Impacts of *Virtual Clinical Trials* Simulations on Science Knowledge and Attitudes

Kristi G. Bowling
Rice University, USA

Leslie M. Miller
Rice University, USA

Ruchita Patel
Rockman et al, USA

Kristin M. Bass
Rockman et al, USA

Abstract

Virtual Clinical Trials simulations were designed to highlight neuroscience research and reinforce experimental design through the recreation of published clinical trials. This paper reports the effectiveness of *Virtual Clinical Trials* simulations in improving knowledge of concepts related to the experimental design process and attitudes toward clinical trials, science careers, and scientific possible selves among high school Anatomy and Physiology students. A three-arm experimental design (N=525) was implemented to test the "dose effect" of playing one verses two simulations. Results confirmed that all students increased their knowledge of experimental design concepts and improved their attitudes toward clinical trials, with students completing two simulations having the greatest shifts. All students also had a small, but significant improvement in scientific possible selves, though completion of two simulations did not confer any extra benefits. There were no detectable differences in clinical trial career interest. Additionally, the simulations were beneficial to students regardless of gender or ethnicity for knowledge gain and attitude change. With regard to measures of satisfaction and engagement, females expressed greater satisfaction with the simulations and minorities were more engaged. The results demonstrate that knowledge gain, attitude change, and the promotion of science identity are achievable through exposure to simulations, while shifts in career interest are not as consistently realized.

Key words: secondary, games, simulations, clinical trials, experimental design, neuroscience

Please address all correspondence to: Kristi G. Bowling, Kristi.green0@gmail.com

Introduction

The demand for science, technology, engineering, and math (STEM) professionals in the U.S. continues to increase (Noonan, 2017), highlighting the need for educational experiences constructed to inspire students to pursue STEM careers and persist in the STEM pipeline. Of equal importance is the need for educational materials that will create scientifically literate citizens capable of making informed everyday decisions regarding everything from personal healthcare to public policy. The topic of clinical trials is one that holds valuable insights for both future scientists and the larger citizenry as clinical trials portray science reasoning, ethical considerations, and the basis for medical advances.

Game-based learning offers a potentially powerful way to impart knowledge and impact attitude formation surrounding clinical trials. By allowing students to conduct in depth scientific investigations modeling real world scenarios, games and simulations are capable of providing learning experiences encompassing the multi-dimensional goals of the Next Generation Science Standards (National Research Council, 2012; NGSS Lead States, 2013). With limited time and resources, schools can utilize games and simulations to maximize students' immersion in science processes, enhance content knowledge, and role-play STEM careers often inaccessible in typical classroom environments. Reality-based digital games provide a means for students to connect curriculum content to eventual applications in real world jobs (National Research Council, 2011). The theory of situated learning undergirds the ability of role-play simulations to make significant changes in science content knowledge (Brown, Collins & Duguid, 1989; Lave & Wenger, 1991).

While goals of games and simulations often include mastering new knowledge and/or procedural skills, knowledge itself is not a sufficient condition to motivate students to persist in STEM careers (Maltese & Tai, 2011). Interest proved more important than enrollment or achievement in STEM courses for predicting whom will select a STEM major in college (Tai, Liu, Maltese, & Fan, 2006). Acquired skills and achievement are important, but interest and motivation are fundamental to the pursuit of a science career. Studies have shown negative shifts in attitudes toward science occurring around middle school and high school age (George, 2006; Gibson & Chase, 2002). This is of high importance due to the attrition of students pursuing STEM degrees in college (Chen, 2013). STEM employment is projected to grow faster than non-STEM employment (Langdon, 2011) so developing resources to mitigate this shift and help retain students in the STEM pipeline is crucial.

Another impact of digital games is their potential ability to motivate and inspire a greater, diverse number of people. Gaming, formally known as a male leisure activity, is no longer a male only activity, thus game based learning is an ideal tool appealing to both genders (Duggan, 2015). With the widespread use of the internet and increased presence of computers and digital devices in schools, games and simulations are also the perfect tool for reaching students of all ethnicities and demographic backgrounds (U.S Energy Information Administration, 2016). A recent survey shows that 84% of U.S households have a computer and 74% of U.S. households have a computer with broadband access, making games and simulations an ideal tool for reaching diverse numbers of people in both formal and informal environments (File & Ryan, 2014).

Motivated by this educational and technological landscape, we designed a free, online simulation called *Virtual Clinical Trials*. The simulation is structured to engage students in testing medical advancements by designing clinical trials. Students encounter experimental design in a real world context and gain exposure to careers associated with the clinical trial process. The acquisition of knowledge was fundamental to the educational goals of the game, but we further hypothesized that an ancillary outcome would be a shift in students' ability to see themselves in science careers or an enriched "possible self" (Foster, 2008). This paper reports on the results from our evaluation of *Virtual Clinical Trials.*

Literature Review

The benefit of games and simulations as effective educational tools is well established (Barab, Gresalfi, & Ingram-Goble, 2010; Gee, 2011; Schank, Fano, Bell, & Jona, 1994; Shaffer, 2006). Studies

conducted by us (Klisch, Miller, Beier, & Wang, 2012; Klisch, Miller, Wang, & Epstein, 2012; Miller, Chang, Wang, Beier, & Klisch, 2011) and others (for example, Barab, Sadler, Heislet, Hickey, & Zuiker, 2007; Meluso, Zheng, Spires, & Lester, 2012; Shegog et al, 2012) have determined games and simulations as effective tools for teaching specific science content. Our studies have also examined the ability of games to reinforce experimental design concepts and the scientific process (Bowling, Klisch, Wang, & Beier, 2013). Teachers are charged with the difficult task of enabling students to understand experimental design and how it relates to the research process. Engaging students in science fair projects and science experiments are methods typically used to help teach science concepts and reinforce experimental design; however, games and simulations can go one step further and allow students to see the experimental design process from a scientist's perspective. Clinical trials provides an excellent topic for achieving all of these goals.

