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Bacon Brains: Video Games for Teaching the Science of Addiction

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Abstract

Researchers have developed many different computerized interventions designed to teach students about the dangers of substance use. Following in this tradition, we produced a series of video games called *Bacon Brains*. However, unlike many other programs, ours focused on the “Science of Addiction,” providing lessons on how alcohol and other drugs affect the brain. The purpose of this study was to evaluate the effectiveness of our games in teaching students our science-based curriculum. We enrolled over 200 students and randomly assigned them to play our games or a different series of NIDA-produced games. Of the students in the *Bacon Brains* conditions, half were instructed to play collaboratively and the other half was told to play competitively. Results indicate significantly greater knowledge gains among students in *Bacon Brains* compared to the existing games (5.01 mean knowledge score difference; $[F(1,242)=9.588, p=.002]$). Girls demonstrated knowledge gains in both collaborative and competitive conditions, but boys demonstrated similar gains only in the competitive condition. Based on our outcomes, we conclude that video games can serve as an effective method of science instruction. We further discuss the importance of considering gender differences in light of differential response to collaborative vs. competitive learning environments.

Keywords

Video Games; Program Evaluation; Science of Addiction; Science Education; Middle School; Substance Abuse

1.1 Introduction

Substance use among youth is a significant concern in the United States. Approximately 40% of high school seniors report drinking some alcohol in the past month and almost 23% report using marijuana (USDHHS, 2014). Initiation of substance use contributes to a myriad of potential future concerns including addiction, health issues, school failure, loss of employment, and mental health problems. In fact, illicit drug use by teenagers correlates with depression and other psychiatric issues by the time they reach their late twenties (Brook, Brook, Zhang, Cohen, & Whiteman, 2002).

Because adolescence is accompanied with increased engagement in risky behaviors (Rutherford, Mayes, & Potenza, 2010), middle school is an ideal time to provide students accurate scientific information about drug use. Indeed, researchers have developed countless interventions to impact childhood and adolescent substance abuse. Most of these programs focus on the risks and dangers of drug abuse while also teaching positive decision-making skills. Research on the efficacy of some of these programs has not always yielded positive results. For example, a meta-analysis of the most widely used prevention program (*D.A.R.E.*) indicated that the program was ineffective (West & O'Neal, 2004). Similarly, a large-scale evaluation of the popular *Take Charge of Your Life* program concluded that it should not be used as a universal prevention intervention (Sloboda, et. al, 2009).

There are, however, some programs that are quite effective in delaying the onset of substance use (Perry, Williams, Komro, Veblen-Mortenson & Dudovitz, 2009). One approach some programs use is to convey their lessons within the context of science education (Surratt & Desselle, 2004). Additionally, there is a long history of using technology to deliver these types of programs (Epstein, Thomson, Collins, & Pancellia, 2009).

In keeping with these traditions, we developed a comprehensive “Science of Addiction” curriculum and created a series of video games to deliver the material to middle-school students. This report provides details on the development and evaluation of our program called *Bacon Brains*.

1.1.1 Ubiquity and Benefits of Gaming

Young adults in the United States spend an average of about seven hours a day using media, and a vast majority of them have access to multiple types of media-enabled devices (Rideout, 2010). Furthermore, in an analysis of titles sold on the iTunes and Google Play market places, a recent study revealed that nearly 85% of the top 700 most popular apps were games (Spence, 2014). Gaming is important part of many children and young adults' lives, with approximately 97% playing at least an hour a day (Granic, Lobel, & Engels, 2014).

Despite the potential negative effects of such ubiquitous consumption (e.g., overuse, interference with other daily activities; Bailey, West & Kuffel, 2013), research has demonstrated that game players can learn a wide variety of prosocial skills via the games they play including antiviolence attitudes, empathy, ethnic tolerance, and respect (Strasburger, Jordan, & Donnerstein, 2010). In fact, Parkes, et al. (2013) argued that screen time, regardless of content, does not necessarily correlate with antisocial development. Although not wanting to minimize the potential deleterious effects of gaming (e.g., violence and impulsivity), the authors of a recent review of video gaming argued that users can benefit from play in terms of cognitive, motivational, emotional, and social factors (Granic, et al., 2014).

1.1.2 Serious Games

Recognizing the potential benefits of gaming, educators have adopted games as a way to deliver their curriculum materials (Shute, Rieber, & Van Eck, 2011). These so-called

“Serious Games” use game-like scenarios to provide instruction. A wide range of disciplines have employed serious games including reading, math, and physics (Nietfeld & Shores, 2011). And because so many college-aged students are avid gamers, institutes of higher education have also begun to adopt the use of gaming-as-instruction (Jones, 2003). Similarly, private industry has jumped on the serious game bandwagon. One major automotive manufacturer developed a serious game to help educate its workforce (Cromer, 2011). Health-care researchers are also using “gamification” to help patients be more compliant with medical interventions (Granic, et al., 2014).

