawing Test

Drawing Test

Before beginning the drawing test, please LOGOFF the online system.

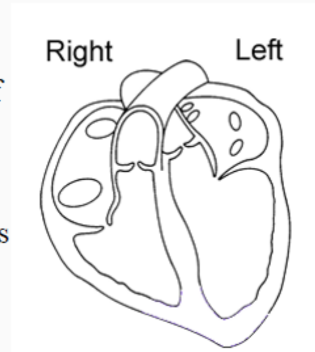
Directions: On this paper, draw a simple line picture of a heart and place the corresponding number of the 20 identified part (see list below) where they would be located on the heart. When you are finished, please hand this paper back to me, you are finished.

1. Superior Vena Cava
2. Aorta
3. Tricuspid Valve
4. Pulmonary Veins
5. Septum
6. Epicardium
7. Aortic Valve
8. Pulmonary Valve
9. Inferior Vena Cava
10. Pulmonary Artery
11. Myocardium
12. Endocardium
13. Mitral Valve
14. Right Auricle
15. Right Ventricle
16. Left Auricle
17. Left Ventricle
18. Apex
19. Tendons
20. Pericardium

Appendix D
Instructional Material

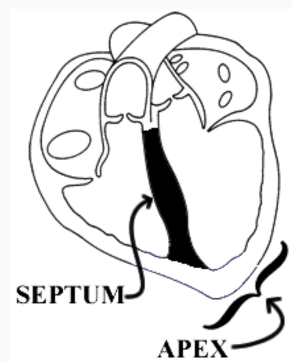
Right and Left Sides

In order to better comprehend the following instruction, it will be helpful to visualize a cross-sectional view of a human heart in a position such that you are facing a person. Therefore, the right side of the person's heart is to your visual left, as shown in the above diagram. Likewise, the left side of the person's heart would be illustrated on the right side of the diagram. The human heart is a hollow, bluntly conical, muscular organ. It is pumping action provides the force that circulates the blood through the body. In the average adult, the heart is about five inches long and about two and one half inches thick. A man's heart weights about 11ozs. And a women's heart weights about 9oz.



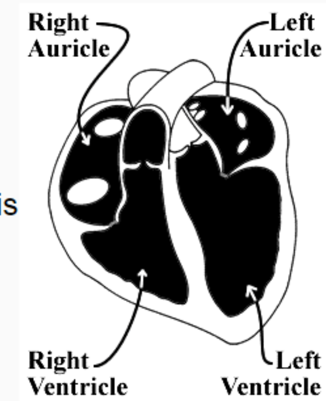
Septum and Apex

The heart lies toward the front of the body and is in a slanting position between the lungs, immediately below the breastbone. The wide end points toward the right shoulder. The small end of the heart points downward to the front of the chest and toward the left. The lower portion of the heart is called the apex and is the part that you feel beating. The human heart is really two pumps combined in a single organ which circulates blood to all parts of the body. The heart is divide longitudinally into two halves by the septum. The two halves may be compared to a block of two houses, which are independent of each other but have a common wall, the septum, between them.



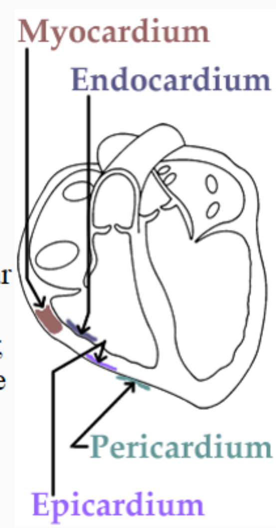
Auricles and Ventricles

Each half of the heart is divided into an upper chamber and a lower chamber. The upper chambers on each side of the septum are called auricles; the lower chambers are called ventricles. Auricles have thin walls and act as receiving rooms for the blood, while the ventricles having thicker walls act as pumps moving the blood away from the heart. Although there is no direct communication between the right and left sides, both sides function simultaneously.



