In response to the solicitation of the National Institute on Drug Use (NIDA) (NIDA, 2006) for the Development of a Virtual Reality Environment for Teaching about the Impact of Drug Abuse on the Brain, a virtual brain exhibit was developed by the joint venture of Entertainment Science, Inc. and Virtual Heroes, Inc.. This exhibit included a virtual reality learning environment combined with a video game, aiming at improving the neuroscience literacy of the general public, conveying knowledge about the impacts of methamphetamine abuse on the brain to the population, and establishing a stronger concept of drug use prevention among children.

This study investigated the effectiveness of this interactive exhibit on middle school students’ understanding and attitudes toward drug use. Three main research questions are addressed: 1) What do students learn about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain via the exhibit? 2) How are students’ attitudes toward methamphetamine use changed after exposure to the exhibit? 3) What are students’ experiences and perceptions of using the exhibit to learn the impact of methamphetamine abuse on the brain? A mixed-method design, including pre/post/delayed-post test instruments, interviews, and video recordings, was conducted for 98 middle school students ranging from sixth to eighth grades to investigate these questions.

The results show that students’ understanding of the impact of methamphetamine abuse on the brain significantly improved after exposure to the exhibit regardless of grade or gender. Their pre-existing knowledge and their understanding after the exhibit indicated a tendency
of progression. Most of the students consistently expressed negative attitudes toward general methamphetamine use regardless of whether it was before or after exposure to the exhibit. However, this exhibit gave them a better reason and made them feel more confident to refuse drugs. Finally, student learning experiences through using the exhibit was a self-regulated learning process. This exhibit possessed several intrinsic values that motivated students to participate and persist in the activity, whereby students performed several cognitive and metacognitive strategies to help the learning activity to best fit individual learning styles and to make the cognitive processes more efficient.
Middle School Students’ Learning of the Impact of Methamphetamine Abuse on the Brain through Serious Game Play

by
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A dissertation submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the degree of Doctoral of Philosophy

Science Education

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DEDICATION

To my dearest parents who have always provided unconditional support to me no matter where I am or what I do. Any achievements I have are all because of you.
Meng-Tzu Cheng was born on December 19, 1977 in I-Lan, a beautiful city in Taiwan embraced by both beautiful mountains and oceans. Raised in a loving home, she was surrounded by the selfless and endless love of her parents and two older sisters.

Meng-Tzu got her Bachelor of Science in Botany from National Taiwan University in 2000 and earned a Master of Science in Biology from National Taiwan Normal University in 2003. While pursuing her master’s degree, she got a chance to attend the teacher education program and to receive professional teaching training. In the meantime, she met several wonderful professors who led her to realize her love for education.

After one year of teaching experience in Taipei Municipal Sun Shan High School, she decided to pursue a higher degree in the United States. She entered the doctoral program in science education at North Carolina State University in the fall of 2005 and joined the research group under the advisement of Dr. Len Annetta in 2006.

She has been working with Dr. Len Annetta for three years, focusing on using technologies, especially video games, to assist and improve students’ learning. She was also an intern in the North Carolina Museum of Natural Sciences in the spring of 2009, where she constructed surveys and collected and analyzed data from the surveys to help evaluate several school programs that are currently running. These great and valuable experiences have given her a solid foundation in the theories, processes, and methodologies involved in science education research and have also prepared her for a career in research in the future.
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I would like to express my deepest appreciation to many people, whose support and help have made this journey possible. My sincerest gratitude goes to my committee chair and advisor, Dr. Len Annetta, who has always inspired me in all possible ways and encouraged me at the times when I needed it. I am grateful to have such an excellent mentor and thank him for his vast patience and support.

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CHAPTER ONE

Introduction

*Drug Use Problems in America*

Ever since illicit drug use burgeoned its way into the youth population in the mid 1960’s, it has remained a major public health problem in America. Findings from the 2007 National Survey on Drug Use and Health (Substance Abuse and Mental Health Services Administration [SAMHSA], 2008a, 2008b) show that an estimated 19.9 million (8.0%) Americans aged 12 or older were current illicit drug users, which was similar to the rate in 2006 (8.3%) and has been since 2002 (8.3%). Of the 19.9 million current illicit drug users in 2007, 9.5% of them were youths aged 12 to 17. Although the rates of current illicit drug use among youths aged 12 to 17 declined significantly between 2002 (11.6%) and 2007 (9.5%), they have remained relatively stable since 2005 (9.9%). Additionally, the state reports for North Carolina indicated that the rate of current illicit drug use among youths aged 12 to 17 has also remained stable since 2004 (SAMHSA, 2008). The rates of 2004 through 2006 were 11.06%, 10.87%, and 10.38%, respectively.

Reports from *Monitoring the Future: National Results on Adolescent Drug Use* (Johnston, O'Malley, Bachman, & Schulenberg, 2008) indicate that the use of any illicit drug has gradually been declining among 8th, 10th, and 12th graders over the past 10 years. In 2007, the lifetime prevalence rates of illicit drug use were 19%, 36%, and 47% in grades 8, 10, and 12, respectively. On the one hand, this can be seen as good news because gradual declines have been occurring in all grades since the mid-1990s, and under half of American secondary students today have tried to use any illicit drugs by the time they approach high school.
Nevertheless, regardless of these declines, the results point out that the problem of drug use in youths today still exists, and more efforts are needed to improve drug use prevention, ultimately aiming to achieve a drug-free environment where youths could learn about the consequences of drug use and grow up in a healthy manner.

Recently, a series of neuroscience research reports have shown that drug use induces abnormal neurotransmitter releases, as well as severe and persistent brain damage, which subsequently lead to motor and cognition impairments (Bowyer & Ali, 2006; Harper & Kril, 1994; Simon et al., 2000; Thompson et al., 2004; Volkow et al., 2001). Bowyer and Ali (2006) treated mice with a single high dose of methamphetamine (meth), causing rapid and extensive hippocampal and amygdalar damage which should be sufficient in compromising the functions of learning and memory. Humans who have used meth have been evidenced to have structural deficits in dopaminergic and serotonergic systems and cerebral metabolic abnormalities (Thompson et al., 2004), and hence performed significantly worse on several cognitive tasks (Simon et al., 2000). Long-term neural damage caused by methamphetamine-dependence may also lead to difficulties in sustaining attention in humans (Nordahl, Salo, & Leamon, 2003). Moreover, these neurocognitive impairments might be unrecoverable, since research has also indicated that methamphetamine-dependent individuals who were in the initial phases of abstinence (Kalechstein, Newton, & Green, 2003) or were even abstinent for up to one year (Volkow et al., 2001) still had memory deficits and motor slowing, and performed significantly worse than control subjects on several neurocognitive measures. Drug use results in severely negative consequences, yet people generally lack the knowledge about the impact of illicit or licit drugs on the brain.
Most of the current drug use prevention programs are categorized as social skills or influence programs which have been called ‘the most promising strategies to drug prevention’ (Brown, 2001; Ellickson, 1995). They focus on life skills training, and these skills could be classified into two categories, resistance skills for rejecting social influence and misconceptions of drug use, and generalized skills for coping with social competency and stressful life situations (Ellickson, 1995; Marsch, Bickel, & Badger, 2007; Western CAPT, 1999). Other programs that teach students the information of drug use are categorized as information programs, generally focusing on introducing the facts about drugs including history, pharmacology, physical and psychological effects, and legal sanctions (Ellickson, 1995). However, programs which teach students the consequences of drug use from a neuroscience perspective are few.

*Solicitation of National Institute on Drug Abuse (NIDA)*

The Division of Basic Neuroscience and Behavioral Research (DBNBR) of the National Institute on Drug Abuse (NIDA) therefore initiated the solicitation for the *Development of a Virtual Reality Environment for Teaching about the Impact of Drug Abuse on the Brain* since 2006, providing grants to fund projects that aim at teaching the public of the impact of drug abuse on the brain (NIDA, 2006). The solicitation indicates that since virtual reality (VR) is an emerging technology that has been broadly used for medical sciences and treatments, the use of VR to virtually present and compare brain functions under normal and drug-influenced conditions will be useful in educating individuals about the medical, behavioral and social effects of drug abuse.
‘Virtual Reality’ is defined as an electronic generated environment. This environment is filled with computer generated graphics, enabling users to see in a 2D or 3D visual display apparatus or stereo viewing goggles, and interaction with objects in the environment is achieved with the aid of a variety of input devices such as a mouse, joystick or reality gloves (Steuer, 1992). Using virtual reality to simulate the real-world environment provides users a unique immersive experience, allowing new possibilities for experimentation, operation, manipulation, and exploration that are normally impossible or impractical (Johns Hopkins University Applied Physics Laboratory, n.d.). Virtual reality is an emerging technology that has already been in use effectively for a number of years for various purposes, such as medical and surgical education (Lemole, Banerjee, Luciano, Neckrysh, & Charbel, 2007; Sarker & Patel, 2007; Ward, Charissis, Rowley, Anderson, & Brady, 2008), business and industry training (Sawhney, Mund, & Koczenasz, 2001), and the treatment of phobias and pain control (Hoffman et al., 2008; Reger & Gahm, 2008). Especially since neuroscience includes a number of models of the brain and the skull, virtual reality models that provide an extra dimension from 2D images are more informative for both the quality of visual information and utility of surface visualization (Kelley et al., 2007).

Drugs and the Brain: A Serious Game

In response to NIDA’s solicitation, a museum touring exhibit named Drugs and the Brain: A Serious Game was developed by the joint venture of Entertainment Science, Inc. and Virtual Heroes, Inc. By definition, ‘Serious Game’ refers to “game technology used for other than purely entertainment purposes such as strategic messaging, training and education, and mission planning and rehearsal.” (Heneghan, 2008, p. x). This exhibit was designed to
present detailed, 3D graphical models of the functioning brain, combining it with a video game as a fun and engaging way to convey knowledge and concepts about neuroscience, as well as the neurotoxic and long-term effects of drug abuse on the brain.

Through this exhibit, people virtually view and manipulate the images between normal and methamphetamine-impaired brains to make a comparison between the two, and play a video game that simulates driving skills under methamphetamine-abused conditions. NIDA’s objective is to let all members of society understand the role of science, biology, and technology, and their relationship to neuroscience, behavioral science, and drug abuse and addiction research. Thus, the exhibit is aimed at improving the neuroscience literacy of the general public, conveying knowledge about the impacts of methamphetamine abuse on the brain to the population, and establishing a stronger concept of drug use prevention among children.

Statement of the Problem

Applying video games and simulations as a teaching and learning tool in fields outside of entertainment was initiated in 2003 by a movement called ‘Serious Games’ (Gudmundsen, 2006). Nowadays, Serious Game has become a general term that refers to any simulation with a game format that is used for instructional and educational purposes. Many researchers have also started to suggest that video games have enormous potential in classroom instruction (Annetta & Cheng, 2008; Annetta, Murray, Gull-Laird, Bohr, & Park, 2006; Dede, 2004; Gee, 2003; Kirriemuir & McFarlane, 2004; Prensky, 2001a; Squire, 2003, 2008). With advances in computer technologies and networked learning, educators and researchers are beginning to create our next generation of blended learning environments that
are highly interactive, authentic, meaningful, learner-centered, engaging, and fun (Kirkley & Kirkley, 2004). It turns out that the exhibit, *Drugs and the Brain: A Serious Game*, has the potential to be an enjoyable learning experience for the next generation by combining a virtual reality learning environment with a video game.

After conducting a pilot study that tested and evaluated the prototype of this exhibit in the North Carolina Museum of Life and Science at Durham, NC, many parents expressed highly positive feedback. They in turn suggested that it should be brought into schools to provide students the experience of learning the impact of drug use on the brain, helping them to create negative (anti-drug) attitudes toward drug use. This study was hence proposed. It was hoped that the exhibit could increase the possibility of attracting and holding the attention of middle school students and subsequently improve their understanding of and negative attitudes toward drug use.

**Purpose of the study/Research Questions**

This study investigated the effectiveness of the interactive exhibit, which included a virtual reality learning environment combined with a video game, on middle school students’ understanding and attitudes toward drug use. As the awareness of the educational uses of video games increases, this is a timely study that provides practical evidence to support the role of video games in education. This study also contributes an idea and useful resources for both pre- and in-service science teachers to think about how to enhance students’ neuroscience literacy. Moreover, this is also a study that provides valuable information for the considerations of policy makers and program designers about reformation and improvement of current drug prevention programs. To this end the specific research
questions that were addressed:

1. What do students learn about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain via the exhibit?

   1.1. What do students know about basic concepts of neuroscience and the impact of methamphetamine abuse before exposure to the exhibit?

   After the exhibit:

   1.2. Do students identify the basic brain structures and their functions?
   1.3. Do students understand the physical and functional impairments associated with taking methamphetamines?
   1.4. How do students describe the negative consequences of taking methamphetamines in their daily lives?

2. How are students’ attitudes toward methamphetamine use changed after exposure to the exhibit?

   2.1. Have their general attitudes toward methamphetamine use changed?
   2.2. Have their attitudes toward the relationship between methamphetamine use and health changed?

3. What are students’ experiences and perceptions of using the exhibit to learn the impact of methamphetamine abuse on the brain?

   These research questions provided the framework for conducting a mixed-method research design for this study.
Hypotheses

It was hypothesized that an effective, virtual reality learning environment with a video game, which provides the latest findings in neuroscience research to teach the impact of drug abuse on the brain, may be of substantial benefit in enhancing the neuroscience literacy of middle school students, thus conveying knowledge about the impact of drug abuse on the brain to them, and improving their negative attitudes toward drug use.

Limitations of the study

Several limitations should be considered in this study. Sampling and generalizability would be the first limitation encountered. This study was conducted at the Friday Institute (FI) using a convenient sample. A total of 98 students from Centennial Campus Middle School (CCMS) volunteered to participate with the research during their health classes. Since it is not a random sample and the population is relatively small compared to the whole nation, interpretations of the study’s results and generalizations to other states or nations should be taken with care to avoid any form of bias.

This exhibit was originally designed as a touring museum exhibit. Thus, in order to convey the most precise and clear information to the public in a relatively short time (about 10-13 minutes that visitors spend on average for an exhibit) (Boisvert & Sleza, 1994) in the museum setting, this exhibit features only a single drug, methamphetamine. However, more relative exhibits that feature other drugs might be available in the future. It is hoped that more efforts could be made by educators and neuroscientists.

It is hoped that by obtaining more knowledge about the impact of drug use on the brain, it could help students to develop a more negative attitude toward drugs, which consequently
decrease their drug use. However, it is also known that attitude change does not ensure behavior change. This study did not involve a longitudinal research design tracking students’ attitudes and monitoring their behaviors of drug use. Hence, a long-term effect might not be inferred from the findings of this study.

All interview and observation data were collected and analyzed by the researcher personally. Even though the researcher has already done as much as possible to deal with the data as objectively as possible, the subjective biases are still unavoidable. This also cannot be ignored.

**Definition of Terms**

**Illicit drugs:** Illicit drugs include marijuana or hashish, cocaine (including crack), inhalants, hallucinogens (including phencyclidine [PCP], or prescription-type psychotherapeutics used nonmedically, which include stimulants, sedatives, tranquilizers, and pain relievers.

**Neuroscience Literacy:** The knowledge and understanding of concepts and processes in neuroscience required to understanding issues related to diseases and disorders of the brain, as well as how humans interact with their environment and each other because of their unique nervous system characteristics.

**Virtual Reality:** An electronic environment that is filled with computer generated graphics, enabling users to see in a 2D or 3D visual display apparatus or stereo viewing goggles, and to interact with it with the aid of some sort of input device like mouse, joystick or reality gloves.

**Simulation:** A representation of real life that accurately demonstrates a physical or simulated process or phenomenon.
Games: Deliberately simplified representations of phenomenon based on goal-directed and competitive activities conducted within a framework of established rules.

Video Games: An electronic or computerized game played by manipulating images on a video display or television screen.

Serious Games: Any simulation and video game that is used as a platform in fields outside of entertainment for educational purposes.
CHAPTER TWO

Literature Review

Overview

To elaborate and support the important role of video games in education, the literature is discussed in four key sections. The first section generally discusses why play is a serious matter. It starts by clarifying misconceptions about play that people usually have and then tries to give play a general definition. After that, both classical and modern theories of play are drawn out to inquire into the origin and fundamental nature of play. Those theories give rationale for answering the question about why play has influenced education for quite a long time and has provided justifications for content in many educational programs.