1.1.3 Games for Health Promotion and Substance Abuse Prevention

Researchers have developed numerous computer games designed to help promote healthy behaviors. For example, in a large-scale evaluation, young cancer patients who played a video game about cancer treatment were more adherent and demonstrated significantly more knowledge about their condition than those who did not play the game (Kato et al., 2008). AIDS prevention has been another popular topic for health-related games. Markham, Shogog, Leonard, Bui, & Paul, (2009) demonstrated that their game about HIV was effective in increasing teens’ reported self-efficacy in using condoms. The use of health-related video games is not solely limited to younger people. In fact, the *Dancetown* game was developed specifically to promote improved health outcomes in an elderly population (Hawn, 2009). The promise of health games is so alluring, that the Robert Wood Johnson Foundation now has a funding mechanism devoted solely to health games (RWJ, 2014).

Some of the earliest health-related games addressed substance abuse and prevention. As early as the late 1980s, researchers began releasing interactive videos designed to teach adolescents about the dangers of using drugs. Early programs such as *Say No With Donny* (Gropper, 2002), *Life Moves* (Schmidt, 1994) and *If You Drink* (Meier & Sampson, 1989) functioned primarily as interactive videos. Other early programs, such as *Refuse to Use* (Duncan, et. al., 2000) actually contained structured interventions designed to teach students specific skills (e.g., drug refusal).

More recently, Klisch et al. (2011) evaluated the effectiveness of their on-line interactive substance abuse education modules. Funded by grants from NIDA, these highly engaging web adventures allow students to learn about the biological consequences of exposure to toxic chemicals and relate this information to the dangers of inhalant use. Results indicated that the games were quite effective in improving students’ knowledge and changing their attitudes towards using inhalants. These programs, along with others from the same lab (Miller, et al., 2002) have demonstrated that highly interactive substance abuse education programs designed as games can be effective teaching tools.

1.1.4 Gender Differences

One area of research that has largely been neglected is the impact of gender on response to game-based teaching tools. This is an important issue to consider because boys and girls approach learning differently. Gurian, Henley, and Trueman (2001) point out that these differences include the use of deductive versus inductive reasoning styles, abstract versus concrete reasoning, language versus symbolism, and general sensitivity to group dynamics

(Fisher & Grégoire, 2006). Literature suggests that girls tend to choose interactive social activities that allow for increased verbalization while boys tend to choose interactive social activities that are less verbal and more aggressive (Gurian, Stevens, & King, 2008). Girls are much more likely to report liking “educational” games than boys, who are much more likely to report liking games about sports and violence (van Schie & Wiegman, 1997).

Males and females also differ in their willingness to compete, especially in stereotypically male tasks (Niederle & Vesterlund, 2011). There are, however, some exceptions. Females are more willing to compete against other women (Gupta, Poulsen, & Villeval, 2013) and at tasks at which they feel they excel (Ifcher & Zarghamee, 2015). Overall, however, the net result is that fewer women enter male-dominated fields. In fact, there is the perception of science as a “male” rather than “female” endeavor. Girls do have less positive attitudes than boys towards science (Cannon & Simpson, 1985; Simpson & Oliver, 1990; Sikora & Pokropek, 2012; Gokhale, Rabe-Hemp, Woeste, & Machina, 2014), and by middle school these attitudes tend to decline steadily and may persist through high school (Sullins, Hernandez, Fuller & Tashiro, 1995). These negative attitudes can influence a female student’s decision not to enroll in advanced science courses, which is strongly related to intentions to pursue a career in science (Kerr, 1991). Catsambis (1995) found that over twice as many middle school boys as girls are interested in a future career in science. In fact, men are still overrepresented in science and technology fields (Gokhale, et. al, 2014).

Additionally, peers have a strong influence on students’ attitudes toward science and that relationship increases significantly from sixth grade forward. This is important because girls often hold more negative attitudes toward science and tend to be strongly influenced by their peer relationships. Therefore, gifted girls may embrace negative attitudes toward science in an effort to conform and be seen as one of the group (Buescher, Olszewski & Higham, 1987). For example, Baker and Leary (1995) found that a sample of 8th grade girls reported that although the girls generally liked science, they thought their friends would not be supportive of a career choice in science.

Recognizing the importance of considering gender differences in response to interactive games designed to teach students about the science of addiction, the National Institute on Drug Abuse (NIDA) funded our proposal (R25-DA022306) to create a series of video games that capitalized on gender differences as they related competitive and cooperative play.