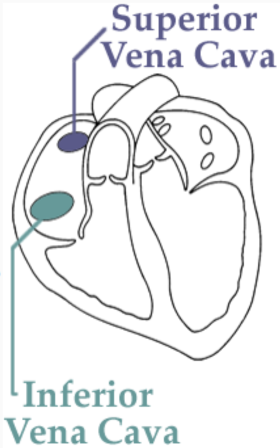
Layers of the Heart

The heart contains several layers of membranes and muscle. The first set of membranes enclose the heart in a thin double walled sac. The layer which forms the outer wall of the sac is called the pericardium. It is composed of a tough, transparent elastic tissue. It protects the heart from rubbing against the lungs and the walls of the chest. The inner portion of the double walled sac is called the epicardium. It is attached to the heart muscle. The heart muscle is called the myocardium; it controls the contraction and relaxation of the heart. The myocardium constitutes by far the greatest volume of the heart and its contraction is responsible for the propulsion of the blood through the body. The muscle varies in thickness; for example, the muscle in the auricle walls are thin when compared to the thickness of the muscle in the ventricle walls. Finally the endocardium is the name given to the membrane lining inside of the heart wall.



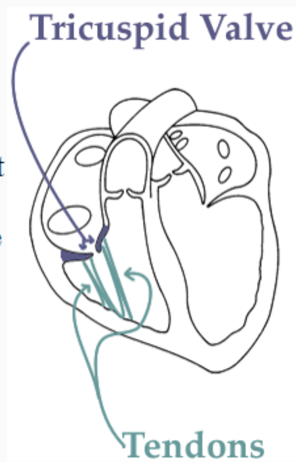
Vena Cavas

Blood enters the heart through veins. Only veins carry blood to the heart. The superior and inferior vena cavas are the two veins which deposit blood in the right auricle; there are no valves at the opening of these veins. The superior vena cava deposits blood into the right auricle from all body parts above heart level, for example, the head and arms. The inferior vena cava carries blood from parts of the body below heart level, for example, the trunk and legs, depositing the blood in the right auricles. As blood from the body fills the right auricles, some of it begins to flow into the right ventricle immediately, through a common opening.



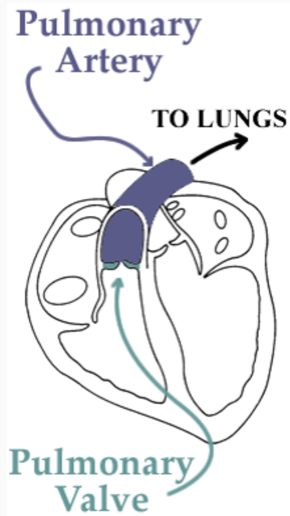
Tricuspid Valve

This common opening, between the right auricle and right ventricle, is called the tricuspid valve. This valve consists of three triangular flaps on thin, strong, fibrous tissue. These flaps permit the flow of blood into the right ventricle, but prevent it from flowing backward into the right auricle because the ends of the flaps are anchored to the floor of the right ventricle by slender tendons. Thus, blood passes from the right auricle through the tricuspid valve into the right ventricle. As the right ventricle is filled with blood, both ventricles begin to contract creating pressure.



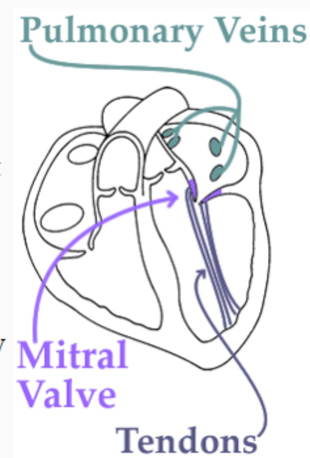
Pulmonary Artery and Valve

While the blood pressure behind the tricuspid valve brings the flaps together and prevents the flow of blood between the right auricle and right ventricle, the contraction of the right ventricle continues until the blood presses hard enough to open the pulmonary valve. The pulmonary valve, located between the right ventricle and the pulmonary artery, consists of three flaps like the tricuspid valve. As soon as the right ventricle begins to relax from its contraction, the valve flaps are filled with blood backing up from the pulmonary artery. The flaps are pressed together stopping the blood flow back into the right ventricle. The pulmonary valve only opens when the pressure in the right ventricle is greater than the pressure in the pulmonary artery, forcing the blood into the artery. In the pulmonary artery the blood is carried away from the heart to both the left and right lungs where it is cleansed and oxygenated.