Since play includes many varieties and settings, video game play that has burgeoned over the past two decades is discussed in the second section. This section provides evidence from previous research to support that video games actually have enormous potential to facilitate learning. First, it discusses the relation between video game play and flow experience. The experience of flow is fundamental to all learning since it is a major incentive of intrinsically motivated behavior. Then, it continues by using Piagetian and Vygotskian theories as lenses to examine how video game play affects learning. Further, the responses of brain activities and the enhancements of cognitive skills under video game play are discussed by investigating scientific evidence from a cognitive neuroscience perspective. And of course, not all video games are good for all learners, therefore, the features of so-called good video games defined by Gee (2008) that help thinking and learning are given at the end of this section.
The third section mainly discusses Serious Games. The always blurred and confusing relationship between simulations and video games is discussed at first. It is followed by investigating constructivist theory and microworld that give rationale and underpinning to the concept of Serious Games. This is followed by some practical applications of using Serious Games for multiple purposes, especially for drug use education.

The last section of the literature review discusses the approaches employed for drug use education. Although the programs that focus on teaching and training children the skills to deal with life pressures and to resist drug use have been considered as the most promising approaches, information dissemination still can not be ignored because it gives children a rationale to say no to drug use. Moreover, disseminating information about the negative consequences of drug abuse from a neuroscience perspective could be helpful for improving neuroscience literacy of students, and thus affecting their attitudes toward drug use. Unlike the traditional approaches of information dissemination that are always delivered by a one-way communication from the source to the audience directly, Serious Games that provide interactive, engaging learning environment to children would give a new process and opportunity to information dissemination.

Through these four sections of literature review, a clear idea that supports the use of Serious Games to convey knowledge about the impact of drug abuse on the brain to students emerges.

**Serious Play**

*Play is necessary for the development of higher intelligence; for if we were provided with perfected instincts, as insects are, life would be automatic and there would be no such thing*
as education and no increase of ability or intelligence, either in the individual or the species.

-- Mitchell & Mason, 1935, pp. 56-57

Misconceptions about Play

Play is serious. The importance of play has been studied by extensive research in a variety of disciplines; however, some misconceptions still exist in thinking about play (Mann, 1996; Rieber, 1996). The first one is that play and entertainment are traditionally considered as synonymous. Mann (1996) argues that the only similarity between play and entertainment is that both of them are fun and enjoyable. However, play is active, making it very different from the passive entertainment mode. Play is something that requires and even compels children to actively participate, and the active participation serves as an engine for learning. In other words, the more active the children are and the more they participate and the more they learn. On the contrary, children actually learn very little from entertainment such as watching TV, because they are entertained and passively consuming something presented only for their enjoyment (Mann, 1996).

Another misconception is that play applies only to children, but not to adults (Rieber, 1996). Play is generally considered as something to be given up when growing up (Provost, 2001, as cited in Rieber, 1996). Unlike work, play is not respectable in adults. Some feel there should not be play in adult world, moreover, adults tend to refuse to use the word ‘play’ to describe their activities. However, the truth is that adults might impose additional characteristics on play, but both children and adults do play and learn from play (Mann, 1996). Play in adults might be more goal-directed and more like a means, leading to an end. And for children, play is simply play, an activity that they spontaneously enjoy, engage, and
undertake for its own sake (J. Lee, 1915).

The last but the most important misconception is that play has little to do with learning. In fact, play facilitates cognitive growth by providing children with experiences and opportunities to interact with the world. As Rogers and Sharapan contend, “Play is a very serious matter, indeed. It is an expression of our creativity; and creativity is at the very root of our ability to learn, to cope, and to become whatever we may be.” (Rogers & Sharapan, 1994, p. 1). The value of play in education is important and should not be underrated (Weininger, 1929).

**Defining Play**

Play is a natural part of life. It is so broad a phenomenon, so universal that it cannot be easily defined (Mitchell & Mason, 1935). Play includes a variety of forms, and consists of many factors, even though there might be some general attributes that are considered as being involved in play. For example, play is a self-initiated and self-regulated activity, which is also relatively risk free and not necessarily goal-oriented (Verenikina, Harris, & Lysaght, 2003). Fromberg proposes a definition of play, clearly indicating that young children's play is (Fromberg, 1999, p. 28):

*Symbolic*, in that it represents reality with an “as if” or “what if” attitude;
*Meaningful*, because it connects and/or relates experiences;
*Active*, in that children are doing things;
*Pleasurable*, even while children are engaged in a serious activity;
*Voluntary and intrinsically motivated*, whether the motive is curiosity, mastery, affiliation, or something else;
*Rule-governed*, whether implicitly or explicitly expressed; and
*Episodic*, characterized by emerging and shifting goals that children develop.
spontaneously and flexibly.

These characteristics may provide an overall idea about what play looks like, but why do children play? And why do all children like to play? Many theories have been reported by scholars and researchers since the beginning of 1870's, attempting to inquire into the origin and fundamental nature of play (Mitchell & Mason, 1935). Reviewing those theories gives opportunities to understand how play impacts children's development and how children develop meaning through play (Verenikina et al., 2003).

Play theories could be classified into two clusters: classical theories and modern theories. Classical theories of play were generated in the nineteenth and early twentieth centuries. They mainly focus on the driving forces and physical and instinctive aspects, striving to provide a reason or purpose for play and its functions. On the other hand, modern theories of play were generated after 1920. They are more concerned with the ways that play benefits psychological and cognitive development. Research stimulated by these modern theories provides an understanding of play as either a form of cognition or a form of symbolization, which has the most influence on education (Mellou, 1994; Mitchell & Mason, 1935; Sapora & Mitchell, 1961; Saracho & Spodek, 1995; Verenikina et al., 2003).

Classical theories of Play

There are four classical theories of play: surplus energy theory, recreation theory, instinct-practice theory, and recapitulation theory. The oldest and simplest theory is surplus energy theory, which views play as nothing but “the aimless expenditure of exuberant energy” (Schiller, 1875, as cited in Mitchell & Mason, 1935). In other words, play in this theory is considered as a kind of activity that helps humans to get rid of an excess of energy.
Another theory is the recreation theory. Different from surplus energy theory, recreation theory posits that play is used to recuperate and restore energy (Lazarus, 1883, as cited in Mitchell & Mason, 1935). People who have exhausted energy can recuperate from an active and interesting occupation through play.

After these two energy-driven theories, Groos (1898; 1901) argues that play gives practice and training to human and higher thinking animals for developing important instincts before reaching maturity. In other words, play develops physical and mental capacities in children, serving as a preparation for adult activities (Verenikina et al., 2003). Groos' idea of play is named as the instinct-practice theory, which is the first theory that considers the benefits of play from an intellectual and cognitive perspective. Later, the recapitulation theory is given by Hall (1906) to explain play as a result of biological inheritance (Mitchell & Mason, 1935). Hall asserts that play per se is a recapitulation of the evolutionary history, in which we rehearse the activities of our ancestors as if we relive the past of our race. Different from Groo's theory that play is for practicing and strengthening instincts, Hall argues that the rehearsal of the culture of the race provides children opportunities to express their instincts, and thereby weaken them. For example, if children can exercise their fighting instinct freely in play, then the fighting instinct becomes weakened and will not function so strongly in their later lives.

Modern Theories of Play

Modern theories of play include self-expression theory, psychoanalytic theory, arousal modulation theory, metacommunicative theory, and cognitive theories. The self-expression theory was first advanced by Mitchell and Mason (Mitchell & Mason, 1935; Sapora &
Mitchell, 1961). The key point of this theory contends that because man is an active, dynamic creature, activities are the primary need of life. Both the physical and anatomical structure and the psychological inclinations of the individual all predispose him to certain types of activity. Hence, play provides man the feeling of accomplishment, as Mitchell and Mason argue, “Man plays to achieve, to create, to conquer, to acquire, to impress, and to win approval” (Sapora & Mitchell, 1961, p. 91).

Focusing on the emotional domain, psychoanalytic theory was developed by Freud and his followers (A. Freud, 1968; S. Freud, 1959), speculating that play is a catharsis, providing a safety valve for releasing emotions. Children incorporate stressful situations into their play, and play serves as a coping mechanism that helps children understand or deal with stressful situations; eventually helping them master the world.

Arousal modulation theory is stimulation-related theory (Berlyne, 1960; Ellis, 1973). What it argues is that play is a means used to maintain and keep an optimal level of arousal by either raising or decreasing arousal level. Excess stimulation that raises arousal to disturbingly high levels could be decreased in play activities. On the other hand, play also serves as an additional source of arousal-seeking activity that helps raise arousal levels in children when the stimulation is insufficient.

The theory by Bateson (1955; 1976) focuses on the development of communication and metacommunication in children as they play together. Play communication refers to children’s talk or dialogue as they are in character through play, and metacommunication is their talk about the play. In other words, they talk about the rules of the play and what the characters have to do in play. Metacommunication shapes children’s understanding about the
play and the strategies to communicate their understanding. Play provides the metacommunicative context for the development of children’s understanding and awareness of the rules and strategies to talk about their understanding. Hence, it serves an important role in a child’s cognitive development.

Cognitive theories impact education the most, because they try to explain the relationship between play and cognitive development. In other words, cognitive theorists endeavor to understand play and its role in the cognitive development of children. Two major theories, Piagetian learning theory and Vygotskian sociocultural theory, give the most profound influence.

**Piagetian learning theory.** Piaget (1951) supports two concepts that account for cognitive development in children: assimilation and accommodation. According to Piaget, assimilation takes place when individuals attempt to integrate new information from the external world connecting reality into existing mental structures directly; Piaget refers to existing mental structures as ‘schemata.’ On the other hand, when individuals modify or change the existing schemata to fit new information, accommodation occurs. The dual processes of assimilation and accommodation allow new schemata to be formed. Essentially, cognitive disequilibrium sets in while a person encounters a new event, and a state of balance or equilibrium is attained again as he is able to assimilate or accommodate the new information (Ginn, 1995; Howard, 1998; Tamburrini, 1974).

Forman and Pufall (1988, as cited in Rieber, 1996) summarize Piaget’s theory as three properties: epistemic conflict, self-reflection, and self-regulation. Generally, people tend to seek an organized, structured world; however, what we are continually confronted with is an
ever-changing environment. This epistemic conflict easily evokes our cognitive
disequilibrium. In the meantime, self-reflection makes us assess and understand a given
situation, and finally, a resolution through either assimilating or accommodating new
information will be achieved through self-regulation. According to this theory, Rieber claims
that “learning cannot occur unless an individual is in a state of disequilibrium.” (Rieber, 1996,
p. 47). Learning thereby is defined as the construction of new knowledge through the dual
processes of assimilation and accommodation. In other words, when new knowledge is
constructed from a resolution to conflict, learning occurs.

Piaget (1951) argues that the primacy of assimilation is over accommodation in play. In
other words, children make the world adapt to them through play. They pretend the world is
other than it is, and hence could simply fit everything to their current mental schemata
(Saracho & Spodek, 1995). However, Tamburrini contends that although assimilation is
dominant, “this is not to say that there is no accommodation in play, for assimilation is never
pure” (Tamburrini, 1974, p. 52). In fact, accommodative elements occur in at least three
ways. First, when children pretend to be a character and imitate what they conceive as the
characteristic actions of this character in make-believe or symbolic play, they adapt their
actions to a reality that involves accommodation. Secondly, accommodation is also involved
when children experience interiorized imitations (Piaget, 1951) by imaging some absent
objects or events in symbolic play. Finally and most importantly, some obstacles in play such
as the different opinions from their playmates or limitations of material objects might force
children to modify their actions to adapt to external reality in some way, which is also
accommodation and referred to as incidental learning.
Tamburrini (1974) thereby asserts three important interrelationships between play and Piaget’s theory of cognitive development in play. First, play reflects children’s schemata. Piaget proposes three stages of play in accordance with the stages of cognitive development, functional or practice play, make-believe or symbolic play, and games with rules, respectively. Each particular type of play requires a particular level of cognitive sophistication in children, and play simply reflects the level of cognitive development that has been attained (Saracho & Spodek, 1995). Secondly, Play consolidates the skills, actions, and meanings children have acquired by maintenance or exercise of activities to prevent the atrophy of schemata for lack of use, which is close to Groo’s instinct-practice theory (Groos, 1898, 1901). And finally, play is an incidental learning.

Vygotskian sociocultural theory. Vygotsky (1967; 1978) sees play as the leading source of cognitive development, which means that play is an activity that directly supports cognitive development in children. According to Vygotsky, play gives children an imaginary, illusory world, in which unrealizable desires can be realized. That is, children create and engage in an imaginary situation in play where they use objects in place of other things, and the meaning of the objects begins to become separated. This imaginary situation in play (symbolic play) helps children to be able to think about meanings independently of the objects they represent, which in turn promotes the development of abstract thinking.

Vygotsky makes a distinction between two levels of development: actual development level as determined by independent problem solving, and potential development level as determined through problem solving under adult guidance or in collaboration with more capable peers. The zone of proximal development (ZPD) is defined as the distance between
these two levels of performance. He argues that play is a kind of magnifying glass that creates a broad ZPD both for the social and emotional development in children, as well as for their cognitive development. Vygotsky states, “Play creates the ZPD of the child. In play a child always behaves beyond his average age, above his daily behavior; in play it is as though he were a head taller than himself” (Vygotsky, 1978, p. 102).

For Vygotsky, the imaginary situation in play always contains social and cultural rules. He asserts that, “all games with imaginary situations are simultaneously games with rules, and vice versa” (Vygotsky, 1967). For children pretending to be real life characters, they must present the social images of the roles and obey the rules of society. Hence, children always acquire the tools and meanings of their culture and society when they play (Verenikina et al., 2003).

Each of the aforementioned theories gives explanations for play and its role in a wide range of development areas in children, which have influenced education for a long time and provided justifications for content in many educational programs (Saracho & Spodek, 1995). Play includes many varieties and settings and video game play is one that has grown at an astronomical pace over the past two decades. Since video games have successfully invaded our daily lives with an incredible fan-base, the potential consequences of video game play have unavoidably evoked much attention.

*Video Game Play*

*When kids play video games they experience a much more powerful form of learning than when they are in the classroom.*

-- Gee, 2003
A national survey indicates that 97% of young people aged 12-17 play video games (Lenhart, Kahne, Macgill, Evans, & Vitak, 2008). In other words, almost all teens today play video games. With such a high percentage of teens playing video games, today’s learning generation is extremely video game literate. Play serves an important role in children’s development. Video games in particular might carry enormous potential to be valuable learning tools (Oblinger, 2006).

*Video Game Play and Flow*

Video game play provides people a so-called *flow* experience in which individuals enjoy and engage themselves. Csikszentmihalyi (1990) describes *flow* as an optimal experience, a state that people attain when they are intensely involved in an activity with a high level of enjoyment and fulfillment. Because this gratifying state is so enjoyable, people are willing to put forth effort to reach and maintain that state, with little concern for their surroundings or what they will be getting out of it, even when it is difficult or becomes dangerous.

*Flow* theory is based on a symbiotic relationship between challenges and abilities, and the abilities must to meet those challenges. The *flow* experience is believed to occur when one’s abilities are neither overmatched nor underused to meet a given challenge. In other words, when the challenge is greater than abilities, people feel anxious; whereas people experience boredom if the challenge is significantly less than that of which they are worthy. When people are focused on playing video games, they can reach the state where everything but the game itself is ignored and forgotten; including sleeping and eating. Video game play
thus allows people to experience the flow state with a much enjoyment, engagement and fulfillment.

*Flow theory and learning.* The experience of flow is a major incentive of intrinsically motivated behavior (Schiefele, 2001), which is fundamental to all learning. Jones (1998) argues that in order to reach flow experience, people must use two kinds of cognition: experiential and reflective cognition (Norman, 1993, as cited in Jones, 1998). According to Norman (1993), experiential cognition refers to a combination of skills, reflexes, and knowledge gained after practice that helps one react to events efficiently and effortlessly, whereas reflective cognition is one of comparison of thought and of decision making that usually results in new ideas. Problem solving generally results from the combination of both experiential and reflective cognition. While playing video games, people reach flow by using both experiential and reflective cognition. As people continue to engage in video games and gradually master them, learning is spontaneously furthered and knowledge and skill are increased.

*Scientific evidence.* Neuroscience research provides some direct evidence to support the relationship between video game play and flow experiences. It has been generally considered that the involvement of the mesocorticolimbic dopamine system, the brain reward circuit, somehow assigns value to, or reinforces, certain behaviors. In other words, the activation of the mesocorticolimbic dopamine system is believed to provide a hedonic reward, pleasure, which motivates and reinforces people to engage in activities (Bear, Connors, & Paradiso, 2001). Marr (2001) argues that the mesocorticolimbic dopamine release might be the neurochemical processes underpinning flow experiences, and playing video games actually
induces the release of mesocorticolimbic dopamine (Hoeft, Watson, Kesler, Bettinger, & Reiss, 2008; Koepp et al., 1998). In other words, this mesocorticolimbic dopamine release through video game play might be the neurochemical process that gives people flow experiences. Moreover, the involvement of dopamine release is far more than a hedonic reward. It is generally thought that dopamine is also involved in a wide range of human behaviors including learning, attention, sensorimotor coordination, and so forth (Koepp et al., 1998; Robbins & Everitt, 1992).