1.1.6 Overview of the Present Study and Hypotheses

Given both the past history of using video games to educate students about substance use and our experience creating interactive educational materials, we were confident that we could create an intervention that students would not only enjoy, but would be effective in teaching them a core “Science of Addiction” curriculum.

We sought to develop a series of educational modules designed to teach students about brain structure and function as well as how drug use can disrupt the way the brain works. We worked with educators and substance abuse researchers to align our program to state and national curriculum guidelines. Our overarching goal was to compare knowledge gains for

students who played our newly developed games versus students who played an existing series of educational games that covered similar material.

Given the existing literature on the effect of gender on both the tendency and willingness to compete, we also sought to test the impact of game instructions emphasizing collaboration versus competition on curriculum effectiveness for girls versus boys. Finally, we assessed attitudes toward science as a potential covariate in predicting curriculum effectiveness.

We hypothesized that:

1. When assigned to play *Bacon Brains*, students' interim scores on a measure of knowledge of the science of addiction will be greater than their pre-test scores.
2. Students' knowledge gains will persist through the post-test assessment period.
3. Students assigned to play *Bacon Brains* will have significantly higher gains in their scores of knowledge compared to the students assigned to the control condition.
4. Students assigned to play *Bacon Brains* will report enjoying the intervention more than the students assigned to the control condition.
5. Girls who play *Bacon Brains* collaboratively will have higher gains in knowledge than girls who play the games competitively.
6. Boys who play *Bacon Brains* competitively will have higher gains in knowledge than boys who play the games collaboratively.

2.1 Methods

2.1.1 Program Development

Although excellent science-based drug abuse education programs exist, many of them focus solely on a single substance (e.g., alcohol or inhalants). Our goal was to create a more comprehensive curriculum that provided students a solid foundation in the underlying biology of addiction. To that end, we began our development efforts by creating the program's core content. This included conducting literature reviews and consulting with substance abuse researchers. Because addiction is such a broad topic, we relied heavily on our consultants to help us select the most relevant and meaningful information. The result of these efforts was a series of content outlines that provided an overview of the science of addiction and served as the underlying scaffolding of our interactive program.

We then had our educational consultants review our outlines. These individuals helped us align our content to state and national curriculum guidelines including the *National Science Education Standards*, the *Next Generation Science Standards*, and *Missouri Grade Level Expectations* and *Performance Standards for Health and Science*. Once we had final sign-off from both our scientific and educational consultants on our content outlines, we held a series of five separate focus groups with a total of 73 middle-school students aged 10–14 to help us develop the game's overarching creative approach. We conducted these groups during the early evenings at a number of settings including schools and boys and girls clubs. We had a

balanced mix of genders across our five groups. During these lively discussions, we talked to the students about their media preferences and ways we could incorporate our content into engaging educational modules. In fact, it was through these student-centered focus groups that we developed the title *Bacon Brains* and the basic gameplay for each of the program's modules.

Following the focus groups with students, we developed detailed design documents that provided screen-by-screen specifications for our program as well as instructions for how we would modify the program to allow for either competitive or collaborative game play. With these specifications in place, we once again returned to our educational consultants and substance abuse researchers. This time, we wanted to insure that our efforts to “gamify” the curriculum did not distort the underlying science and that our messages were still educationally sound. Based on feedback we received, we made further modifications to our design documents.

It was only after having completed these preliminary planning steps that we felt comfortable moving forward with the actual development of the program. Over the course of the next several months, we used Adobe's Flash development studio to create the games for delivery via the Internet.

After the games were completed, we held another series of focus groups with middle school students in order to receive feedback and identify any lingering problems. The students responded quite favorably to our games and were also able to help us identify a number of minor modifications that needed to be made.

2.1.2 Description of Intervention

We designed our games so that each module would cover one core concept of our curriculum. We developed three different game types across the six different modules.

Game	Name	Type	Objective
1	Tour de Swine I	Racing	Learn about <i>brain structure and function</i> through the identification of ten separate brain structures
2	Tour de Swine II	Racing	Learn about how the brain works by examining the process of <i>neurotransmission</i>
3	All Fired Up I	Arcade	Learn about the <i>brain reward system</i> by collecting reinforcers and observing their effects
4	Hooray For Hoggwood I	Maze	Learn about the <i>disease model of addiction</i> by finding and assembling animated sequences
5	All Fired Up II	Arcade	Learn about the <i>genetics of addiction</i> by gathering and installing various genes into a robotic pig
6	Hooray For Hoggwood II	Maze	Learn about the <i>treatment for addiction</i> by finding and assembling animated sequences

In the Racing Game modules, students guide their robotic pig characters through a track littered with brain parts. The game is broken into short “missions” that involve a lap around the track. Once back in the lab, students must install the correct brain part they collected on the track to satisfy the objective of that mission. For example, in order to improve their pig’s memory, they must seek out and install the hippocampus.