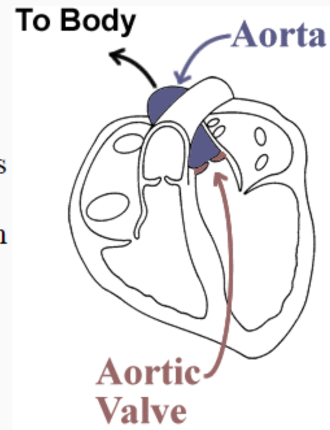
Pulmonary Veins and Mitral Valve

Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle; these vein openings, like the vena cavas, have no valves. The left auricle then contracts when it is full, squeezing blood through the mitral valve into the left ventricle. The mitral valve, located between the left auricle and the left ventricle, it is similar in construction the tricuspid valve. As the left ventricle contracts simultaneously with its mate, the right ventricle, it forces blood behind the flaps of the valve thereby closing the passageway back to the left auricle. Like the tricuspid valve, the ends of the mitral valve flaps are anchored to the floor of the left ventricle by slender tendons.



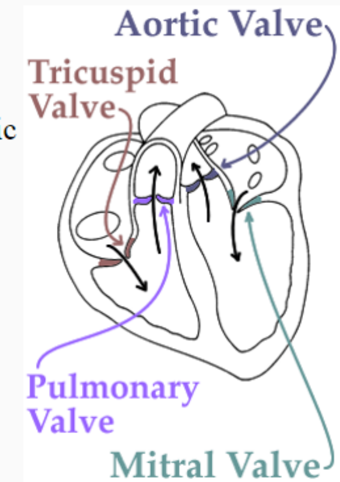
Aorta and Aortic Valve

The contraction of the left ventricle pumps the blood through the entire body. For this reason it is the largest, strongest, and most muscular section of the heart. When the left ventricle is filled with blood, it contracts resulting in the pressure opening the aortic valve. The aortic valve is similar to the other flap like valves; the valve stops the backward flow of blood to the left ventricle and opens for the forward flow of blood to the aorta. The aorta is the large artery which carries the blood away from the heart back to the various parts of the body.



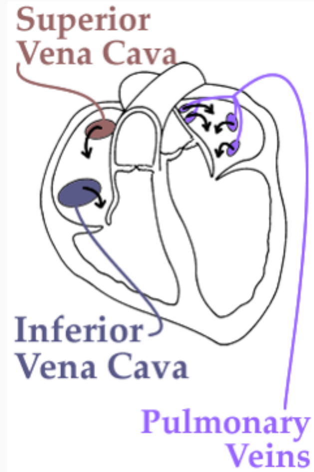
Circulation of Blood Through the Heart

The directional flow of blood in the heart is determined by valves which allow the blood to flow in only one direction. These sets of valves are the tricuspid and mitral valves, which control the flow of blood from the auricles to the ventricles, and the pulmonary and aortic valves which control the flow of blood from the ventricles to the arteries.



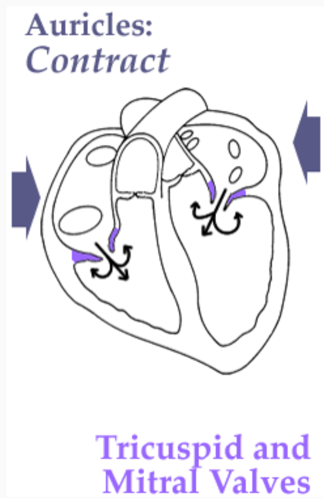
Superior and Inferior Vena Cava

Both auricles receive blood simultaneously through vein openings which have no valves. The right auricle receives its blood through the superior and inferior vena cavas, while the left auricle receives its blood through the pulmonary veins.