**Video Game Play and Learning**

There are various research studies that support the idea that people learn through playing video games. For instance, video games create learning environments that are more entertaining and engaging because they are challenging and surreal and arouse curiosity, which in turn motivate players to learn new things and engage players through an enjoyable experience (de Aguilera & Mendiz, 2003; Garris et al., 2002; Malone, 1981; Vorderer, Hartmann, & Klimmt, 2003). In the virtual world of video games, players learn through performing actions and movements, which provide them opportunities to experiment, practice, manipulate, and try repeatedly until they complete their tasks (Downes, 2002; Ko, 2002; Shaffer, Squire, Halverson, & Gee, 2005). Moreover, video games provide clear goals, providing immediate feedback that allows players to improve their performance, and to review whether their decisions and actions are useful in achieving the goals, thus letting them know whether or not they are on the correct path to success (Gee, 2004; Kiili, 2005). Players learn because video games allow them to collaborate with other people, to discuss strategies,
to share information, and to interact with each other (Barab, Thomas, Dodge, Carteaux, &
Tuzun, 2005; Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, n.d.)

Piagetian theory. Van Eck (2006) argues that video games that promote curiosity and
challenge student’s abilities facilitate the processes of what Piaget calls cognitive
disequilibrium and resolution. The extent to which games foil expectations, thus creating
cognitive disequilibrium, without exceeding the capacity of the player to succeed largely
determines whether games are engaging. Interacting with a game therefore requires a
constant cycle of hypothesis formulation, testing, and revision, and this process happens
rapidly and often while the game is played, with immediate feedback. In other words,
curiosity and challenge increase the intrinsic motivation of games and thus encourages
players to resolve conflict if a goal seems attainable. This implies that games that are either
too easy or difficult to solve will not be engaging. Thus video games with appropriate
curiosity and challenge constantly require input from and provide feedback to the players.
Hence, according to Van Eck (2006), games could be potential teaching and learning tools as
long as they create a continuous cycle of cognitive disequilibrium and resolution that engages
players while also allowing players to be successful.

Vygotskian theory. Ritterfeld & Weber (2006) claim that the concept of ZPD introduced
by Vygotsky gives an explanation of the most influential input. From Vygotsky’s point of
view, a most influential input is one that matches the developmental stage of children, which
could be easily connected to the established mental structure, and thereby extending it. To
this end, video games that challenge players with an attainable goal and allow players to
collaborate with other people and get assistant from experts contain the most appropriately
influential input for children. In other words, video game play that reaches ZPD has enormous upside as it pertains to learning.

Ritterfeld & Weber continue arguing that this contention is also supported by the notion of developmental tasks (Havighurst, 1971, as cited by Ritterfeld & Weber, 2006). Havighurst defines a developmental task as “a task which arises at or about a certain period in the life of the individual, successful achievement of which leads to his happiness and success with later tasks, while failure leads to unhappiness in the individual, disapproval by society, and difficulty with later tasks” (Havighurst, 1956, p. 215). From this point of view, video games are similar to developmental tasks. Playing with video games that are collaborative, curious and challenging while allowing the players to be successful by letting children reach achievement gradually, continually engaging them in later tasks, and mastering those tasks, will subsequently lead to cognitive, emotional and social improvement.

*Video Game Play and Brain Activity*

Brain imaging research directly reflects responses of the brain during video game play. In considering the findings from brain research, however, the impact of video game play on brain activity, especially the prefrontal cortex which is generally considered as brain areas associated with learning, memory, thinking, emotion, and impulse control, still remains controversial.

*Activation of prefrontal cortex.* Saito, Mukawa, and Saito (2007) employed functional Magnetic Resonance Imaging (fMRI) to examine brain activity in adults during video game play. The study compared brain activities while playing with three different types of games, typical board game, shooting game, and puzzle game. Their findings indicate that a typical
board game, which requires logical thinking, activated broader areas of the prefrontal cortex. The shooting game, which requires real-time reaction, activated broader areas of the premotor and parietal cortex, and the puzzle game, which requires both logical thinking and real-time reaction, activated broader areas of the prefrontal, premotor, and parietal cortex. All three types of games also showed activation in the visual association cortex and cerebellum that are responsible for vision and movement coordination respectively (Kandel, Schwartz, & Jessell, 2000).

The study by Nagamitsu, Nagano, Yamashita, Takahima, and Matsuishi (2006) measured cerebral hemoglobin concentrations using near infrared spectroscopy (NIRS) to investigate the effect that action video games have on regional cerebral blood volume in 12 normal volunteers, including six adults and six children. The results indicate that during video game play, five adults and two children showed significant increases of total-hemoglobin concentrations in either the unilateral or bilateral prefrontal region, while significant decrease in prefrontal total-hemoglobin concentration were observed in three children and one adult. They then conjecture an individual game performance, such as different interests and attention devotion, or an age-dependent utilization of different neural circuits during video game tasks, which might contribute to the various changes.

Deactivation of prefrontal cortex. On the other hand, the opposite findings that video game play deactivates prefrontal cortex are also evidenced in other studies. Ryuta Kawashima employed fMRI to measure brain activity in hundreds of teenagers, comparing brain activity in subjects playing Nintendo games with brain activity in those doing a simple, repetitive arithmetical exercise (Kawashima, 2003, as cited in Doğan, 2006). The results
show the game group only had brain activity in the parts of the brain associated with vision and movement, while arithmetic exercise stimulated brain activity in both the left and right hemispheres of the frontal lobe. Hence, Kawashima infers that video game play excessively would halt the process of brain development, especially the frontal lobe, leading to impairments of one’s ability to control behaviors (McVeigh, 2001). Another study, conducted by Mori, recorded and analyzed electroencephalogram (EEG) patterns from 240 participants, comparing the amount of alpha and beta brainwave activity in people who rarely play video games with people who are regular and excessive players. Mori found that beta waves that are thought to represent “online” neural activity were chronically reduced in those who play video games frequently and excessively, and he in turn conjectures that video games lead to brain damage (Jarrett, 2002; Kobayashi, 2002). However, the brain damage claim by Kawashima and Mori is criticized by other researchers. Some neuroscientists and psychologists suggest that since there is no direct evidence for lasting damage, this is really a premature conclusion. Moreover even assuming the findings are correct, it is by no means a certain sign of damage that is caused by gaming per se (Phillips, 2002).

**Video Game Play and Cognitive Skills**

Kirriehuir and McFarlane (2004) assert that games motivate participants because the learning is fun and helps individuals ‘learn through doing.’ In their opinion, video game play not only improves cognitive growth, but also supports valuable skill development, such as strategic thinking, planning, communication, application of numbers, negotiating skills, group-decision making, data-handling, and visual-spatial thinking. Indeed, although the inconsistent results of the impact of video game play on the brain activity remain debatable,
many studies have shown that instead of causing cognitive impairments, video game play can actually improve or modify many perceptual and cognitive abilities (Green & Bavelier, 2006a).

**Visual processing.** The research conducted by Greenfield, DeWinstanley, Kilpatrick, and Kaye (1994) indicates that video game players (VGPs) performed significantly better on tasks requiring divided visual attention, demonstrating that video game play may causally result in improving strategies of divided attention. In another study, a series of experiments were conducted by Green and Bavelier (2003) showing that video games might be capable of modifying visual selective attention. Compared to non-video game players (NVGPs), VGPs had an overall greater attentional capacity, an enhanced spatial distribution of attentional processing over the visual field up to 30°, and better temporal processing of visual information. Both studies also demonstrate that after a period of practice on video games, the performance of NVGPs on those tasks requiring divided and selective visual attention was significantly improved.

Trick, Jaspers-Fayer, & Sethi (2005) investigated the development of multiple object tracking ability in children, showing that after statistically controlling the effects of age, tracking performance of players with action video game experiences was significantly better than NVGPs, especially with large numbers of targets. The same results are further evidenced by Green and Bavelier (2006b), demonstrating that in addition to its effect on the spatial and temporal aspects of visual attention, action video game playing also modified the ability of multiple object tracking. In the same study, it was also found that training on an action video game also enhanced tracking performance in NVGPs. Green and Bavelier
therefore suggest that this enhancement is mediated by changes in visual short-term memory skills. Moreover, the experiments by Castel, Pratt, and Drummond (2005) also evidence that VGPs performed better on visual search tasks than NVGPs.

Green and Bavelier (2007) conducted research to investigate the mechanisms underlying the improvement of visual processing resulting from playing action video games, indicating that playing video games augmented spatial resolution of visual system. Although the mechanism is still not clear enough, so far we can be sure that playing video games does indeed enhance the performance of complex visual tasks, demonstrating improvement of several different aspects of visual processing such as visual attention, object tracking abilities, item detection, and spatial resolution.

**Spatial representational skills.** Research has suggested that video game play improves spatial representational skills. Greenfield, Brannon, and Lohr (1994) found a close relationship between scores on mental paper folding and video game scores, and spatial presentational skills might be developed and improved over long-term video game play. On the other hand, a study by Subrahmanyam and Greenfield (1994) shows that about a 2-hour video game practice was enough to lead to an overall improvement in dynamic spatial performance, and the improvement in spatial skills caused by video game training was maintained and still evident even after several months (Terlecki, Newcombe, & Little, 2008).

More than improving spatial ability in both males and females, video game play has also been demonstrated to particularly benefit females, reducing gender differences in spatial cognition (De Lisi & Wolford, 2002; Feng, Spence, & Pratt, 2007, experiment 2). Researchers therefore suggest that video games might be of potential to be used in school to
enhance children’s spatial abilities and equalize individual differences in spatial performance, including those associated with gender (De Lisi & Wolford, 2002; Subrahmanyam & Greenfield, 1994).

Reaction time and visual-motor coordination. Since playing video games is an activity that requires coordination and quick reactions, many studies have indicated that video game play can improve reaction time, especially for the elderly (Goldstein et al., 1997; Clark, Lanphear, & Riddick, 1987, as cited in Whitcomb, 1990). Orosy-Fildes and Allan (1989, as cited in Green & Bavelier, 2006a) found that only 15 minutes of a video game experience might be enough to improve reaction task performance. Even in children, reaction time was also decreased after video game practice (Yuji, 1996, as cited in Green & Bavelier, 2006a).

For video games, visual-motor coordination is mainly related to hands and eyes, so hand-eye coordination is a popular skill that has been thought to associate with video games. An experiment by Griffith, Voloschin, Gibb and Bailey (1983) conclude that video game players had better performance on visual and motor coordination than non-players in the same peer group.

Executive functions. In addition to the aforementioned perceptual and cognitive skills, it is also evident that video game play improves task switching performance. The aim of a study by Andrews and Murphy (2006) was to examine whether VGPs possess superior abilities compared to the NVGPs on task switching. Their results suggest video game play might improve abilities related to task switching. They thereby conclude that it might be possible to incorporate video game play into educational programs and remediation programs designed to assist individuals with impaired executive function.
Logical reasoning skills. Ko (2002) investigated whether video games improve children’s abilities in using a particular form of logical reasoning. The findings show that children’s performances were significantly improved by practicing games. Hence, they conclude that children could learn through performing tasks that elaborate their logical reasoning skills and problem-solving abilities by playing video games. In other words, children’s understanding of game clues and skills of logical reasoning gradually improve during the video game practice.

All behavior is a function of the brain (Kandel et al., 2000). Even higher cognitive functions are also built upon more basic underlying neurobiological processes (Tallal, Miller, Jenkins, & Merzenich, 1997). The brain cortices in animals are not fixed entities. On the contrary, they are dynamic and are continuously modified by experience, the so-called cortical plasticity (Buonomano & Merzenich, 1998). Hence, the performance of a given task can be dramatically improved with practice and training. It is then reasonable to assume that such improvement in performance would reflect changes in the brain. Learning thereby refers to a robust improvement in performance induced by experience and dependent on practice (Karni & Bertini, 1997). From this perspective, video game experiences could improve perceptual skills and cognitive abilities by playing the role of a facilitator that assists with learning, and ultimately causes changes in neural processing in the brain.

Good Video Games

Play might have potential impact on children’s development and learning, but we also have to be careful not to idealize play (Rieber, 1996); especially video game play. Play is not a panacea, and of course not all games are good for all learners. Gee (2008) provides some
principles for examining good video games for learning.

Gee argues that the human mind works just like a simulator; good video games are a perfect metaphor for the human mind and are a good place to study and produce human thinking and learning:

Human understanding is not primarily a matter of storing general concepts in the head or applying abstract rules to experience. Rather, humans think and understand best when they can imagine (simulate) an experience in such a way that the simulation prepares them for actions they need and want to take in order to accomplish their goal (Gee, 2008, p. 41).

Gee continues by using weddings as an example, arguing that on the basis of previous experiences related to weddings, people can simulate different wedding scenarios and role-playing of other people in their mind before acting and responding in the real world. It is thereby concluded that “videogames turn out to be the perfect metaphor for what this view of the mind amounts to, just as slates and computers were good metaphors for earlier views of the mind” (p. 42). He also provides a list that points out a baker’s dozen of features describing what constitutes a good video game and argues that the more features a game contains from the list, the better it would be for thinking and learning. Those features are presented as follows:

Co-design. Good video games are interactive and give immediate feedback.

Customize. Good video games are designed either to let players to customize the game play to fit their learning styles or to allow different learning styles and playing to work.

Identity. Identity makes players invest heavily. Good games offer players identities by giving different characters to choose from or by providing a relatively empty character from which players can design their own ones.
*Manipulation and distributed knowledge.* Players can manipulate characters and objects intricately, effectively, and easily through the world, which becomes tools for carrying out the player’s goal.

*Well-order problems.* Problems are well ordered, implying that early problems provide enough clues for players to form good guesses for later and difficult problems.

*Pleasantly frustrating.* Games adjust challenges and provide feedback, which makes players feel challenged while success is also attainable.

*Cycles of expertise.* Good games support the cycle of expertise, in which players master the challenges after practice, and as new challenges come, new extended practice forms.

*Information “on demand” and “just in time”.* Verbal information is provided “just in time” and “on demand” in the game. Players can get the information in the game whenever they need.

*Fish tanks.* Good games offer players fish tanks, stripped-down versions of the game, either as tutorial or the first few levels, so that newcomers could easily understand the game as a whole system.

*Sandboxes.* Good games offer players sandboxes either as tutorial or the first few levels, in where game play much like the real game but much easier and things can not go too wrong or too fast.

*Skill as strategies.* Players learn and practice skills as the strategies that help them accomplish things in the game.

*System thinking.* Good games help players get a feel for the ‘rules of the game.’ They know how each element fits into the whole game and the embodied rules and principles by
playing the game.

*Meanings as actions and images.* Good games have to make the meanings of words and concepts clear, and to make the philosophical points be realized and understandable in terms of images and actions.

*Serious Games*

*Video games, once confiscated in class, are now a key teaching tool. If they’re done right.*

-- Shreve, 2005, p. 29

Play and good video games perform an important role in learning and cognitive development and researchers subsequently are studying games as teaching and learning tools as a practical way to assist students in gaining knowledge. The Serious Games movement that aims at using video games and simulations for educational purpose was therefore initiated in 2003. The idea of Serious Games had already been practiced since the 1600s, with war games being used for improving the strategic planning of armies.

*Relationship between Simulations and Video Games*

The relationship between simulations and video games is very close, thus causing some confusion between the two (Leemkuil, 2006). When it comes to making a distinction between simulation and games, Jacobs & Dempsey (1993) contend:

The distinction between simulation and the concept of games or gaming is often blurred, and many recent articles in this area refer to a single “simulation game” entity. After all, a game, like a simulation, generally may be assumed to have goals, activities, constraints, and consequences. A distinction could be made between simulations and games in the following way. Where the task-irrelevant elements of a task are removed from reality to create a simulation, other elements are emphasized to create a game. These elements include competition and externally imposed rules and may include other elements such as fantasy and surprise (pp. 200-201).
Jacobs and Dempsey view games as being separated from simulations and being defined as any training format that involves competition and is rule-guided. However, Leemkuil (2006) places games into six genres: action games, adventure games, fighting games, puzzle games, role playing games, and simulation games. According to his definition, some games like role-playing or simulation games, actually do not involve competition (Leemkuil, 2006). Therefore, the distinction between simulations and video games remains blurred. As Maier and Größler (2000) describe, some researchers just combine both as ‘simulation games,’ some do not distinguish them, and others just separate games from simulations. In terms of computer-based instructional tools, Rieber (1996) argues that both games and simulations offer practical means to reach the constructivist idea of a microworld.