In the Arcade-Style games, the primary action occurs in an arena in which students use a ray to release objects from a grid. Once released, these objects must be caught in the pig’s bucket before falling to the floor. In the “Brain Reward System” module, each mission involves catching various “reinforcers” in the arena (e.g., veggies, sundaes, etc.). In the “Genetics of Addiction” module, students use their rays to burst open cells to reveal the nucleus, chromosomes, and genes. Each mission consists of collecting the requisite genes for their pig.

In the Maze Games, students guide their pigs through the basement of a movie studio in search of movie clips. These clips are stored on discs that are littered throughout the basement. Upon collection of each clip, the student learns a small bit about the underlying curriculum. The game is punctuated with a mini matching game to further reinforce the content. Once the students have gathered all of the clips, they proceed to the editing room where they apply various audio and visual effects before viewing an animation of the entire content for that module.

2.1.3 Research Venue and Randomization Procedure

We conducted our intervention at a local charter school within the city of St. Louis, Missouri. Founded in 2000, the school was one of the first charter schools in the area and has won several awards for excellence in education. The school uses a city-wide lottery system for enrollment. Each grade level has approximately one hundred students.

Although the school enrolls students in grades K-8, students in our investigation were in grades six through eight. All students from these grades were eligible to participate as long as their parents had provided informed consent. The first two days of the school year began with parent-teacher conferences. During this time, all teachers met individually with their students’ parents and collected signatures on our University-approved Informed Consent document. We were present during this time to answer any questions parents might have had. Refusal rate was approximately one percent.

The summer before the intervention started, we met with the school’s administration to prepare our implementation plan. They created twelve randomly-assigned cohorts of approximately 25 students and assigned each group to a separate ten-day block during their elective hour. This allowed for every sixth through eighth-grade student to be in the study by the end of the school’s second trimester. During the first day of each cohort, we explained that their parents had already consented to their participation, orally reviewed our assent document, and obtained signatures from each student.

2.1.4 Procedures

All experimental procedures were conducted in a classroom dedicated to our study or (when the room was unavailable) the cafeteria. The school provided ample laptop computers in order to ensure that each student played the games on their own laptop.

Experimental Design—Each participating student was randomly assigned either to play *Bacon Brains* or to interact with a set of comparison game modules previously developed for NIDA. Although the content of these games also centers on drug abuse, they are much more targeted than *Bacon Brains*, often focusing on a particular substance (e.g., stimulants or inhalants). In addition, those playing *Bacon Brains* were randomly assigned to either a collaborative-play (receiving instructions to collaborate with a partner while playing the game) or a competitive play (receiving instructions to compete with a partner while playing game) condition; all participants in the comparison group were instructed to play independently.

Assent & Randomization—We devoted the first day of the cohort to describing the study, collecting assents, and assigning students to one of the three experimental conditions. During this time, we coded the assent forms with the letters A-C. After signing the forms, students were put into pairs based on their random group assignment. We explained to the students that pairs assigned to group “A” would be working collaboratively, those in group “B” would be working competitively, and those in group “C” would be serving as our control condition and would be working independently. We further explained the students in groups A and B would be playing our *Bacon Brains* games and students in group C would be playing a different series of educational games. We provided examples of how they were to work with their partners and in order to reinforce this concept, the remainder of the period was spent completing word-search and acrostic worksheets in the manner of which condition they had been assigned.

Throughout the duration of the intervention, we reminded students to behave according the conditions to which they had been assigned. We encouraged students in the collaborative condition to help their partner (e.g., assisting them find objects in the maze, discussing which power-ups were best to purchase, etc.). We reminded students in the competitive condition to celebrate their individual successes and to strive to do better than their partner.

Pre-Test—Students spent the entire second day of the cohort taking our pre-test assessment (see Measures section below). In order to insure standardization of administration, we pre-recorded the individual questions and played these audio files to the students while they completed the survey on their laptop computers. We used the Qualtrics online surveying tool in order to collect all data for this project.

Intervention & Interim Assessments—During the subsequent six sessions, each participating student spent forty minutes interacting with an individual module, with game content determined by the student’s assignment to *Bacon Brains* or the comparison group. We began each session by describing the type of game they’d be playing and the content we expected them to learn. We also reminded them that they were to be playing the games either

collaboratively, competitively, or individually. Students worked on their own laptops, but were encouraged, depending on their group assignment, to either provide assistance to their partner or do their best to outperform their partner. After completing the intervention period, we used the same procedures described above to administer the online interim test of the content covered in that particular module.