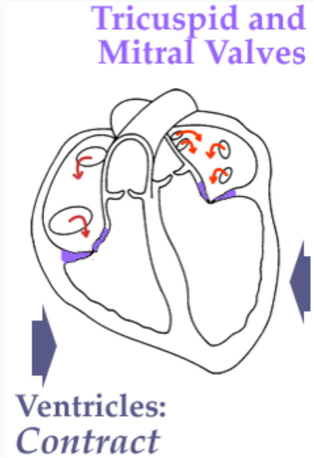
Auricles Contract

A wave of muscular contraction starts at the top of the heart and passes downward, simultaneously, over both sides of the heart; that is, both auricles contract at the same time and then relax as the contraction passes down to the ventricles. When the auricles are caused to contract, they become small and pale and in doing so the blood in their chambers is subjected to increased pressure which forces blood to the ventricles through the opened tricuspid and mitral valves. As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves back to a partially closed position.



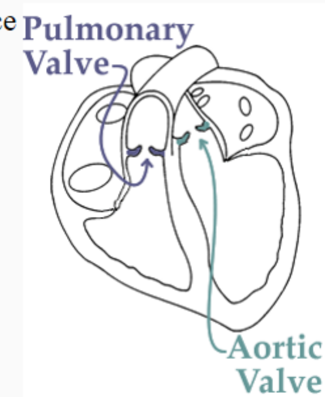
Ventricles Contract

The instant that the contraction of the auricles has been completed, the ventricles are stimulated to contract. This contraction increases the pressure in the ventricle chambers forcing the tricuspid and mitral valves completely closed, thereby preventing blood from being forced backwards into the auricles. The auricles, relaxing from their contraction, receive a continuous blood flow from the vena cavas and the veins.



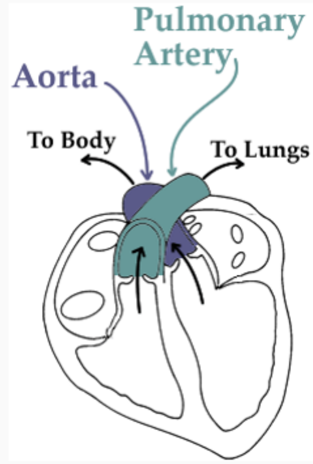
Pulmonary and Aortic Valves

As the ventricles continue to contract, pressure in these chambers force the pulmonary and aortic valves to open. The pulmonary valve, leading from the right ventricle, guards the entrance to the pulmonary artery. The aortic valve, leading from the left ventricle, guards the entrance to the aorta or aortic artery. Both are 3 flapped valves, and are together known as the semi-lunar valves. Prior to ventricle contraction, the valves are closed by back pressure provided by blood already in the exit arteries. When pressure in the ventricles becomes greater than that in the exit arteries due to ventricle contraction, the semi-lunar valves open.



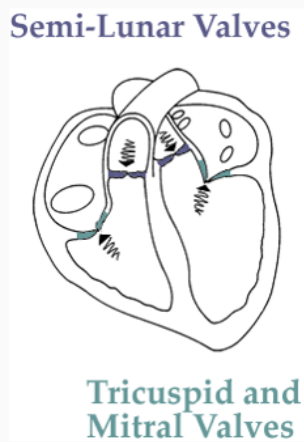
Circulation: Pulmonary Artery and Aorta

With the semi-lunar valves open, blood flows from the right ventricle into the pulmonary artery on route to the lungs for cleaning and oxygen. Simultaneously, blood flows from the left ventricle into the aorta for distribution throughout the entire body.



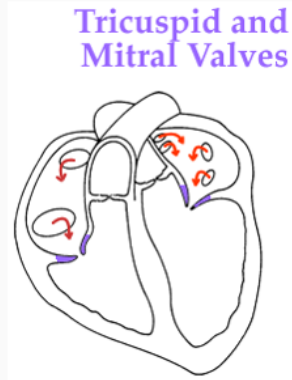
Circulation: Semi-Lunar Valves

With the semi-lunar valves open, blood flows from the right ventricle into the pulmonary artery on route to the lungs for cleaning and oxygen. Simultaneously, blood flows from the left ventricle into the aorta for distribution throughout the entire body.