*Constructivist Theory and Microworlds*

The rationale underpinning the concept of Serious Games fits broadly under constructivist theory. Contrary to the traditional view that there is a single correct mental model of knowledge, constructivist theory asserts that various knowledge representations might be constructed individually. In terms of teaching, constructivist theory focuses on knowledge construction rather than knowledge transmission, which constructivists distinguish as objectivism (Dalgarno, 1996). According to Dalgarno, there are three principles that together define the constructivist view of learning. The fundamental principle is that individuals construct their own mental representations of knowledge, while the second principle claims that when the experiences of individuals can not be explained by their current knowledge, and when this inconsistency between their experiences and current knowledge leads them to reach a state of cognitive disequilibrium, learning occurs. Finally,
learning is situated in a context. Hence, social interactions are a necessary part of the learning process. Obviously, the works of both Piaget and Vygotsky are broadly implicit within constructivist theory.

Inspired by constructivist views of learning, the microworld is a constructivist invention that was first coined by Papert (1980). It can be defined as “a small but complete subset of reality into which one can go to learn a specific domain through personal discovery and exploration” (Rieber, 1992, p. 94; Scherly, Roux, & Dillenbourg, 2000, p. 127). Rieber (1996) argues that microworlds have two important characteristics. They present the learner with the ‘simplest case’ of the domain and this must match the learner’s cognitive and affective states. Besides, the most important assumption of a microworld is that individuals in a microworld are expected to be self-regulated learners (Rieber, 1992, 1996). Zimmerman (1989) describes self-regulated learners as being active in participating in their own learning process motivationally, metacognitively, and behaviorally. In other words, learners participate in a learning activity not for any reward but intrinsically, where they are able to monitor and evaluate their own learning and take the necessary steps to meet their learning styles.

Serious Games and microworlds. Simulations and video games are two common types of computer-based microworlds. According to Rieber (1992; 1996), the design of simulations-as-microworld is similar to the idea of conceptual models, which are artifacts invented by teachers, scientists, or instructional designers to provide appropriate presentations of the system being studied and to help learners build mental models of the system (Mayer, 1989; Norman, 1983; Wu, Dale, & Bethel, 1998).
Virtual reality provides “a high fidelity simulation of the real world that allows users to interact with the virtual environment in a manner similar to how users do it in the real world” (Hernandez-Serrano, Choi, & Jonassen, 2000, p. 117). Hence, the simplified but immersive virtual reality environments could be considered as functioning like simulations-as-microworlds in which people explore and experience almost the same things as they do in the real world.

Although simulations-as-microworlds could be considered as an interactive conceptual model, they can not ensure the active participation of learners (Rieber, 1996). In other words, they are as not intrinsically motivating as video games. Video games with features such as challenge, curiosity, fantasy, and control might be intrinsically motivating and have much potential for learners to engage and persist in the learning activities embodied. Rieber (1996) therefore argues that, “Simulations offer a direct link to the subject matter or content; and games offer a practical means for meeting the microworld assumption of self-regulation” (p. 49).

Practical Applications

Serious Games have been used for multiple purposes and have generated a substantial body of research for quite a long time. Briefly speaking, they have been employed for the treatment of phobias (Bornas, Tortella-Feliu, Llabés, & Fullana, 2001; Strickland, Hodges, North, & Weghorst, 1997; Vincelli, Choi, Molinari, Wiederhold, & Riva, 2001), language-learning deficits (Merzenich et al., 1996; Tallal et al., 1996), attention deficits (Alhambra, Fowler, & Alhambra, 1995; McGraw, Burdette, & Chadwick, 2005), learning disabilities (Adamo-Villani & Wright, 2007; Okolo, 1992; Woodward, Carnine, & Gersten, 1988), and
physical disabilities (McComas, Pivik, & Laflamme, 1998; Stanton, Wilson, Foreman, & Duffy, 2000; Wilson, Foreman, & Stanton, 1998). Furthermore, they have been used for assisting the elderly to increase their knowledge, to improve their skill performance, and to enhance their cognitive functioning (Ryan, 1986, as cited in Drew & Waters, 1985; Farris, Bates, Resnick, & Stabler, 1994; G. Miller, 2005).

Because Serious Games are used within a professional learning environment, offering a safe, learner-center way to master delicate technical skills through repeated practice, Serious Games are extensively used for medical and surgical training (Ali, Mowery, Kaplan, & DeMaria, 2002; T. P. Grantcharov et al., 2003; T. P. Grantcharov, Rosenberg, Pahle, & Funch-Jensen, 2001; Issenberg et al., 1999; Kneebone, 2003; Lemole et al., 2007; Mooney & Bligh, 1998; Sarker & Patel, 2007; Ward et al., 2008), firefighter training (Backlund, Engstrom, Hammar, Johannesson, & Lebram, 2007; Romano & Brna, 2001), military training (D. C. Miller & Thorpe, 1995; Prensky, 2001b; Weil, Hussain, Brunye, Sidman, & Spahr, 2005), and driving and flight practice (Backlund, Engström, & Johannesson, 2006; Backlund, Engström, Johannesson, & Lebram, 2008, in press; Baker, Prince, Shrestha, Oser, & Salas, 1993; Jentsch & Bowers, 1998).

Serious Games have also been used by many primary and secondary school children for language learning (Palmberg, 1988) and science and mathematics education (Annetta, Mangrum, Holmes, Collazo, & Cheng, in press; Barab et al., 2005; Klawe, 1998; Kraus, 1981; Sedighian & Sedighian, 1996; Squire, Narnett, Grant, & Higginbotham, 2004). In addition, they are also developed and used for conveying health care information (Lieberman, 1997; Westbrook & Braithwaite, 2001) as well as for HIV/AIDS prevention programs.
(Thomas, Cahill, & Santilli, 1997) and pregnancy prevention (Paperny & Starn, 1989) in both children and adolescents.

In order to convey the concepts of the neurobiology underlying substance abuse and the latest findings of various drugs, Miller et al. (L. Miller, Moreno, Willcockson, Smith, & Mayes, 2006; L. Miller, Schweingruber, Oliver, Mayes, & Smith, 2002) integrated problem-based learning, multimedia pedagogy, and the National Science Education Standards (1996) to develop an episodic series of interactive online games, called The Reconstructors™ (http://reconstructors.rice.edu). This uses a 2D web-based format to construct a series of adventure games and, from my understanding, it is the only Serious Game so far that aims at introducing substance abuse from a neuroscience perspective. Their findings indicate that middle school students’ knowledge about drugs and the basic neuroscience concepts underpinning the impact of drug abuse significantly improved after playing the game. However, they did not examine whether the use of Serious Games presents the potential to influence students’ attitudes towards drug use.

Drug Education

Drug prevention education is more than teaching the facts about drugs, it is teaching children and youth about themselves—what is possible in their life now, and what is possible for the future.


Ellickson (1995) categorizes the approaches that are employed for drug use education into three models: information model, affective model, and social influence model. The information model is the traditional form of drug education, focusing on providing children
with the facts about drugs including history, pharmacology, physical and psychological effects, and legal sanctions. Overall, this model posits a causal sequence that gaining knowledge about drugs leads to attitude change, which subsequently results in behavior change. The affective model assumes that some personality problems involving low self-esteem, inadequate communication skills, or inappropriate decision-making skills lead children to use drugs. Hence, this model focuses on improving their self-images, communication and decision-making skills, and problem-solving abilities without providing information on drugs. Finally, the social influence model stresses both external and internal influences that push children to use drugs. External influences include pressures and misconceptions from family, friends, or media, while internal influences involve children’s desires to be accepted by their peers or to look cool. This model focuses on teaching children how to deal with these pressures and how to resist drug use. Moreover, it also seeks to motivate children’s resistance against drug use (Ellickson & Robyn, 1987). Programs based on the social influences model are the most used and have been considered as the most promising approaches.

Botvin (1995) argues that traditional approaches that introduce children to the facts about drugs and the risks of drug use are not very effective. In other words, information alone actually does not work well. Indeed, many programs stressing information do generally increase children’s knowledge about drugs and occasionally present impacts on attitudes, but they rarely reduce actual drug use behavior (Botvin, 1995; Ellickson, 1995). Although the information model seems insufficient to deter drug use, Botvin (1995) also suggests that information that addresses adverse consequences still contributes to the impact of drug use
education, because children still need to be provided with basic information so that they could be aware of negative consequences. In other words, children need to understand why they have to say no to drug use and information gives them the rationale.

These traditional information programs are always delivered by lectures without much classroom discussion (Ellickson, 1995), which is characterized as a one-way communication from the source to the audience directly (Western CAPT, 1999). Serious Games provide an interactive environment that engages children in the learning activities which might give the traditional information model a new opportunity, whereby children learn about the negative consequences of drug use in a more interesting way, which may in turn provide much more potential to influence their attitudes toward drug use.

Neuroscience Literacy

On the other hand, although traditional information programs generally focus on introducing the facts and knowledge about drugs, those programs that teach students the consequences of drug use from a neuroscience perspective are few. Moreover, neuroscience topics are usually not in school science curricula.

‘Neuroscience Literacy’ could be defined as “the knowledge and understanding of concepts and processes in neuroscience required to understand issues related to diseases and disorders of the brain, as well as how humans interact with their environments and each other because of their unique nervous system characteristics” (Zardetto-Smith, Mu, Phelps, Houtz, & Royeen, 2002, p. 397). In short, it refers to public understanding of neuroscience, which is important for individuals to better understand themselves and make informed decisions about health and drug abuse in their daily lives.
Zardetto-Smith et al. (2002) argue that the larger goal of neuroscience literacy is associated with school neuroscience education. They then indicate that neuroscience concepts was in fact included in the National Science Education Standards for Life Science, and the standards clearly outlined that grades 5-8 students should have the concepts of structure and function in living systems. The fundamental concepts and principles involving neuroscience concepts that underlie the standard, *Structure and function in living systems*, include (National Research Council, 1996):

- Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.
- Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle. Different tissues are in turn grouped together to form larger functional units, called organs. Each type of cell, tissue, or organ has a distinct structure and set of functions that serve the organism as a whole.
- The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control, and coordination, and for protection from disease. These systems interact with one another.
- Disease is a breakdown in structure or function of an organism. Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms (1996, p. 156).

Moreover, a set of recommendations that are essential to scientific literacy are given by the National Council on Science and Technology (American Association for the Advancement of Science [AAAS], 1989). Based on these recommendations, the *Benchmarks for Science Literacy* clearly provides criteria about what students grades 6 through 8 should know or be able to do in science (AAAS, 1993). Of these, the contents of some criteria are essentially the same as the neuroscience concepts and knowledge regarding the negative effects of drug use on the brain (Zardetto-Smith et al., 2002):
• **Basic functions:** Interactions among the senses, nerves, and the brain makes possible the learning that enables humans to predict, analyze, and respond to changes in their environment.

• **Physical health:** Toxic substances, some dietary habits, and some personal behaviors may be bad for one's health. Some effects show up right away; while others, years later. Avoiding toxic substances, such as tobacco, and changing dietary habits increase the chance of living longer.

Neuroscience concepts are generally involved in the National Science Education Life Science Standards and project 2061 recommendations, yet they have often been overlooked in the K-12 curriculum. Zardetto-Smith et al. (2002) contend that the major challenge could be the teachers, because the teachers themselves do not have enough knowledge nor the professional training needed to teach this particular area of science, and thus may even be reluctant to tackle neuroscience concepts in the classrooms. Hence, as the awareness of the importance of neuroscience literacy and the lack of neuroscience resources in the schools increases, neuroscience professionals have started programs that aim at increasing the neuroscience literacy among the public to help both children and adults learn about the brain and the nervous system, and subsequently to indirectly decrease drug use and unhealthy behaviors (Fox, 2007; Zardetto-Smith, Mu, Ahmad, & Royeen, 2000; Zardetto-Smith, Mu, Carruth, & Frantz, 2006; Zardetto-Smith et al., 2002). Using Serious Games to teach the impact of drug abuse from a neuroscience perspective may be of substantial benefit in enhancing the neuroscience literacy of middle school students and, thus, improving their negative attitudes toward drug use.

**Conclusions**

Play is important for psychological and cognitive development of children. Video game play, moreover, has surprising potential to assist learning. This chapter brings together
the theories, foundations, and scientific evidence as rationale underpinning the use of simulations and video games for educational purposes, attempting to support that Serious Games might be an interesting and feasible way to teach the basic concepts of neuroscience and to convey knowledge about the impact of drug abuse on the brain to middle school students, ultimately affecting their attitudes toward drug use.
CHAPTER THREE

Methods

Setting of the Study and Participants

The study was set in a meeting room on the first floor of the Friday Institute, a separate building housing the research and development aim of the college of education, which served as a quiet and safe area to perform this study. Flyers (Appendix A) together with consent forms were distributed to the adjacent Centennial Campus Middle School (CCMS) students two weeks before this study was conducted. Students volunteered to participate in the study during their health classes and were compensated with a $10 iTunes gift card or a t-shirt for participation.

A total of 98 students in grades 6 to 8 participated in the study, consisting of 26 6th graders, 26 7th graders, and 46 8th graders, respectively. In addition, gender and ethnic profiles were also accounted for. It overall included 46 females and 52 males with an ethnic composition of 15 Hispanics or Latinos, 2 American Indians or Alaska Natives, 1 Asian, 42 Black or African Americans, and 38 Caucasians.

Science Content

Compared to control group subjects, methamphetamine-dependent individuals performed significantly worse on executive functions (Chang et al., 2002; Kalechstein et al., 2003). Executive function is defined as “a set of cognitive abilities that control and regulate other abilities and behaviours” (Barry, n.d.). One of the typical executive functions is the ability to intentionally stop or prevent actions that are already underway, which is called response inhibition. Research indicates that methamphetamine-dependent users have deficits
in their ability to inhibit responses, causing reduced cognitive inhibition (Salo et al., 2002). Such deficits in response inhibition are typically associated with impairments of the right-lateralized inferior frontal gyrus (IFG) (Aron, Fletcher, Bullmore, Sahakian, & Robbins, 2003; Rubia et al., 2001). Hence, the causal relationship is that methamphetamine causes persistent damage of the IFG, which subsequently impairs response inhibition.

These deficits of inhibitory abilities bring inconveniences to our daily lives, and sometimes may lead to severe damage. For instance, the delayed stop-signal inhibition, which individuals perform delayed reaction time to do a no-go (stop) response, may influence driving skills, causing severe accidents. Hence, the exhibit employs 3D models of the functioning brain as well as a video game to virtually visualize and display the aforementioned consequences to students. Three exhibit objectives were:

- Identify the basic brain structures and their functions (Figure 3.1).
- Examine the physical and functional impairments associated with taking methamphetamines, based on the latest research (Figure 3.2).
- Recognize the negative consequences of taking methamphetamines in daily life (Figure 3.3).

Exhibit Design

The exhibit features a single drug, methamphetamine, and consists of two parts, which takes participants approximately 10-15 minutes to complete. A 3D virtual brain tour, viewing and manipulating a comparison between a normal brain and a methamphetamine-impaired brain, was first presented. Then a mini video game simulating driving skills under methamphetamine-abused condition was given.
The models of the brain were presented on an autostereoscopic 3D display, which provides the same virtual reality as VR goggles, but without the need to wear a headset, and is viewable on the same monitor by multiple people simultaneously (Sierra, 2008). The autostereoscopic 3D display consists of a sheet of transparent lenses which is fixed onto the LCD screen, sending different images to each eye that are subsequently combined by the brain to create a 3D effect. Because the sheet is transparent, the brightness, contrast, and color could be truly and fully represented without any distortion. It is like a TV but includes depth, allowing the 3D image to appear to pop out. A screenshot presenting the 3D effects of the brain is shown in Figure 3.1. With a video game controller, students then navigate and manipulate the virtual brain. Students were also allowed to rotate and zoom in or out on the virtual brain models, authoring their own learning experience.

Figure 3.1. A screenshot showing the 3D effects of the brain.

The virtual brain tour included a series of brain images to present the structures of the brain and to model their functions. Every model is followed by a brief description (shown in
Figure 3.2). The structures of the brain and the areas that are damaged by methamphetamine, together with their corresponding descriptions are emphasized by different colors. For example, the portion of the motor cortex related to the production of go-signal is presented in green. Red is used to present the IFG and stop-signal pathway. Yellow shows the mass loss caused by methamphetamine use, and the overlapping area that shows where meth related mass loss has heavily affected a specific part of brain that is active when trying to stop an action is presented in black. During the whole exhibit, students could always go back to revisit the content they just learned.

![Meth Affected Brain Signals]

Figure 3.2. A screenshot presenting brief descriptions of the brain being modeled.