Post-Test—During the ninth day of the cohort, we once again administered our entire assessment battery. Some of the cohorts lasted for an additional tenth day; in this case, students were allowed to visit other educational game sites. In order to insure consistent exposure to our intervention, we did not allow the students to replay any of our games. In fact, because students repeatedly asked us about access to these modules, we had to modify our website so that the games would only be available during the hours we were at the school; attempts to access the games outside of this time period resulted in a message stating that they were currently unavailable. This blocking procedure helped to ensure that students were not using the games outside of our intervention.

Follow-up—Approximately eight weeks following the last day of their cohort, students were instructed to reconvene for a final assessment session. Unfortunately, because this session was not built into the school's schedule and because students were often involved in other classroom activities during this time, we had a disappointingly low participation rate (44%) for this final session. Consequently, all analyses were conducted using only three time periods (pre, interim, and post).

2.1.5 Measures

All instruments used for this investigation were administered within the Qualtrics online surveying software. This system provides a secure method of data collection and eliminates the need for the costly and unreliable data entry necessary when paper and pencil surveys are used. To further standardize the assessment procedures, we recorded each assessment item and played these audio files to the students within the classroom setting while they read along and indicated their answers on the online survey. All students, regardless of experimental condition to which they had been assigned, completed the same set of measures using these structured procedures.

Knowledge—For each of the six game modules, we developed a set of ten multiple-choice questions that covered the basic concepts addressed in that module. Although these questions directly correspond to facts derived from the core content outlines we initially developed, we asked our educational consultants to review these tests to ensure that the items were well constructed. We also asked our substance abuse consultants to review the test to ensure its accuracy. Primary outcomes are based on the summation of correct answers for each module (from 0–10) as well as the total correct across all six modules (from 0 to 60).

Science Attitudes—Because this project was supported by NIDA's Science Education Drug Abuse Partnership Award (SEDAPA), we were particularly interested in analyzing students' attitudes toward science and examining whether our intervention had any impact

on these feelings. Consequently, we modified scales from our previous SEDAPA projects (Epstein, Thomson, Collins, & Pancella, 2009; Epstein, Collins, Thomson, Pancella, & Pauley, 2007). The resultant scale consists of nine five-point Likert scale items such as “I enjoy my science course” and “Doing science often makes me feel nervous”.

3.1 Results

We began our analyses by summarizing participant demographic characteristics. We then evaluated whether students who received our intervention showed greater gains in knowledge compared to students who completed an existing intervention. We followed these analyses with examination of the impact of attitudes towards science, age, and gender on knowledge outcomes. The sections below provide details of our results.

3.1.1 Participants

During the seven-month intervention period, we enrolled a total of 244 participants into our study. We enrolled more boys ($n=132$, 54.1%) than girls ($n=112$, 45.9%). We also had a greater proportion of sixth-graders ($n=90$, 36.9%) compared to seventh- ($n=80$, 32.8%) and eighth-graders ($n=74$, 30.3%). Participants ranged in age from 11–15 with an average age of 12.42. Approximately 44% of the participants were white, 32% were African American; 13% were Hispanic; 6% were Asian.

3.1.2 Overall Hypothesis Test: Change in Knowledge Over Time by Experimental Group

Review of Primary Outcomes—The primary research question of interest for this investigation was whether students who were in either the *Bacon Brains* collaborative or *Bacon Brains* competitive condition learned more than students who were in the control condition. Analyses assessed within-student change across three data points: pretest, interim, and post-intervention.

For purposes of our main analyses, we created a composite knowledge score based upon students' responses on the ten knowledge questions for each of the six modules (min=0, max=60) at each of the three data collection periods. It is important to note that pretest and posttest total knowledge scores were each collected in separate, single pretest and posttest assessment sessions. Interim knowledge scores, however, were collected across six separate sessions, immediately following students' interactions with the intervention modules. For purposes of our main outcome analyses, we totaled all six interim scores across modules, to create a single interim timepoint score.

In order to determine the effect of game format on student knowledge gains, we conducted separate analyses for each individual module. However, because the results of these analyses largely mirrored results of the composite measure, below we only report outcomes based on the total score.

Multiple Imputation—Study hypotheses were tested via mixed-factor analyses of variance (ANOVAs) with assessment time-point (pretest, interim, and post-test) as a within-subjects factor and experimental condition (collaborative, competitive, or control game), gender, and grade-level as between-subjects factors. ANOVAs were conducted using the General Linear

Model (GLM) procedure in SPSS. One major limitation of the GLM procedure is that it drops cases that have missing data points. Because our assessment sessions occurred across eight separate days, it was not uncommon for students to be absent during one of these sessions. In fact, of our total sample ($n=244$), we had complete data for only 107 students (44.85%).