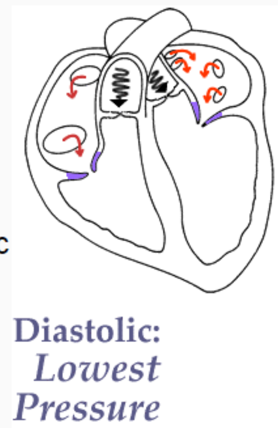
Circulation: Tricuspid and Mitral Valves

Immediately following the pumping of blood into the arteries, the ventricles begin to relax. This relaxation lowers the pressure within their chambers and the greater pressure in the arteries close the semi-lunar valves. Pressure within the ventricles is sufficient, however, to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.



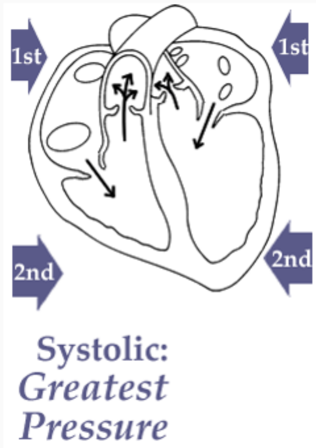
Blood Pressure: Diastolic

The cycle of blood pressure in the heart consists of two distinct phases. One of these phases is called the diastolic or relaxation phase. In the diastolic phase, the heart relaxes between contractions. Blood flows into the heart, filling both auricles. While blood is flowing in to the auricles, the arteries still maintain part of the pressure developed by a prior ventricle contraction. This is the time of lowest pressure in the arteries, or what is called the diastolic pressure. During this phase, the ventricles are also relaxing. The ventricles are slowly being filled with blood, due to the full auricles and partially opened tricuspid and mitral valves.



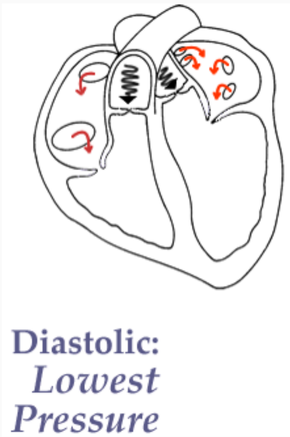
Blood Pressure: Systolic

The second phase, the systolic or contraction phase, begins when the auricles contract. The blood is forced through the tricuspid and mitral valves into the ventricles. The ventricles then contract forcing the blood through the semi-lunar valves into the pulmonary and aortic arteries. The blood leaves the ventricles under the terrific pressure and surges though the arteries with a force so great that it bulges their elastic walls. At this point, arterial blood pressure is greatest; we refer to this pressure as the systolic pressure.



Blood Pressure: Diastolic 2

The heart begins to relax again. The semi-lunar valves are closed; blood flows into the auricles from the veins; and the tricuspid and mitral valves are forced partially open. The diastolic phase begins, and the cycle of blood pressure starts again.



Appendix E
Demographic Survey

1. What is your age?
    a. 18
    b. 19
    c. 20
    d. 21
    e. 22
    f. 23 or older
2. What is your gender?
    a. Female
    b. Male
3. What is your current GPA?
    a. Below 2.0
    b. 2.0-2.5
    c. 2.6-3.0
    d. 3.1-3.5
    e. 3.6-4.0
    f. Don't Know
4. What is your class ranking?
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior
5. How many classes have you taken that involved the parts and operations of the human heart?
    a. 0
    b. 1-2
    c. 2 or more
6. Do you play games on your cell phone
    a. Choice (yes or no)
7. About how many years have you been playing electronic games?
    a. I have never played electronic games
    b. 0-2 years
    c. 2-4 years
    d. 4-6 years
    e. 6-8 years
    f. 8-10 years
    g. More than 10 years
8. About how many hours per week do you play games (either on your cell or other device)
    a. 1-3 hours
    b. 3-6 hours
    c. 6-9 hours
    d. 9-12 hours
    e. More than 12 hours