The driving video game simulates methamphetamine-abused conditions. Since methamphetamine abusers have deficits in response inhibition, it would be difficult for them to produce a no-go response in time if they were driving. In the game environment once the player sped across the street when the light turns green, they had a delayed reaction time to
stop, causing them to hit cars or pedestrians; thus creating accidents. Figure 3.3 shows a screenshot of the mini driving video game.

*Figure 3.3. A screenshot showing the mini driving game that simulates methamphetamine-abused conditions.*

Upon game completion, feedback is provided to the player illustrating his/her performance. A rationale embodied in the game context is immediately presented to students. Figure 3.4 shows a screenshot of the presented feedback.
Figure 3.4. A screenshot of final feedback presenting a student’s performance and the rationale embodied in the game context.

Data collection and Research Design

Revisit the research questions

In order to examine middle school students’ understanding of the impact of drug abuse on the brain and their attitudes toward drug use via interacting with the exhibit, three main research questions served as a framework shaping this study:

1. What do students learn about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain via the exhibit?

2. How are students’ attitudes toward methamphetamine use changed after exposure to the exhibit?

3. What are students’ experiences and perceptions of using the exhibit to learn the impact of methamphetamine abuse on the brain?
Research Design Matrix

Overall, this study used a one-group pretest posttest research design. Multiple methods collecting both quantitative and qualitative data were employed to answer the three aforementioned research questions. The data resources included a pencil-and-paper knowledge assessment, an attitude questionnaire, recorded observations, and semi-structured interviews. Multiple data resources serve as a triangulation for checking and further supporting the quantitative findings. A research design matrix that outlines data resources and methods used for each research question is shown as Table 3.1.
Table 3.1.
Research design matrix showing data resources and methods for each research question.

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Resource</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What do students learn about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain via the exhibit?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1. What do students know about basic concepts of neuroscience and the impact of methamphetamine abuse before exposure to the exhibit?</td>
<td>Pre-knowledge assessment Interviews</td>
<td>Pre/post/delayed posttest Semi-structured interviews</td>
</tr>
<tr>
<td>After the exhibit:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2. Do students identify the basic brain structures and their functions?</td>
<td>Knowledge assessment question #1, #2, #3, #4</td>
<td></td>
</tr>
<tr>
<td>1.3. Do students understand the physical and functional impairments associated with taking methamphetamines?</td>
<td>Knowledge test question #5, #6</td>
<td></td>
</tr>
<tr>
<td>1.4. How do students describe the negative consequences of taking methamphetamines in their daily lives?</td>
<td>Open-ended question Interviews</td>
<td></td>
</tr>
<tr>
<td>2. How are students’ attitudes toward methamphetamine use changed after exposure to the exhibit?</td>
<td>Attitude survey (Fetherston &amp; Lenton, 2005) Interviews</td>
<td>Pre/post/delayed posttest Semi-structured interviews</td>
</tr>
<tr>
<td>2.1. Have their general attitudes toward methamphetamine use changed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2. Have their attitudes toward the relationship between methamphetamine use and health changed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. What are students’ experiences and perceptions of using the exhibit to learn the impact of methamphetamine abuse on the brain?</td>
<td>Field notes Video recording Interviews</td>
<td>On-site observations Semi-structured interviews</td>
</tr>
</tbody>
</table>
Research Instrumentation

A student information sheet, two paper-and-pencil instruments used as pretest, posttest, and delayed posttest and a post-exposure interview are described as follows.

- **Student information sheet:** This questionnaire sheet (Appendix B) provided students’ demographic information including age, gender, and ethnic background. It also provided information regarding whether students had a history of seizure activity. Research indicates that video displays might induce seizures in some individuals (Fisher, Harding, Erba, Barkley, & Wilkins, 2005; Fylan, Harding, Edson, & Webb, 1999; Singh, Bhalla, Lehl, & Sachdev, 2001), hence students with epilepsy or a history of seizure activities were excluded from this study.

- **Knowledge pre and post assessment:** This assessment was developed by a neuroscientist who contributed ideas to creating the exhibit, ensuring its’ content validity. It included six multiple-choice items that were consistent with the science content embedded in the virtual brain exhibit. Of these, item #1, #2, #3, and #4 were aimed at testing students’ understanding of the brain structures and their functions. Item #5 and #6 were used to test students’ knowledge about the impact of methamphetamine use on the brain. The items from the pre-test, post-test, and delayed post-test were identical. However, one extra open-ended question was shown in the post-test to examine student descriptions about the negative consequences of taking methamphetamines (Appendix C).

- **Attitude questionnaire survey:** This survey (Appendix D) was modified from the study by Fetherston & Lenton (2005). Originally, it was designed to investigate
people’s attitudes toward cannabis use. The researcher substituted methamphetamine use to replace cannabis use. The researcher also took out several items as well as inserted two new items to make this survey more appropriate for the study. Finally, it resulted in a self-reported survey that consisted of two parts, which included a total of 10 Likert-scale items. Students were asked to respond on a scale of 1 to 5 (1-strongly disagree to 5-strongly agree) to the 10 items. One part included four items used to examine students’ general attitudes toward methamphetamine use, while another part consisted of six items aimed at investigating students’ attitudes toward the relationship between methamphetamine use and health. The survey was distributed to students before, after, and following a one month delayed period after the exhibit to investigate any attitude change.

- **Comments:** A free response question (Appendix E) was given to each student after completing the post-test instruments, which allowed students to provide reflections and their impressions of the exhibit.

- **Open-ended knowledge question:** One open-ended knowledge (Appendix E) question was also distributed to each student after completing post-test instruments. This asked students to explain in detail the negative consequences of methamphetamine on your brain. This question was designed to investigate how students described the impact of methamphetamine abuse on the brain after exposure to the exhibit.

- **Interview:** The interview protocol (Appendix F) included a series of leading questions followed by probing questions that highlighted the students’ opinions and
experiences after engaging with the exhibit. It was designed to gain insight into what aspects of the exhibit students found salient. The post-experience interview also provided more in-depth information regarding students’ understanding and attitudes towards drug use before and after exposure to the exhibit. Prior to the study, this interview protocol was tested in a pilot study that aimed at investigating the impact of the exhibit in the museum to assess face and content validity.

Research Procedure

It took approximately 30-35 minutes for each student to participate in this study. Students generally came in alone or as a group consisting of 2-5 individuals to experience the exhibit together. The procedural detail is simply depicted as Figure 3.5.
Figure 3.5. Overview of research procedural detail for each student.

When students first entered the meeting room, they were asked to fill out a student information sheet. This information helped to screen students who had epilepsy or who had a history of seizures. The qualified students then completed a paper-and-pencil pretest instrument including a knowledge assessment and an attitude survey. Students then spent about 15 minutes interacting with the exhibit by themselves. The researcher did not give students any instructions or explanations regarding the science content embedded in the exhibit during the exposure. After finishing the exhibit, posttest instruments were completed.
by students. Finally, the researcher conducted a semi-structured interview with each student. Students who completed all tasks were compensated with a gift card or a t-shirt.

**Data Analysis**

**Overview**

102 participants completed pre and post instruments in this study. Of these, the data from 4 participants, who were CCMS staff coming to view the exhibit and test the whole procedure, were excluded from this study. Hence, a total of 98 pre and post instruments were collected during the research week. One month later, the same instruments were distributed to the participating students again. In order not to disturb the school schedule, instruments were delivered to school and students were asked to complete them in their free time. Only 44 delayed posttest instruments were retrieved. Of the 44 retrieved, 2 were excluded because of incomplete answers. Hence, a total of 42 delayed posttests were collected.

Students’ responses to the multiple-choice questions from the knowledge assessments were scored as correct or incorrect. They were given one point for each correct answer which resulted in a maximal full score of six points. This study also calculated and operationally defined the knowledge gain score as the difference between student posttest and pretest scores. The final score was presented as the percent of correct answers. On the other hand, students’ responses on the 10 Likert-scale attitude surveys were coded as 1 (Strongly disagree) to 5 (Strongly agree) in order to be quantitatively calculated.

As for the qualitative data, interviews were recorded with the permission of the interviewees and transcribed verbatim as interview transcriptions. The interviews were conducted either with an individual or with a focus group that included 2-4 participants,
resulting in a total of 71 students interviewed. The raw data from the interview audio collected from this study consisted of about 359 minutes (5.98 hours). All transcriptions were broken into coded segments representing complete thought statements by the researcher to generate categories and appropriate interpretations.

In addition, some field notes and videotape recordings of students using the exhibit were made during the data collection week. The videotape recordings included a total of approximately 368 minutes (6.13 hours). After finishing the data collection, those videotape recordings were viewed and coded according to the students’ actions while using the exhibit and their interactions with their peer group. The data analyzing methods by each research question are simply presented as a matrix (shown as Table 3.2) and are discussed in detail as below.
Table 3.2.

*Data analysis matrix showing data analysing methods for both quantitative and qualitative data by each research question.*

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Resource</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What do students learn about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain via the exhibit?</td>
<td>Pre-knowledge assessment</td>
<td>Two-way ANOVA</td>
</tr>
<tr>
<td>1.1. What do students know about basic concepts of neuroscience and the impact of methamphetamine abuse before exposure to the exhibit?</td>
<td>Interviews</td>
<td>Coding Categorization Comparison</td>
</tr>
<tr>
<td>After the exhibit:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2. Do students identify the basic brain structures and their functions?</td>
<td>Knowledge assessment question #1, #2, #3, #4</td>
<td>One-way ANOVA</td>
</tr>
<tr>
<td>1.3. Do students understand the physical and functional impairments associated with taking methamphetamines?</td>
<td>Knowledge test question #5, #6</td>
<td>One-way ANOVA</td>
</tr>
<tr>
<td>1.4. How do students describe the negative consequences of taking methamphetamines in their daily lives?</td>
<td>Open-ended question</td>
<td>Coding Categorization Comparison</td>
</tr>
<tr>
<td>2. How are students’ attitudes toward methamphetamine use changed after exposure to the exhibit?</td>
<td>Attitude survey (Fetherston &amp; Lenton, 2005)</td>
<td>One-way ANOVA</td>
</tr>
<tr>
<td>2.1. Have their general attitudes toward methamphetamine use changed?</td>
<td>Interviews</td>
<td>Coding Categorization Comparison</td>
</tr>
<tr>
<td>2.2. Have their attitudes toward the relationship between methamphetamine use and health changed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. What are students’ experiences and perceptions of using the exhibit to learn the impact of methamphetamine abuse on the brain?</td>
<td>Field notes Video recording Interviews</td>
<td>Coding</td>
</tr>
</tbody>
</table>
**Question 1. What do students learn about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain via the exhibit?**

1.1. What do students know about basic concepts of neuroscience and the impact of methamphetamine abuse before exposure to the exhibit?

*Knowledge pre-assessment.* Descriptive statistics were calculated for the knowledge pre-assessment and a two-way Analysis of variance (ANOVA) was employed in order to determine if there were differences of pre-existing knowledge between grade and gender. The distribution of ethnicity is critically unequal, so it was excluded from being an independent variable of this study.

*Interviews.* In order to investigate what students knew before coming to the exhibit, three steps, coding, categorization, and comparison, were employed to analyze those interview transcriptions (Figure 3.6).

*Figure 3.6.* Three phases consisting of coding, categorization, and comparison for analyzing interview transcriptions.

During the coding phase, the researcher had to read the interview transcriptions several
times. The statements obtained from the interviewees regarding their pre-existing knowledge were coded and broken into segments, and then those segments were grouped together accordingly. During the phase of categorization, the researcher examined these statements repeatedly for salient categories. In addition, a constant comparative approach was used during the phase of comparison, in which the researcher continued to look for instances from those statements that represented the categories. New categories or subcategories might be generated during the comparison phase if current categories did not fit with all statements. The statements were repeatedly compared regardless of whether they were within the same categories or not. This was done until all information was classified into various categories. Finally, themes or patterns were produced to appropriately interpret the results.

A coding-recoding procedure was employed by the researcher to analyze the data over a period of time to ensure its reliability. After the first coding, the data were set aside for three weeks and then recoded to compare the results. There was consistency between the first coding and recoding on 67 out of a total of 71 students’ statements, yielding a reliability coefficient of .94.

1.2. Do students identify the basic brain structures and their functions after the exhibit?

The total score of knowledge assessment questions #1, #2, #3, and #4 were calculated and presented as a percentage of correct answers. A one-way ANOVA was employed to test whether there were differences between the scores of pretest, posttest, and delayed posttest. Least square means (LSMEANS) was used as post hoc statistical analysis.
1.3. Do students understand the physical and functional impairments associated with taking methamphetamines after the exhibit?

The total score from knowledge assessment questions #5 and #6 were calculated and presented as percent correct. A one-way ANOVA was again employed to test whether there were differences between the scores of pre-test, post-test, and delay post-test. Least square means (LSMEANS) was again used as post hoc statistical analysis.

Further, a two-way ANOVA was used to examine if there were grade or gender effects for the final knowledge gain score.

1.4. How do students describe the negative consequences of taking methamphetamines in our daily lives after the exhibit?

The posttest instruments were followed by an open-ended question, please explain in details about the impact of methamphetamine on the brain, which aims to investigate students’ descriptions of the negative influences of methamphetamines on the brain. After finishing this question, students were interviewed and asked to explain their answers and the reasons why they cannot stop while playing the video game. Students’ answers together with interview transcriptions were analyzed for answering this research question.

The procedures to analyze those interpretations and interview transcriptions were closely related to methods for analyzing pre-existing knowledge. Those data were read by the researcher several times. At first, data were coded according to the categories created from the results of analyzing pre-existing knowledge. The data would not completely fit in to the original categories because students were supposed to have learned something from the exhibit, and hence new categories and subcategories were generated from repeatedly
examining the data in order to appropriately classify all information. Finally, a constant
comparative approach was employed to check that all instances from the students’ answers
and explanations were appropriately presented by the categories until all information was
classified. Coding-recoding procedures were used to ensure reliability. Recoding took place
about one month after the first coding, and the results between the first coding and recoding
were consistent on 88 out of a total of 98 student responses; resulting in a reliability
coefficient of .90.

**Question 2. How are students’ attitudes toward methamphetamine use changed after
exposure to the exhibit?**

2.1. *Have their general attitudes toward methamphetamine use changed?*

2.2. *Have their attitudes toward the relationship between methamphetamine use and health
changed?*

*Attitude survey questionnaire:* In order to answer these two research sub-questions,
descriptive statistics were calculated and a series of one-way ANOVAs were used to
compare student responses among pretest, posttest, and delayed posttest for each item.
LSMANS methods were subsequently used as *post hoc* tests to examine whether there were
significant differences among these three groups.

*Interviews:* For the interviews, the analysis was focused on examining whether the
information students learned from the exhibit helped them to make a decision about drugs or
methamphetamine use. Students’ statements relative to their attitudes toward drugs or
methamphetamine use were coded, and the statements were read multiple times to generate
main patterns that were used in support of quantitative results from the survey questionnaire
analysis. A coding-recoding procedure over a period of about a month produced a reliability coefficient of .99.

**Question 3. What are students’ experiences and perceptions of using the exhibit to learn the impact of methamphetamine abuse on the brain?**

In order to examine student learning experiences and their perceptions of using the exhibit, self-regulated learning served as a framework to analyze the data from interviews and videotape recordings. In other words, their learning experiences through using the exhibit were assumed to be a learning process in which students participate motivationally, behaviorally, and metacognitively (Zimmerman, 1989).

Hence, three major aspects, motivational (intrinsic values), behavioral (cognitive strategies use), and metacognitive (metacognitive strategies use) (Pintrich & De Groot, 1990) processes, shaped the analysis of those data for answering this research question. As for the motivational aspect (intrinsic values), student perceptions of the exhibit would serve as good indicators for motivation. Malone & Lepper (1987) posit that challenge, curiosity, fantasy, and control are four important intrinsically motivating features that provide individuals intrinsic motivation, and thus they were used as intrinsic values for coding of comments, interviews, and videotape recordings. For example, we coded as curiosity when students’ comments, statements, or their talking with peers described the exhibit as interesting or fun and expressed a desire for knowledge (Berlyne, 1960, as cited in Garris et al., 2002) saying they came to the exhibit because they were curious and wanted to know about methamphetamine and its impact on the brain, were coded as curiosity. If students said that the exhibit was challenging, not easy to figure out, or they played the exhibit more than twice,
then those statements were coded as challenge. Student statements that described the exhibit as cool, fantastic, awesome, or amazing, were coded as fantasy. Finally, if their statements described the exhibit as interactive and easily controlled and manipulated, they were coded as control.