One approach for dealing with missing data is to use SPSS's Multiple Imputation (MI) procedure to predict missing values by analyzing each variable's mean and variance across both the individual and the entire data set. This procedure was used in a study roughly analogous to ours which examined the effects of a web-based health literacy game (Li, T., Chau, M., Lai, E., & Yip, P., 2013). We present findings here using both the original dataset with missing cases dropped, and the dataset resulting from MI.

Original Dataset—In the original data, mixed-factor ANOVA resulted in a significant main effect of time [$F(2,208)=37.874, p<.001, \eta_p^2 = .27$] and a significant time by group interaction [$F(4,208)=4.037, p<.01, \eta_p^2 = .07$]; the main effect of group was not significant ($p=.30$). Analyses of polynomial contrasts revealed a significant quadratic effect for time [$F(1,104)=53.676, p<.001, \eta_p^2 = .34$] and for the time by group interaction [$F(2,104)=5.976, p<.01, \eta_p^2 = .10$].

Dataset Following Multiple Imputation—Rerunning these analyses with the new dataset containing imputed values also resulted in a significant main effect of time [$F(2,482)=96.293, p<.001, \eta_p^2 = .29$]; in this dataset, the main effect of group was also significant, [$F(2,241)=6.8334, p<.05, \eta_p^2 = .05$]. In line with results from the original dataset, the time by group interaction was also significant [$F(4,482)=10.029, p<.001, \eta_p^2 = .08$].

Also in agreement with the original dataset, analyses of polynomial contrasts revealed a significant quadratic effect for time [$F(1,241)=118.026, p<.001, \eta_p^2 = .33$] and for the time by group interaction [$F(2,241)=16.402, p<.001, \eta_p^2 = .12$]. Because the analyses using the imputed data set have significantly more power, yet reveal largely the same results as the non-imputed set, we used the imputed data set for all subsequent analyses.

See Figure 1 for a graph of these overall group x time results.

3.1.3 Hypothesis Tests: Attitudes toward Science

Because our curriculum was primarily designed to teach participants about the science of addiction, we analyzed the effect of the interventions on students' attitudes towards science (ATS). There were no significant differences between the groups at either pre-test [$F(2,241)=.516, p=.597$] or post-test [$F(2,241)=.448, p=.640$]. However, because there were significant differences in ATS across grade [$F(2,241)=3.774, p=.024$], we used these scores as a covariate in subsequent analyses.

3.1.4 Hypothesis Tests: Time by Experimental Group with Grade and Gender

Preliminary—We ran a preliminary analysis on our primary outcome variable (total knowledge across all six modules) to insure that there were no baseline differences between

the three experimental conditions (i.e., 1=playing *BaconBrains* collaboratively; 2=playing *BaconBrains* competitively; 3=control). We also investigated whether there were any differences on total knowledge scores at pre-test by gender or grade. None of these analyses revealed any significant differences.

Primary Outcomes—To analyze our data, we used SPSS's repeated measure GLM procedure to conduct a 2 (gender) x 3 (group: BB Competitive, BB Cooperative, or Comparison Group) x 3 (grade) x 3 (time point: baseline, interim, follow-up) mixed-factor Analysis of Variance (ANOVA) with time as a within-subjects factor and Attitudes Towards Science (ATS) as a covariate.

The overall test of the model resulted in significant main effects of group [$F(2,237)=6.532$, $p<.01$, $\eta_p^2 = .05$], gender [$F(1,237)=4.061$, $p<.05$, $\eta_p^2 = .02$], and the attitudes toward science covariate [$F(1,237)=37.584$, $p<.001$, $\eta_p^2 = .14$]; the main effect of time was not significant ($p=.69$). All main effects were qualified by significant interactions including: Time by ATS [$F(2,474)=4.760$, $p<.05$, $\eta_p^2 = .02$], time by group [$F(4,474)=9.795$, $p<.001$, $\eta_p^2 = .08$], and time by group by gender [$F(4,474)=2.951$, $p<.05$, $\eta_p^2 = .02$].

Analyses of polynomial contrasts indicated a number of significant linear interaction effects including: Time by ATS [$F(1,237)=5.814$, $p<.05$, $\eta_p^2 = .02$] and Time by Group [$F(2,237)=6.201$, $p<.01$]. These contrasts also revealed a number of significant quadratic interaction effects including: Time by Group [$F(2,237)=16.296$, $p<.001$, $\eta_p^2 = .12$]; Time by Gender [$F(1,237)=4.183$, $p<.05$, $\eta_p^2 = .02$]; and Time by Group by Gender [$F(2,237)=7.448$, $p<.01$, $\eta_p^2 = .06$]. Thus, after accounting for variance in knowledge over time associated with pretest attitudes toward science, the impact of group on knowledge change remained significant and primarily in the expected direction. It is notable that grade level was not a significant factor in any of these analyses. See Figure 2 for a graph of the full model means.

3.1.5 Follow-up Analyses

In order to clarify the three-way interaction of time, group and gender obtained by the GLM analyses, we first ran multiple paired *t*-tests to compare means between specific timepoints for each combination of group and gender; that is, we tested the significance of the difference between paired timepoints along each line in Figure 2 above. Results indicated that there were no significant differences across any timepoints for boys in the control condition. However, for girls in the control condition and boys in the collaborative condition, there were significant pre vs. interim and pre vs. post differences. For boys in the competitive condition, and girls in either the collaborative or competitive conditions, there were significant pre vs. interim, pre vs. post, and interim vs. post differences. (Note that simple contrasts within the GLM procedure, with pretest as the reference category, yielded the same pattern as the *t*-tests). See Table 1 for an overview of these differences.

Then, to compare differences *within* timepoints and across conditions, we conducted one-way analyses of variance to test mean differences at each time period across the six separate gender by group cells; where the ANOVA was significant, post-hoc tests identified significant paired comparisons. Results indicated that there were no significant differences

between any of the cells at pre-test. There were, however, a number of significant differences at both the interim and post-test periods. See Table 2 for an overview of these results.

Some notable findings at the interim timepoint, where the strongest learning had occurred, include the higher score for boys in the competitive group than in either the collaborative or control group, and the higher score for boys in the competitive group compared to girls in all groups. Girls, on the other hand, did equally well at interim in the collaborative and competitive groups; however, although girls in both *BaconBrains* groups had higher interim knowledge than girls in the control group, this group difference among girls was only significant for the collaborative versus control pairwise comparison.

3.1.5 Satisfaction

Finally, we wanted to assess how much the students enjoyed interacting with the interventions. To conduct this analysis, we performed an ANOVA looking at responses to our “Attitudes Towards Intervention” measure based on students’ gender, grade, and whether they were in one of the *BaconBrain* interventions (collapsed across Competitive and Collaborative groups) or the Control condition. Results indicated significant main effects for both condition [$F(1, 206) = 13.059, p < .001, \eta_p^2 = .06$] and grade [$F(2, 206) = 7.761, p < .01, \eta_p^2 = .07$]. There was also a significant condition by grade interaction [$F(2, 206) = 3.107, p < .05, \eta_p^2 = .03$]. Follow-up analyses revealed that students preferred *BaconBrains* over the control condition games. See Figure 3 for a graph of these means.

4.1 Discussion

The results of our investigation demonstrate that video games can be effective teaching tools. We further showed that responses to our games was influenced by pre-existing factors such as grade, gender, and attitudes towards science.

In congruence with the first and second hypotheses, our intervention was indeed helpful in teaching students core concepts about the science of addiction, and the knowledge they learned persisted through post-testing assessment. Similarly, in line with our third hypothesis, students assigned to play *BaconBrains* demonstrated significantly more gains in knowledge than students who were assigned to the control condition. We were served well by our meticulous process of development. Involving substance abuse researchers and educators helped us to insure that the content delivered in our programs is not only scientifically accurate, but that it is also educationally sound.

Involving students in the development process also helped to ensure that *BaconBrains* was fun and engaging. Supporting our fourth hypothesis, students in the experimental conditions reported enjoying playing the games more than students in the control condition.

Perhaps the most interesting finding of our investigation, however, was the different response patterns to the program across gender. These differed from our original hypotheses that stated that boys would learn more when playing competitively and girls would learn more when playing collaboratively. In fact, when playing the games competitively, *both* boys and girls demonstrated significant learning as compared to the students in the control

condition. However, when playing the games collaboratively, it seems as if *only the girls* demonstrated significant learning. Further, at the interim timepoint, boys in the competitive condition outperformed all other group by gender cells.

4.1.1 Limitations and Future Directions

The present study has some limitations. Trying to conduct an experimental study within a school system during regular instructional hours is admittedly quite difficult. It is a tribute to our participating school that they allowed us to structure our intervention in such a way that allowed us access to all of their students. But by doing this, we had to make a couple significant sacrifices. First, we were not able to successfully collect data at our planned eight-week follow-up period. Although the school had agreed to allow this to happen, the reality was that the follow-up session did not work as well as anticipated within their existing schedule.