For the behavioral aspect, students were supposed to take the necessary steps to make the learning process and environment best fit their own learning styles, and hence the cognitive strategies that they used to help with their learning were examined. For the metacognitive aspect, student metacognitive strategy use, such as evaluating and comprehension monitoring, were investigated. In these two cases, field notes, interviews, and videotape recordings were not coded and analyzed in detail. They instead served as resources that offered evidence for generally examining the strategies students actually used while they were interacting with the exhibit. The categories of cognitive and metacognitive strategies use were developed from repeatedly viewing the field notes, interviews, and videotapes, and from other existing instruments on investigating self-regulated learning (Azevedo, Guthrie, & Seibert, 2004; Dabbagh & Kitsantas, 2005; O. Lee, Fradd, & Sutman, 1995; Pintrich & De Groot, 1990).

Overall, this chapter describes how data analysis was conducted for both quantitative and qualitative data. The results that came out by using aforementioned methods are then presented in the next chapter.
CHAPTER FOUR

Results

The results of the study are presented in detail by each research question.

**Question 1. What do students learn about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain via the exhibit?**

1.1. *What do students know about basic concepts of neuroscience and the impact of methamphetamine abuse before exposure to the exhibit?*

A two-way ANOVA was run testing the interaction effect of grade and gender on the knowledge pretest. The correct mean percentage of total knowledge from the pre-assessment for all students was 21.93% (SD=23.76%), and the results of two-way ANOVA are shown as Table 4.1. There were no significant differences of the interactions between grade and gender. The results indicated that overall students came into the exhibit with little knowledge about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain.

Table 4.1.

*The results of two-way ANOVA for pre-existing knowledge about basic concepts of neuroscience and the impact of methamphetamine abuse by grade and gender.*

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>2</td>
<td>673.2950</td>
<td>1.17</td>
<td>0.3148</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>50.3400</td>
<td>0.09</td>
<td>0.7680</td>
</tr>
<tr>
<td>Grade×Gender</td>
<td>2</td>
<td>229.6462</td>
<td>0.40</td>
<td>0.6720</td>
</tr>
</tbody>
</table>

Three steps, coding, categorization, and comparison, were employed to analyze interview transcriptions. The analysis of those interview data were separated into four
categories, which consisted of no understanding, general understanding, basic understanding about the impact on the brain, and moderate (or partial) understanding about the impact on the brain and consequences. (Table 4.2).
Table 4.2.

*Descriptions, examples, and the percentage of students who are classified into the four categories, generated from interviews regarding students’ pre-existing knowledge of the impact of methamphetamine abuse on the brain.*

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Example</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No understanding</td>
<td>Students don’t know anything about methamphetamine.</td>
<td>“I knew nothing about methamphetamine; I didn’t even know there is a thing named methamphetamine.”</td>
<td>19.1%</td>
</tr>
<tr>
<td>General understanding</td>
<td>Students know methamphetamine is a drug, and it is bad and has negative consequences.</td>
<td>“I knew nothing really. I knew it was bad in some cases but I didn’t know why.”</td>
<td>44.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“It is very addictive, and it’s kind of dangerous for your body.”</td>
<td></td>
</tr>
<tr>
<td>Basic understanding about the impact on the brain</td>
<td>Students indicate that methamphetamine affects the brain, but they don’t mention the consequences.</td>
<td>“It’s a kind of drug and it is bad for you and it can affect your brain in some ways but I didn’t really know how it works.”</td>
<td>26.5%</td>
</tr>
<tr>
<td>Moderate (or partial) understanding about the impact on the brain and consequences</td>
<td>Students know methamphetamine affects the brain and leads to some negative consequences.</td>
<td>“I knew that is harm to your brain and slow your reaction time, but I did not know what is reaction time.”</td>
<td>10.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“I knew it damages your brain cells, it affects your movement when you are driving, it could cause accidents.”</td>
<td></td>
</tr>
</tbody>
</table>
No understanding. The results showed that 19.1% of students knew nothing about methamphetamine before coming to the exhibit. They might know other kind of drugs like marijuana and cocaine, but they never heard of the word ‘methamphetamine’ and didn’t know it is a drug.

General understanding. 44.1% had a general understanding about methamphetamine, knowing it is a drug that is bad for the body and causes negative consequences, such as destroys concentration, is highly addictive, and causes hallucinations. However, they didn’t know that methamphetamine affects the brain.

Basic understanding about the impact on the brain. It was also indicated that 26.5% of students basically knew methamphetamine affects the brain. They might or might not know it could result in negative consequences, but they didn’t mention anything about it.

Moderate (or partial) understanding about the impact on the brain. Finally, 10.3% of students mentioned that methamphetamine affects the brain and slows its functions, causing negative effects such as impairing driving skills or certain basic routines, but could not explain how the drug causes these effects.

Of those who already knew about methamphetamine before exposure to the exhibit, 31% of students mentioned they learned about it and other drugs from health classes or Drug Abuse Resistance Education (DARE) programs. Moreover, about half of the students heard about it from their friends, parents, some TV shows and commercials, and/or books.

1.2. Do students identify the basic brain structures and their functions after the exhibit?

The results of a one-way ANOVA for each of the pretest, posttest, and delayed posttest, respectively, are shown as figure 4.1. The correct percentage mean for the pretest was
15.82% (SD=24.45%), for the posttest was 77.30% (SD=35.37%), and for the delayed posttest was 57.74% (41.50%). The post hoc LSMANS tests indicated that there were significant differences between pretest and posttest ($p<.01$), between pretest and delayed posttest ($p<.01$), and between posttest and delayed posttest ($p<.01$), respectively, indicating that students learned to identify the basic brain structures and their functions after the exhibit. Although their knowledge of basic brain structures and their functions performed on delayed posttests a month later significantly decreased compared to posttests, students still performed a significantly better understanding than pretests.

![Figure 4.1](image)

*Figure 4.1. Comparison of mean of correct percentage among knowledge pre-test, post-test, and delay post-test for the knowledge of basic brain structures and their functions (a. error bar: standard error (S.E.); b. pretest: $N=98$, posttest: $N=98$, delayed posttest: $N=42$; c. $**p<.01$).*
1.3. Do students understand the physical and functional impairments associated with taking methamphetamines after the exhibit?

One-way ANOVA and post hoc LSMEANS tests used to examine whether there were differences between scores on pretest, posttest, and delayed posttests of the physical and functional impairments associated with taking methamphetamines showed that student performances on both posttest and delayed posttest were significantly better than pretest ($p<0.01$) (Figure 4.2), pointing out that students still retain the knowledge of the physical and functional impairments associated with taking methamphetamines a month after interacting with the exhibit. The correct percentage mean from the pretest was 34.18% (SD=39.71%), from the posttest was 62.24% (SD=40.01%), and from the delayed posttest was 63.10% (SD=41.41%).
Figure 4.2. Comparison of correct percentage mean among pretest, posttest, and delayed posttest for knowledge of physical and functional impairments associated with taking methamphetamines (a. error bar: standard error (S.E.); b. pretest: \(N=98\), posttest: \(N=98\), delayed posttest: \(N=42\); c. **\(p< .01\)).

Further, a two-way ANOVA showed that neither grade nor gender effect was evidenced in the study in terms of total knowledge gain score between pretest and posttest (as shown in Table 4.3). The findings indicated that regardless of grade or gender, all of the students learned from the exhibit equally.
Table 4.3.
The results of two-way ANOVA for the correct percentage of total knowledge gain score about basic concepts of neuroscience and the impact of methamphetamine abuse by grade and gender.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>2</td>
<td>1137.3524</td>
<td>1.03</td>
<td>0.3628</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>0.1878</td>
<td>0.00</td>
<td>0.9896</td>
</tr>
<tr>
<td>Grade×Gender</td>
<td>2</td>
<td>1028.0708</td>
<td>0.93</td>
<td>0.3996</td>
</tr>
</tbody>
</table>

1.4. How do students describe the negative consequences of taking methamphetamines in their daily lives after the exhibit?

Four major categories emerged from data analysis of student answers and explanations, consisting of general understanding, basic understanding about the impact on the brain, moderate (or partially) understanding about the impact on the brain and consequences, and accurate understanding about the impact of methamphetamine, respectively. The descriptions, examples, and percentage of students who are classified into each category are shown as Table 4.4. In order to interpret the information appropriately, several subcategories emerged from the category of moderate (or partially) understanding about the impact on the brain and consequences, which are discussed as follows.
Table 4.4.

Descriptions, examples, and the percentage of students who are classified into the four categories generated from students’ answers and explanations regarding students’ descriptions of the impact of methamphetamine abuse on the brain.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Example</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>General understanding</td>
<td>Students know methamphetamine is a drug, and it is bad and has negative consequences.</td>
<td>“Using meth can kill you.” “That is hard for the person to stop when using meth.”</td>
<td>13.3%</td>
</tr>
<tr>
<td>Basic understanding about the impact on the brain</td>
<td>Students indicate that methamphetamine affects the brain, but they don’t mention the consequences.</td>
<td>“Because it is a drug, and drugs messes up your brain.” “The damage areas are in yellow, and yellow is 5% brain damage.”</td>
<td>6.1%</td>
</tr>
<tr>
<td>Moderate (or partial) understanding about the impact on the brain and consequences</td>
<td>Students know methamphetamine affects the brain and leads to some negative consequences.</td>
<td>“It affects your brain and it can mess up your driving skills.”</td>
<td>32.5%</td>
</tr>
<tr>
<td>Accurate understanding about the impact of methamphetamine</td>
<td>Students can explain exactly the impact methamphetamine has on the brain and how it results in negative consequences.</td>
<td>“Meth can damage the brain. It causes stop signals from your brain to react slower than a normal person.” “It slows down brain reactions, it delays the stop signal from getting the go signal, and so meth users can’t stop as quickly as people who are healthy.”</td>
<td>48.1%</td>
</tr>
</tbody>
</table>

Note. The moderate (or partial) understanding about the impact on the brain and consequences consists of several subcategories which are described later in the text.
General understanding. 13.3% of students didn’t know that methamphetamine affects the brain after exposure to the exhibit. They understood that methamphetamine is a drug, and understood that it is a dangerous substance which, when used, could result in death. They also realized it is hard for people to stop when using methamphetamine, but they did not seem to have acquired the knowledge regarding the dysfunction of stop signals result from brain damage.

Basic understanding about the impact on the brain. Only 6.1% of the students fell into this category. They knew that methamphetamine affects the brain, and can even recall that methamphetamine causes about 5% of brain damage, but they can’t explain why methamphetamine users can’t ‘stop’ in the video game played during the exhibit.

Moderate (or partial) understanding about the impact on the brain and the consequences. 32.5% of students knew that methamphetamine damages about 5% of brain activities and also knew negative consequences occur, such as worsened reaction times worsened due to methamphetamine use. However, when they were further asked to explain how the reaction times changed or why methamphetamine users can’t ‘stop’ in the video game from the exhibit, either they couldn’t explain it or they just explained it in different ways. Some alternative explanations that were generated by students to answer these questions are described as follows.

Methamphetamine makes you high. Instead of explaining by reaction times, students thought the reason for why they couldn’t stop in the video game and kept hitting pedestrians or crashing cars was that methamphetamines make people high and cause hallucinations, thus leading to car accidents. The explanations of two students are presented as follows:
Methamphetamine impacts your brain by making you high. Which means that it makes you dizzy and is hard to stop a car.

Well, if you are driving or walking, you will hallucinate and will crash into things.

*Methamphetamine affects your vision.* Some students also thought that because methamphetamine affects people’s vision and makes signs on the road blurry, car accidents thereby occur. In this case, students still didn’t mention anything about reaction times. The examples are provided as follows. The first example is a statement of how a student tried to explain what happens in the video game.

*It [meth] affects your brain and it affects driving, and if you use it, you can end up in an accident, or crashing, or murder, and that’s really bad because you can end up in jail. It works in your brain like your eyes on the road, you might be blurry or kind of can’t really see the road or something, and you can’t just see the road and crash to something or die while in the car. Well, for example, like if the light is red, you might go on red and not on green and you can get like in trouble and that’s something that might happen.*

The second example is that of a student explaining with his drawing, what methamphetamine users might be seeing when they are driving under the influence of methamphetamine. (Figure 4.3).
When you drive, you can’t really see that much. And it’s like this.

![Diagram showing non-meth and meth visions.](image)

*Figure 4.3.* A student’s drawing used by the student to attempt to explain the difference between the visions in meth users and normal people.

*Methamphetamine makes your reaction times to go-signals faster.* Some students clearly knew that using methamphetamine changes people’s reaction times. However, they explained the reaction time change as methamphetamine users having faster reaction times to go-signals than non-impaired people, but their reaction times to stop-signals are not affected. In other words, they believe that when methamphetamine users drive, the faster go-signals result in them not being able to stop in time, and therefore cause accidents. An example of a student’s explanation is presented as follows.

*It [the exhibit] shows you the difference between the regular brain and who use meth, and it shows you the difference to the effects the person gives when they use methamphetamine. Like if you are driving a car, meth gonna make you high, like go fast while driving at a high speed and that can be dangerous because you can cause car crash. Like it [meth] rushes you, it will affect your go signal more. Stop signal won’t be affected because you don’t want to stop something like that. It affects mainly go signal.*
Another student drew to demonstrate how reaction times process during driving under a methamphetamine influence (Figure 4.4). The drawing is very similar to another students’ drawing. However, their explanations are the exactly opposite of each other, which will be presented later.

*When you use methamphetamine, your go signal is faster and your stop signal is normal.*

![Figure 4.4. A student’s drawing explaining that meth users have faster reaction times to go-signals.](image)

*Accurate understanding about the impact of methamphetamine.* Finally, 48.1% of students provided accurate statements explaining the changing reaction times, and why meth users couldn’t ‘stop’ in the video game from the exhibit, using the information embedded in the exhibit. One student used a drawing to explain that compared to non-impaired people, meth users perform slower stop-signals and normal go-signals (Figure 4.5).
Like it [meth] can mess up your brain. It can slow down your brain areas that tell you to stop. If you continue doing it, it probably will be permanent and like slow down your brain and make it smaller.

Figure 4.5. A student’s drawing used by the student to explain that meth users have slower reaction times to stop-signals.

Further, the findings of students’ pre-existing knowledge and their understanding after the exhibit were plotted to present students’ understanding progression (Figure 4.6).
Figure 4.6. Students’ progression of the understanding of the impact of methamphetamine abuse on the brain through using the exhibit (pre-test: N=98, post-test: N=98).

Question 2. How are students’ attitudes toward methamphetamine use changed after exposure to the exhibit?

2.1. Have their general attitudes toward methamphetamine use changed?

The results of a series of one-way ANOVAs for each item of students’ general attitudes toward methamphetamine use indicated that there were no significant differences between students’ responses among pretest, posttest, and delayed posttest (as shown in Figure 4.7). Students’ general attitudes toward methamphetamine did not change significantly after
exposure to the exhibit, as they consistently demonstrated negative attitudes toward methamphetamine use.

![General Attitudes toward Methamphetamine Use](image)

**Figure 4.7.** Comparison of students’ general attitude towards methamphetamine among pre-test, post-test, and delay post-test. Results were presented by each item (a. error bar: standard error (S.E.); b. pretest: N=98, posttest: N=98, delayed posttest: N=42).

2.2. *Have their attitudes toward the relationship between methamphetamine use and health changed?*

On the other hand, it was evident that there had been a significant increase in students’ negative attitudes toward methamphetamine and health issues between pretest and posttest (Figure 4.8). On the posttest, they tended to agree much more with the statements
Methamphetamine use may result in brain damage. Being high on methamphetamine impairs driving skills, and methamphetamine impairs people’s driving skills even when they are not high, respectively ($p<.01$). Moreover, the findings also showed that students still showed negative attitudes on the delayed posttest a month after exhibit exposure ($p<.01$). Students significantly ($p<.05$) expressed a more negative attitude on the posttest in terms of the item Using methamphetamine once a month is not dangerous, but they didn’t consistently express this on the delayed posttest a month later.
Attitudes toward Methamphetamine and Health

Figure 4.8. Comparison of students’ attitudes toward methamphetamine and health among pre-test, post-test, and delay post-test. Results were presented by each item (a. error bar: standard error (S.E.); b. pre-test: N=98, post-test: N=98, delay post-test: N=42; c. *p< .05, **p< .01).

The findings from the interviews were consistent with the quantitative results. Even though some students might not know what methamphetamine is before exposure to the
exhibit, almost all the students expressed a clear statement arguing that they don’t like drugs and that they didn’t think about using drugs. And since the exhibit provided them an opportunity to learn more about the harm and disadvantages with drug use, they felt more confident in saying no to drug use in the future because this exhibit gave them a better reason to not do methamphetamine or other drugs. Moreover, they would also like to share what they learned from this exhibit with their friends or families who are doing drugs or wanting to do drugs, and try to advise them to quit using drugs.

For example, one students’ statements is shown as follows:

_I’ve never wanted to try it because I mean I am just not interested in it, I mean I know that drugs can like make you happy like high but I just don’t wanna mess up my brain like that. I don’t wanna mess myself up because I’ve heard that drugs mess you up. […] And after the exhibit, I definitely would not like to do drugs. I mean before I just knew drug is bad for you, but now I know why and this makes me to not like it even more. […] I will say to my friends, hey, stop, this can screw up your brain and make you impaired for life._

There were only two students who mentioned that they thought about trying drugs sometimes because of stresses in their lives. However, this exhibit made them feel that would not be a good choice to use drugs. An example of their responses is presented as below.

_Sometimes I don’t feel like living on the earth or something and wanna die or something, I sometimes want to try drugs, because of just pressures. Well, I knew it was bad, I just wanted to try it. […] But I don’t want to try drugs now, no more. I learned more about it affects your brain more, so I feel more confident to say no. I will tell my friends to stop because in the future it like gonna damage your brain and you won’t be able to do a lot more activities and stuff that you are doing now._
Question 3. What are students’ experiences and perceptions of using the exhibit to learn the impact of methamphetamine abuse on the brain?

Motivational Aspect (Intrinsic Values)

Figure 4.9 shows the results of students’ perceptions of the exhibit in terms of four intrinsic values: curiosity, fantasy, challenge, and control, respectively. Overall, 90.1% of the students came to the exhibit because they felt it was interesting and they really liked to know how methamphetamine affects the brain. 31.0% of students described the exhibit as cool or amazing, especially the 3D effect such as the colorful models of the brain. Almost 50% of the students stated that the exhibit was challenging and not very easy to figure out, thus making them play it more than twice. One student talked about his experience with the video game by stating, *I played the game three times, it was really fun because I want to improve my scores. So it’s a little challenging because the guys are on meth, it kind of impairs you.* On the other hand, 2.8% described the exhibit as a bit too simple. Finally, control is the intrinsic value by which students expressed more negative opinions. Although there were 14.1% of the students mentioned that the exhibit was easily controlled and manipulated, another 14.1% stated that the video game needs to be more interactive so players can drive the car to make turns or a steering wheel and/or use a pedal could be provided to be more like really controlling the car instead of just pushing a button to accelerate. Some students also argued that it would be a better exhibit if two controllers were used so that they can manipulate the brain and race each other in the video game whilst learning from it.
Figure 4.9. Students’ perceptions of the exhibit in terms of four intrinsic values, curiosity, fantasy, challenge, and control.

Behavioral Aspect (Cognitive Strategies Use)

When students were experiencing the exhibit, several cognitive strategies such as read aloud, compromise, help seeking, peer mentoring, re-examining and revisiting the information, and re-reading, were used. These strategies are presented separately as follows.

Read aloud. When students interacted with the exhibit as a group consisting of 2-5 individuals, they either read all the information aloud together or a leader read it aloud for every group member. A student described their read aloud strategy by stating:
We went through the information first because I was guessing it helps us learn more about it before we did it in the video game. And like we did it together, and we like found a way that actually read it clear so that we understood the information and video game a little bit better. Read it out loudly helps us to understand it.

Compromise. Since there was only one controller in the exhibit, students sometimes came up with a compromise so that they could manipulate the exhibit together. For example, the conversation between two students who played the exhibit together as a group was presented as followed:

S1: Can I do it?
S2: (Demonstrate how to use the controller and then Give it to S1) Just turn it like this.
S1: (Manipulate the brain for a while) Ok! Oh, gosh, it’s cool!
(Then return the controller back to S1) Now it’s your business. But can I click the ‘Next’ button?
S2: Ok!

And later on, they just described their situation as a compromise while interviewing with the researcher by stating, but we, at the end we compromised that she did it, and then I did it, you know, we compromised.

Help seeking. Students also tried to seek help from the researcher. They asked the researcher questions and discussed them together so that they got to clarify their understanding.

S1: (Watch the exhibit and manipulate the brain) What are they [go signal and stop signal] supposed to do? Interact with each other?
R: If you have a go signal, your stop signal is supposed to interrupt the go signal, so…
S1: Oh, so you can stop.
R: Ya, but if you use meth, your go signal is still going, but your stop signal can not interrupt it in time, hence you keep going just cannot stop…
S1: Is it because of drugs? So if you use drugs, you cannot stop…
S2: Like forever or…?
R: If you keep doing drugs, it might be forever.
S3: Oh, I would never use drugs.

*Peer mentoring.* Moreover, some students were also trying to explain the information to their peers. In this case, the students who asked the questions and the ones who tried to answer the questions all got to understand the concepts embedded in the exhibit finally.

S1: What is it, dude?
S2: Well, let’s see.
   (Watch the exhibit and manipulate the brain) The red is stop signals.
S3: And the yellow is 5% brain mass lose. All the yellow are all the brain that’s been lost from methamphetamine abuse.
   See! All that yellow.
S1: Ya!
S3: That’s all the brain mass lose from methamphetamine.

*Re-examining and revisiting the information.* Video games serve as an important vehicle for students to examine if they really understand all the information the exhibit provided. A student mentioned that *while I was driving, I was kind of thinking about what I read from the information and it kind of helps me to play the game.* And if students still could not figure out how to play the video game or didn’t know what was going on in the video game, they went back to the 3D exhibit to check the information again. A student described his experience in revisiting the information:

*I read almost everything first then go to the video game, and then I came back to it and read it again because when I played the video game, something in the video game shows you things you have to understand first whatever you play to win. So if you read all that, then you will be able to be good at it.*

*Re-reading.* Some students mentioned that although they didn’t go back to revisit the information, they did read it twice. As a student stated:
I read through it and played the game and looked at the pictures and twist it around to see exactly what the brain does. I didn’t go back a couple of pages to check the information but I did read it about twice.

Metacognitive Aspect (Metacognitive Strategies Use)

As for the metacognitive aspect, several strategies were also performed by students while playing within the exhibit, showing that they were aware of what they had learned and used those strategies to make their cognitive process more efficient. The strategies that students used included monitoring, evaluating, awareness of knowledge, and judgment of learning, respectively.

Monitoring. While interacting with the exhibit, students monitored their learning processes at all times. In other words, they tried to make sure they had a clear understanding of every step. An example of one of the student’s response was I read the information totally and I make sure I understand everything then keep going.

Evaluating. Students evaluated the information they had to learn first, and although they might think the information is too long and they might not be patient enough to finish it, they still read it and tried to understand it because they thought it was important. A students’ statement that described the situation is shown:

I kind of like read some of it [the information], and some of it like ‘oh my god’ it is too long so I just skipped it, but I just went back and read it again because I thought it should be important.

Awareness of knowledge. In this category, students stated that they were aware of the knowledge being presented while reading the information and looking at the models of the
brain, which made them to think more deeply about the presented text. Students tried to
describe this awareness of knowledge by stating:

*I read the information and look at the picture of the brain and how it reacts when
you do the drugs and like when I read it, it like had impact in my brain, it got me
thinking for like a minute.*

*Judgment of learning.* And finally, students also performed a judgment of their learning
when they were interacting with the exhibit. They stated their whole learning processes and
judged what part of the learning process made them to realize they had obtained the
knowledge. For example, a student expressed her judgment of her learning as below:

*While I was doing the test [pretest] I didn’t know anything about the drug [meth]
but I just use my knowledge about it because I knew other drugs affect the brain
that I am pretty sure. And then I was showed that it [meth] affects your reactions
somehow, and then in the driving game I just kind of thought of it because I try to
stop the first time and it won’t let you stop and I realize you can not stop when
you are doing this drug and that makes me realize that.*

In summary, the detailed results regarding the impact of the virtual brain exhibit by
each research question have already been presented in this chapter. The significances of those
results and explanations are going to be discussed in the following section.
CHAPTER FIVE

Discussion

*In a playful context kids seem to have an almost infinite capacity for learning. It’s very easy, it’s effortless, it’s exciting. If you put them in some kind of game situation—a computer game or a video game—they’ll pick up skills very quickly, learn how to do things, at an amazing rate.*

-- Danny Hillis, as cited in Prensky, 2001, p.180

Overview

The present study investigated an interactive exhibit which includes a virtual reality learning environment combined with a video game for the purpose of enhancing middle school students’ understanding of the impact of methamphetamine abuse on the brain and subsequently improving their negative attitudes toward drug use. The significant findings of the present study provide practical evidence supporting the role of Serious Games in education, which is an inspiration for all advocates who support video games as useful education tools. This chapter attempts to bring together those observed results of the present study and gives both theoretical and practical explanations of these findings.

Regarding each research question, the summary of significant findings and possible explanations of these findings are presented first, and implications and ideas for future research are then discussed.

**Question 1. What do students learn about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain via the exhibit?**
Summary of Findings

The results of the present study indicate that students’ understanding of the impact of methamphetamine abuse on the brain was significantly improved after exposure to the exhibit regardless of grade or gender. Students continued to demonstrate a better understanding in delayed posttests compared to pretests. In particular, regarding the knowledge of the physical and functional impairments associated with taking methamphetamines, student performance on delayed posttests were as good as posttests, meaning they retained understanding even a month after the exhibit. Further, in order to describe the situation that occurred in the video game, students generated several alternative explanations instead of using the content embedded in the exhibit. And finally, the findings of students’ pre-existing knowledge and their understanding after the exhibit indicated a progressive tendency. Overall, these findings have implied that Serious Games have a positive influence on students’ learning, especially for learning the impact of methamphetamine abuse on the brain from a neuroscience perspective.

Surface Knowledge v.s. Deep Knowledge

It is of particular interest that students have learned to identify basic brain structures and their functions immediately after exposure to the exhibit; however, they did not retain the same knowledge a month later. On the other hand, their understanding of the physical and functional impairments associated with taking methamphetamines was perfectly retained even a month after the exhibit. A possible explanation of the different knowledge retention might lie in the difference between surface knowledge and deep knowledge.
De Jong & Ferguson-Hessler (1996) examined different types and qualities of knowledge, and indicated that a rough distinction could be made between deep and surface in terms of the level of knowledge by stating:

Deep-level knowledge is associated with comprehension and abstraction, with critical judgment and evaluation, and the like. This knowledge has been thoroughly processed, structured, and stored in memory in a way that makes it useful for application and task performance. […] Surface-level knowledge is associated with reproduction and rote learning, trail and error, and a lack of critical judgment. This knowledge is stored in memory more or less as a copy of external information (de Jong & Ferguson-Hessler, 1996, p. 107).

Surface knowledge is easy to forget because of the lack of meaning and connections to improve recall. Contrarily, deep knowledge requires students to integrate and to develop understanding and meaning. It is not easy to forget as long as the meaning and understanding have been successfully developed (Bennet & Bennet, 2008).

In the present study, the knowledge of basic brain structures and their functions would be more like surface knowledge. For example, students were asked questions like, *What is the name of the brain area shown here in GREEN?* or *What does the Motor Cortex do?* These questions require students to simply recall or recognize information from the exhibit. If the knowledge is not repeatedly presented or used in context by the students, students tend to forget it easily. On the other hand, the physical and functional impairments associated with taking methamphetamines are more in line with deep knowledge. The asked questions, such as *Which of the following statements is most correct?* require students make logical analyses or critical judgments about those abstract conceptions. Once students have developed understanding according to their logical analyses or critical judgments, it becomes less easy to forget. Therefore, students retained solid understanding of the physical and functional
impairments associated with taking methamphetamines, although they tended to forget the basic brain structures and their functions a month later.

**Learning through Serious Games as a Conceptual Model**

This study employed 3D simulated models of functioning brains as conceptual models that aim at facilitating and assisting students to build a mental model of abstract conceptions about the impact of methamphetamine abuse on the brain. A driving game after the virtual brain exhibit provided an authentic experience that served as a bridge to help students successfully transfer knowledge they learned from the conceptual models to explain or to solve real life problems. In other words, video games play a role of facilitator that ensure so-called meaningful learning (Mayer, 2002) or authentic learning (Galarneau, 2005) to occur.

It was rightly assumed that students would use the scientific content embedded in the exhibit to describe the situation that occurred in the video game; however, the finding of the present study suggests that several alternative explanations were generated. Often students drew very similar diagrams to demonstrate how stop and go signals work under methamphetamine-influenced condition, even though the points they were trying to make through the explanation were opposite of each other.

Greca & Moreira describe how people construct mental models by stating (Greca & Moreira, 2000, p. 6),

[…] when people intend to understand a conceptual model, they extract from it those elements they consider relevant, then they relate it – if this is possible – to what they already know, generating, or not, mental models that are not necessarily similar to the conceptual models presented to them.
In order to ensure that students could construct mental models that are coherent with the scientifically accepted conceptual models, Greca & Moreira (2000) suggest that the teaching of processes of modeling becomes more important than just the presentation of conceptual models themselves. In other words, rather than merely presenting the conceptual models, the offering of cognitive scaffolding should be considered when researchers and educators develop Serious Games.

As for the present study, the conceptual model about how methamphetamine affects reaction times in the brain was directly presented to students. Although textual instructions were given to students prior to the 3D simulated models, it still does not appear to be enough to elicit deep knowledge. This could be due to the students not having the necessary knowledge to interpret the conceptual model of reaction times (Greca & Moreira, 2000), hence they simply ignored it and employed what they already knew about the impact of drugs such as making you high or affecting your vision as their mental model to explain the situation in the video game. Moreover, it could also be due to the fact that the current exhibit design might easily give students a misunderstanding about how stop and go signals are affected by methamphetamine abuse, leading them to produce the opposite explanation such as methamphetamine making your reaction times to go-signals faster instead of causing slower reaction times to stop-signals on similar drawings. The possible improvements for the current exhibit regarding cognitive scaffolding issues that could be done in the future will be discussed later.
Do Boys Learn Better than Girls?

Technologies or video games seem to be traditionally thought of as male domains and regarded as male pastimes. Gender differences seem to also exist in terms of computer-aided instruction. In other words, compared to boys, girls generally have more difficulty in learning with the help of computer-aided instruction (Reinen & Plomp, 1997; Sutton, 1991; Volman & van Eck, 2001). However, the present study does not show those gender differences. The results indicate that the understanding of the impact of drug abuse on the brain of both girls and boys was equally improved through using the exhibit combining 3D simulation with a video game. Although boys are more likely than girls to play with and be fascinated by video games (Funk, 1993; Kubey & Larson, 1990; Lucas & Sherry, 2004), more researchers have come to agree that boys and girls can be equally skilled at using computers and video games. It appears that new technological applications such as Serious Games offer opportunities for educational institutes to deal with gender issues. Aligned with other research evidencing no gender effect on physics learning (Annetta et al., in press; Squire et al., 2004), the current results illustrate that by using Serious Games, girls could learn as much as boys about basic concepts of neuroscience.

As the rapid acculturation to the Internet and new technologies takes place among current youths, the gender gap on general computer and technology outcomes have narrowed significantly over the past 10 years (Schweingruber, Brandenburg, & Moller, 2001). Girls and boys might still have different patterns in terms of learning styles (Hickson & Baltimore, 1996; Honigsfeld & Dunn, 2003), but the present study demonstrates that Serious Games have enough flexibility to allow both girls and boys to learn equally in their own ways. The
important gender issues regarding Serious Games that need researchers and educators to make more efforts in the future might be through enhancing girls’ self-efficacy and interests in technologies and science, and trying to eliminate gender stereotype, thus helping girls to be more confident, and to believe that they can succeed and master the necessary concepts in science as well as using technology.

**Question 2. How are students’ attitudes toward methamphetamine use changed after exposure to the exhibit?**

**Summary of Findings**

The observed results indicate that most of the students consistently expressed negative attitudes toward general methamphetamine use, arguing that they wouldn’t like to use methamphetamine or other drugs regardless of before or after exposure to the exhibit. However, they also stated that this exhibit gave them a better reason and made them feel more confident to refuse drugs. On the other hand, students tended to agree much more with several items regarding the issues of methamphetamine and health after the exhibit and still possessed the same attitudes a month later, indicating that they tended to agree that methamphetamine impairs their brain and driving skills.

**Serious Games Affect Students’ Attitude toward Drug Use**

It was enlightening that most of the students in the present study consistently expressed negative attitudes toward general methamphetamine use. Their attitudes toward several items regarding issues of methamphetamine and health became more negative after the exhibit and they still possessed the same attitudes a month later. These imply that the majority of the students in the present study agreed that the use of methamphetamines would impair their
brain and their driving skills after attending the exhibit. This change in attitudes toward methamphetamine and health issues is one of the main goals that this study attempted to achieve. However, students expressed somewhat ambiguous attitudes toward two statements, *There is a clear link between methamphetamine and health problems* and *The benefits of using methamphetamine outweigh the harms and risks associated with its use.* This might be because the current exhibit design didn’t give them enough information to make judgments regarding those statements. Hence, more information and instructions addressing these two facets of health issues might have to be provided in future studies.