Another limitation of this study was the way in which the control vs. intervention groups were structured. Students in the collaborative and cooperative conditions both played *Bacon Brains* while students in the control condition played a series of existing substance-abuse related games, but did so individually. Even though all students worked on their own laptops, the fact that only students in the *Bacon Brains* conditions received instructions to either compete or collaborate meant that the design was not balanced; collaborative versus competitive instruction was not crossed with assignment to *Bacon Brains* versus control condition. So although we are able to definitely conclude that exposure to *Bacon Brains* led to gains in knowledge of our underlying curriculum, and that knowledge gains were greater for *Bacon Brains* overall compared to an existing game, future studies using a full factorial design crossing *Bacon Brains* with competition/cooperation would allow the effects of game type and orientation during play to be teased apart.

Perhaps the most significant limitation of our study, however, was the fact that our investigation did not integrate into ongoing science or health instruction. Instead, it was structured as an add-on to all students' existing elective schedules. While this did allow us access to the entire student body, it did not allow us to test the intervention as we intended it to be delivered.

Ideally, teachers of middle school health and science classes would integrate *Bacon Brains* into their existing curricula to help reinforce the concepts they are teaching. In this way, the program would not simply be a stand-alone activity, but rather an additional teaching tool to help students learn complex scientific concepts. Because teachers receive continuing pressure to teach a set curriculum that prepares students for standardized testing, schools are increasingly reluctant to take on new projects that fall outside the scope their curriculum. Therefore, we have worked diligently to ensure that our programs match state and national curriculum guidelines for health and science education.

To this end, we created a detailed teacher's manual. This 90+ page document contains a wealth of resources for teachers who would like to incorporate the games into their existing health or science curricula. The manual provides details for how the games map onto state and national curriculum guidelines including the National Science Education Standards as

well as the new Next Generation Science Standards. Additionally, the manual provides extensive examples of how the games can be used to strengthen cross-curricular ties. For example, there are suggestions for how the games can be used to support lessons in writing and mathematics.

Finally, in the manual we also include detailed instructions for how *Bacon Brains* can be used in the classroom to promote either collaborative or competitive learning. Because the results of our study indicated that there may be some significant gender differences in how boys and girls learn, further investigation may be warranted to replicate the findings and examine how to capitalize on these differences in order to strengthen individual learning.

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Figure 1.
Knowledge Score by Condition Over Time

Figure 2.
Knowledge Scores by Gender, Group, and Time

Figure 3.
Satisfaction with the Intervention by Grade and Condition

Table 1

Significance (p-values) of Difference Between Knowledge Scores by Time, Group and Condition

	pre / int	pre / post	int / post
boys collaborative	0.000	0.000	0.380
boys competitive	0.000	0.000	0.000
boys control	0.705	0.245	0.089
girls collaborative	0.000	0.000	0.011
girls competitive	0.000	0.000	0.026
girls control	0.001	0.042	0.213

Note: shaded cells represent significant difference

Table 2

Significance of Difference Between Conditions by Time

		differences between group at:		
reference	comparison	pre-test	interim-test	post-test
boys-collab	boys-comp	0.107	0.015	0.321
	boys-control	0.970	0.002	0.056
	girls-collab	0.435	0.059	0.308
	girls-comp	0.072	0.199	0.437
	girls-control	0.397	0.620	0.483
boys-comp	boys-collab	0.107	0.015	0.321
	boys-control	0.152	0.000	0.005
	girls-collab	0.460	0.697	0.925
	girls-comp	0.780	0.298	0.868
	girls-control	0.557	0.008	0.109
boys-control	boys-collab	0.970	0.002	0.056
	boys-comp	0.152	0.000	0.005
	girls-collab	0.493	0.000	0.006
	girls-comp	0.105	0.000	0.011
	girls-control	0.451	0.018	0.273
girls-collab	boys-collab	0.435	0.059	0.308
	boys-comp	0.460	0.697	0.925
	boys-control	0.493	0.000	0.006
	girls-comp	0.335	0.543	0.807
	girls-control	0.917	0.029	0.110
girls-comp	boys-collab	0.072	0.199	0.437
	boys-comp	0.780	0.298	0.868
	boys-control	0.105	0.000	0.011
	girls-collab	0.335	0.543	0.807
	girls-control	0.419	0.100	0.166
girls-control	boys-collab	0.397	0.620	0.483
	boys-comp	0.557	0.008	0.109
	boys-control	0.451	0.018	0.273
	girls-collab	0.917	0.029	0.110
	girls-comp	0.419	0.100	0.166