The most gratifying find is that, although there were two students stating that they really thought about doing drugs due to pressures from their daily lives, they decided to say no to it after the exhibit. The result implies some interesting points that could be discussed. First of all, the finding revealed that pressures from daily life is still one of the major reasons that force children to turn to drug use. Most of the current promising drug use preventions focused on life skills training including resistance skills for rejecting social influence, misconceptions of drug use and generalized skills for coping with stressful life situations, which are definitely helpful in preventing children from doing drugs. However, the present study shows that dissemination of knowledge about drug use, such as introducing the negative effects on human body especially from a neuroscience perspective, might also be useful for drug use prevention which still cannot be ignored. Because children need to understand why they have to say no to drug use, information could give them a rationale for refusal. Serious Games, thus, could be an effective way for information dissemination that educators and researchers could take into consideration in the future.
Question 3. What are students' experiences and perceptions of using the exhibit to learn the impact of methamphetamine abuse on the brain?

Summary of Findings

The findings suggest that students’ learning experiences through using the exhibit was a self-regulated learning process. The exhibit possessed several intrinsic values that motivated students to participate and persist in the activity, whereby students performed several cognitive strategies such as read aloud, compromise, help seeking, peer mentoring, re-examining and revisiting the information, and re-reading, which helped the learning activity to best fit individual learning styles. Further, metacognitive strategies such as monitoring, evaluating, awareness of knowledge, and judgment of learning, were also used by students, evidencing their awareness of their learning processes and their efforts to make the cognitive processes more efficient.

Self-Regulated Learning

In the present study, the learning processes of self-regulation were investigated by three aspects, intrinsic values, cognitive strategies use, and metacognitive strategies use, respectively. In terms of intrinsic values, students perceived the exhibit as curious, fantastic, and somewhat challenging. However, they stated that it could be improved in terms of control features, such as the video game could be more interactive, or two controllers could be provided so that players could race each other.

Garris, Ahlers, & Driskell (2002) proposed an input-process-outcome model of instructional games and learning (Figure 5.1). They indicate that intrinsically motivational features of games combined with instructional content and practice are powerful driving
forces in triggering the game cycles that are repeated cycles of user judgment, behavior, and feedback, which engage players in the game play activities. Then, through the process of debriefing, learned knowledge could be transferred to the real world, and the desired learning outcomes would be achieved. In other words, the larger the extent of those features a game possesses, the more likely players will engage in it and the more effective it might be as an instructional game.

**Figure 5.1.** An input-process-outcome model of instructional games and learning proposed by Garris, Ahlers, & Driskell (2002).

The results of the present study indicate that the current control mechanism set in place does not appear to be enough. According to the input-process-outcome model (Garris et al., 2002), the insufficiency of control features might decrease students’ motivation to interact with the exhibit, and subsequently reduce the learning outcomes.

Moreover, the findings also indicate that students employed several cognitive and metacognitive (higher-level) strategies to enhance their learning processes through interacting with the exhibit. Although it has been broadly evidenced that the use of both
cognitive and metacognitive strategies could enhance learning, in certain situations people do not use strategies. For example, children are more likely to employ sophisticated cognitive strategies in a familiar setting of home instead of in a laboratory (Ceci & Bronfenbrenner, 1985). Garner (1990) also argues that the use of strategies is goal-directed. In other words, people tend to employ strategic activities as means to achieve goals; however, goals vary across different settings. These all imply that the use of cognitive and/or metacognitive strategies is particularly context-dependent (Garner, 1990).

The exhibit in this study however, uses a game format creating a playful context that children are familiar with and provides clear instructions and goals to children. Hence students are more likely to employ more cognitive and metacognitive strategies through interacting with the exhibit, which could then enhance their learning.

Overall, the results of the present study demonstrate that students performed a so-called self-regulated learning experience through interacting with the exhibit. According to Zimmerman (2001), *This approach [self-regulation] views learning as an activity that students do for themselves in a proactive way, rather than as a covert event that happens to them reactively as a result of teaching experiences* (Zimmerman, 2001, p. 1). Self-regulated learning has been evidenced as one of the best predictors of academic performance (Lindner & Harris, 1992; Pintrich & De Groot, 1990). In other words, learners who employ self-regulated learning processes tend to have better academic achievement. Hence, the findings indicate that Serious Games might have a huge potential in evoking learners’ self-regulated learning processes in which they actively participate motivationally, behaviorally, and metacognitively, which could subsequently enhance their learning outcomes.
Implications

New Opportunity for Pedagogy

Overall, both quantitative and qualitative results of the present study suggest an understanding progression after exposure to the exhibit. Moreover, students are intrinsically motivated to engage in the learning processes and actively employ both cognitive and metacognitive strategies to facilitate their learning through using Serious Games. These findings imply that Serious Games have a positive influence on students’ learning, especially for learning the impact of methamphetamine abuse on the brain from a neuroscience perspective.

In fact, either from behaviorism to cognitivism in the field of psychology or from objectivism to constructivist theory in the epistemological foundations, the tendency of recent changes in theoretical developments implies that instructional design rationale has shifted from the traditional lecture teaching method to a more interactive, student-centered model (Dalgarno, 1996; Duffy & Jonassen, 1992; Jonassen, Davidson, Collins, Campbell, & Haag, 1995). Serious games that emerged from the tendency of these two broad theoretical developments in both psychological and philosophical fields present a new opportunity for pedagogical methods. Compared to traditional lecture courses, video game-based learning, which exploits emerging interactive technologies, meets students’ expectations for deep digital engagement, motivates persistence, customizes the experience to each student’s unique needs, and promotes both long-term memory and the transfer of learning to the practical realm of everyday life, have much more potential in terms of satisfying desiderata of ideal learning (Foreman, 2003).
The findings of the present study, then, provide practical evidence further proving Foreman’s argument (Foreman, 2003), suggesting video games indeed could be used as a pedagogical method to improve student learning. Just as Aldrich contends, *the effective use of simulations will result in entire new types of material, and new approaches to old material, in our educational institutions* (Morrison & Aldrich, 2003).

**Drug Use Education Programs**

Both life skills training and dissemination of information are key components of successful drug use education programs. And it could be argued that the most effective programs would be those that teach multi-faceted knowledge and skill training to people in a more interactive way. The present study does not aim at replacing current promising prevention programs since it is just a short 15 minutes of interactive activity. It simply aims at providing a new opportunity in information dissemination for drug use education. What the results show us is that since students’ attitudes toward drug use have changed after exposure to the exhibit, if the exhibit could be coupled with other kinds of interventions, then those interventions would become even more effective as drug use education programs, which could ultimately change the behavior of drug use. Moreover, the results also imply that teaching the information of drug use from a neuroscience perspective that enhances the neuroscience literacy of children is a feasible way to assist drug use education. And Serious Games provide an interactive environment engaging children in learning activities that are a feasible teaching tool in conveying the basic concepts of neuroscience.

The present study features only one drug, methamphetamine, and one dysfunction caused by methamphetamine use, driving skill impairment. In order to convey more
knowledge regarding the negative impact of other drugs to the public, it really needs more efforts from more neuroscientists and education researchers.

**Future Studies**

**Improvements for Current Exhibit Design**

*Visual attention overload.* The results from both the pilot and present studies have revealed several shortcomings of current exhibit design that have to be improved in future studies. The first challenge encountered is that the current exhibit design that visually presents verbal explanations in text form with brain models might cause visual attention overload, resulting in some of the information being lost or the process of constructing connections between visual and verbal information might be disrupted (Mayer, 1997).

Mayer and colleagues (Mayer, 1997; Mayer & Anderson, 1991, 1992; Mayer & Moreno, 1998; Mayer & Sims, 1994) endeavor to examine useful methods for presenting scientific explanations to students, suggesting it is most effective for learning when verbal and visual explanations are presented contiguously. Moreover, verbal information should be acoustically presented in order to efficiently utilize cognitive resources. If verbal information is visually presented in text form, the same visual modality is used to process both pictorial and verbal information, which would cause an overload of visual attention. In terms of current exhibit design, students have to split their visual attention to process both pictorial and verbal information, which could thus affect learning outcomes.

In order to avoid overloading visual working memory, the verbal information could be acoustically presented to students in the future. The future exhibit that simultaneously
presents auditory narrations with corresponding brain models might be much more helpful to improve students’ understanding.

**Cognitive scaffolding strategies.** Another challenge revealed in this study is that the current exhibit design might easily give students a misunderstanding about how stop and go signals are affected by methamphetamine abuse. Or some materials provided by the current exhibit might be more like surface knowledge and somewhat emphasize rote learning. Therefore, more guidance and/or more cognitive scaffolding strategies focusing on addressing those alternative explanations generated by students or improving recall might be needed to improve the virtual brain exhibit in future studies. For example, instead of directly presenting the conceptual model to students, cognitive scaffolding could be provided by contextualizing questions in Serious Games (Hmelo & Day, 1999). Moreover, more guidance and/or more instructions providing as many connections as possible might be useful for students to transfer surface knowledge to deep knowledge.

**Control feature.** The third challenge is the insufficiency of control feature of current exhibit design. Actually, the suggestions such as video game could be more interactive, or two controllers could be provided so that players could race each other were provided by participants in the pilot study. These valuable suggestions and opinions that emerged from both the pilot and present studies have already been taken into serious consideration by the joint venture of Entertainment Science Inc., and Virtual Heroes Inc. Since this is a prototype exhibit, it is believed that the suggestions and opinions received would be helpful in improving and creating a superior version of the exhibit in the future.
Future Work for Research Design

In order to further investigate the impact of the virtual brain exhibit, several areas regarding research design could be considered in the future. First, future studies could perform a pretest-posttest control group design instead of using a one-group pretest posttest research design. In other words, a control group learning the same materials through traditional lecture methods or through 2D textual and pictorial presentation could be performed to compare the differences between control and experimental groups. Besides, similar to the first idea, the comparison could be performed between combining the exhibit with other drug use interventions and implementing those interventions alone. Moreover, a longitudinal research design tracking students’ attitudes and monitoring their behaviors of drug use could be conducted. Further, the influences of other variables such as race and/or the amount of video game experience could also be examined in the future studies.

Conclusions

A question has to be asked here, “Can the hypothesis argued in the first chapter be accepted?” The findings of the present study have provided solid evidence supporting the positive answer to this question. Yes, the exhibit employed an effective, virtual reality learning environment with a video game, which provides the latest findings in neuroscience research to teach the impact of drug abuse on the brain, could be of substantial benefit in enhancing the neuroscience literacy of middle school students, thus conveying knowledge about the impact of drug use on the brain to them, and improving their negative attitudes toward drug use.
One of the main goals of science education is to ensure that the teaching and learning of science concepts are effective, subsequently giving the public a positive attitude toward science and helping to improve performance and to make correct decisions in daily lives. The results of the present study ultimately demonstrate that the exhibit is striding forward this goal.
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[http://technologysource.org/article/simulations_and_the_learning_revolution/](http://technologysource.org/article/simulations_and_the_learning_revolution/)


the second international conference on Entertainment computing, Pittsburgh, Pennsylvania.


APPENDIXES
What is methamphetamine?
Do you know how it works on your brain?

Methamphetamine and Your Brain
A serious Game

- A cool virtual tour of your brain
- Explore the secret of methamphetamine
- Mini video game play
- Get a tee shirt as a reward

Don’t hesitate!! You are welcome to join us!!

10.13-17.2008 / Friday Institute
We are looking forward to seeing you!

For more information, please contact Meng-Tzu Cheng at
919-757-1969 / mcheng2@ncsu.edu
Appendix B

STUDENT INFORMATION SHEET

Do you have epilepsy or have you ever had a seizure? □ Yes □ No
If you checked yes, STOP HERE, you are not eligible to participate in this study.

Age_______________________ Grade_______________________

Gender (check one): □ Male □ Female

Ethnicity (check one): □ Hispanic or Latino □ Not Hispanic or Latino

*Hispanic or Latino:* A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race

Race (check one): □ American Indian or Alaska Native □ Asian □ Black or African American □ Native Hawaiian or Other Pacific Islander □ White

*American Indian or Alaska Native:* A person having origins in any of the original peoples of North, Central, or South America, and who maintains tribal affiliations or community attachment.

*Asian:* A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.

*Black or African American:* A person having origins in any of the black racial groups of Africa.

*Native Hawaiian or Other Pacific Islander:* A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.

*White:* A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.
Appendix C

KNOWLEDGE PRE- AND POST ASSESSMENT

*Knowledge Assessment*

1) What is the name of the brain area shown here in green?
   a. Motor Cortex
   b. Inferior Frontal Gyrus (IGF)
   c. Subthalamus
   d. I don’t know.

2) What is the name of the brain area shown here in RED?
   a. Motor Cortex
   b. Inferior Frontal Gyrus (IGF)
   c. Subthalamus
   d. I don’t know.

3) What does the motor Cortex do?
   a. It stores our memories.
   b. It generates command signals to “GO’.
   c. It generates “STOP” command signals.
   d. I don’t know

4) What does the inferior Frontal Gyrus (IGF) do?
   a. It stores our memories.
   b. It generates command signals to “GO’.
   c. It generates “STOP” command signals.
   d. I don’t know.

5) Which of the following statements is most correct?
   a. There is NO evidence suggesting that meth use physically damages the brain.
   b. A meth user’s brain is smaller than normal in specific area, but this doesn’t have any known effect on how well their brains work.
   c. A meth user’s brain is smaller than normal in specific areas, and meth users are a lot worse than non-users at the specific tasks that these areas perform.
   d. I don’t know.
These definitions apply to question 6:

Reaction Time is how quickly you can react to a Go-Signal.

Stop-Signal Reaction Time is how quickly you can stop yourself from doing something you were just about to do when you see a Stop-Signal.

6) Which of the following statements is most correct?
   a. Meth users have normal reaction times to Go-Signals but slower than normal reaction times to Stop-Signals.
   b. Meth users’ reaction times to Go-Signals and Stop-Signals are normal.
   c. Meth users have faster than usual reaction times to Go-Signals and normal reaction times to Stop-Signals.
   d. I don’t know.
Attitude questionnaire survey

General attitudes towards methamphetamine

1) People usually have a good time when they use methamphetamine.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree

2) Methamphetamine is a dangerous drug.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree

3) You would use methamphetamine if a friend offered it to you.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree

4) You would use methamphetamine is someone you didn’t know offered it to you at a party.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree
Attitudes towards methamphetamine and health

1) Using methamphetamine once a month is not dangerous.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree

2) Methamphetamine use may result in brain damage.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree

3) There is a clear link between methamphetamine and health problems.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree

4) The benefits of using methamphetamine outweigh the harms and risks associated with its use.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree

5) Being high on methamphetamine impairs driving skills.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree

6) Methamphetamine impairs people’s driving skills even when they are not high.

1  2  3  4  5
Strongly Disagree  Disagree  I am not sure  Agree  Strongly Agree
Appendix E

POST EXPERIENCE COMMENTS AND OPEN-ENDED QUESTION

Comments:

Please explain in detail about the impact of methamphetamine on your brain. (You can draw, use flowchart, or use any way to explain it).
Appendix F

INTERVIEW QUESTIONS

Semi-Constructed Interview Questions

● Background/Opening Questions
  ➢ Tell me a little bit about yourself (race, gender, age, video game experiences…)

● Research Question 1: What do students learn about basic concepts of neuroscience and the impact of methamphetamine abuse on the brain via the exhibit?
  ➢ What do you know about the effects of meth on your brain before the simulations and games?
  ➢ What do you know about the effects of meth now? How does meth affect you?
  ➢ Can you tell me what happened in the video game? Do you know why you couldn’t stop while playing the video game?

● Research Question 2: How are students’ attitudes toward methamphetamine use changed after exposure to the exhibit?
  ➢ What do you think about drugs before the games? Would you like to try them if possible? Why?
  ➢ What do you think about drugs now? Would you like to try them? Why?

● Research Question 3: What are students’ experiences and perceptions of using the exhibit to learn the impact of methamphetamine abuse on the brain?
  ➢ Did you like the 3D models of brain and the games? Why or why not? What do you like the most/least?
  ➢ What do you think about 3D simulations and video games to be tools to help you learn the brain and the impact of drug abuse?
  ➢ What recommendation regarding the 3D simulations and video games you would provide?
How do you interact with the exhibit?

Final Words/Closing Questions

What else would you like to mention that hasn’t been covered?