There currently exist very few materials covering clinical trials as an educational topic for K-12 students. The materials that do exist are either not intended for classroom use (http://www.childrenandclinicalstudies.org/the-kids-files) or are not game based (Branch & Chester, 2009). In the world of health care, clinical trials provide the crucial bridge between scientific discovery and medical application. Successful completion of clinical trials requires not only trained professionals, but also an adequate number of volunteers to test the new medical advancements. Studies examining adults' attitudes toward participating in clinical trials consistently find that a large proportion of adults have positive general attitudes and interest toward participating in a clinical trial, but lack an understanding about the exact nature of these studies (Comis, Miller, Aldige, Krebs, & Stoval, 2003; Sood et al., 2009). In fact, 32% of American adults reported that they would be "very willing" to participate in a cancer clinical trial. When asked about their understanding of the clinical trials process, 60% of respondents indicated that they understood "somewhat" or "very well" about what a clinical trial is, while 40% reported that they did not understand the idea of a clinical trial at all (Comis et al., 2003). In a separate study, only 10% of 2,000 adults surveyed indicated that they had ever participated in a clinical trial (HarrisInteractive, 2005).

Without an understanding of the research process, enrollment will likely be declined based on uncertainty and fear (Pemberton, Kaltman, & Pearson, 2009). These data underscore the importance of providing educational materials to inform participants about the clinical trials process. Our previous research has already demonstrated the ability of our games to positively shift science attitudes (Bowling et al., 2013; Klisch, Miller, Beier, et al., 2012) and create more negative shifts in attitudes toward drug abuse (Klisch, Bowling, Miller, & Ramos, 2013; Klisch, Miller, Wang, et al., 2012). A simulation focused on clinical trials could provide a way to teach participants about the clinical trials process, while also providing the opportunity to create an informed positive opinion about clinical trials.

Theoretical Framework

Games and simulations have intellectual merit when they are well anchored in learning theory; therefore, the development of *Virtual Clinical Trials* is grounded in two theories: Situated learning and Possible Selves. The theory of situated learning (Brown et al., 1989; Lave & Wenger, 1991) offers support for the creation of well-designed digital games as a means for knowledge acquisition in specific domains or procedural skills. The theory posits that learning should be set within authentic contexts or realistic social situations. For example, a study of the *Quest Atlantis* game (Barab, Heiselt, Hickey, Zuiker, & Sadler, 2010) demonstrated that 4th graders' science content knowledge was positively impacted through

the context of a virtual world. Similarly, research on games such as *MedMyst*, and *CSI: THE EXPERIENCE*, which rely heavily on authentic career role-play, found consistent gains in science knowledge when examined by pre-post testing (Bowling et al., 2013; Miller et al., 2011) In another instance, the virtual world of WHYVILLE that allowed adolescents to create avatars and investigate an infectious disease outbreak, provided a vehicle for increased science learning (Kafia, Fields & Cook, 2010). While there is much yet to be discovered about the parameters of meaningful game-based learning, there is growing evidence of knowledge gain as a consistent outcome when learning is situated within a context.

The theory of possible selves (Markus & Nurius, 1986) offers insight into how the simulation of career experiences may make a difference in interest and motivation. Possible selves are similar to self-concept in that they are derived from initial interest and past experiences; however, they are different in that self-concept is related to a person's assessment of current abilities, whereas possible selves are our thoughts about what we hope to become (hoped-for selves), what we expect to become (expected self), and what we fear becoming (feared self). Research suggests that envisioning a positive possible self can inspire a person to contemplate and execute strategies to achieve the desired self (Ruvulo & Markus, 1992). In prior studies, adolescents who possess both academically-oriented possible selves and strategies for achieving their goals are found to be more likely to have higher grades (Oyserman & Fryberg, 2006). Experimental evidence indicates that shifts in possible selves can lead to shifts in academic behavior (Oyserman, Bybee, & Terry, 2006).

Lee and Hoadley (2007) linked gaming to possible selves by stating that ''one of the defining features of a game that successfully motivates learning is that it takes identity and possible selves into account; the player is able to explore aspects of one's identity (even if unconsciously so) and through these relevant experiences of who one could become, one is motivated to learn associated skills'' (p. 387). A 2012 study (Przybylski, Weinstein, Murayama, Lynch, & Ryan, 2012) addressed the ways in which games allow players to experience the ideal aspects of themselves and the short-term effects on emotion. A similar phenomenon may occur while students play simulations that can influence self-identification with science careers. Therefore, STEM career simulations have the dual potential to influence thinking about future desired careers while concurrently supporting the acquisition of knowledge and skills needed to achieve particular career goals.

Foster (2008) argued that games have the capability to make STEM careers "personally valued, concrete, and applicable to students' lives, as well as fostering changes in possible selves" (p. 597). In other words, players who experience successes in game-like career simulations may learn new knowledge/skills that shape thinking about their future "possible selves". A recent study by Foster & Shah (2016) describes how the added features of reflection and discussion led by a skilled teacher can enhance game play among students exposed to a digital mathematics game. The authors go on to develop a Game Network Analysis (GaNA) that includes a "focus on student learning by introducing projective reflection, the process by which a person who is engaging in digital gameplay constructs and/or enacts an identity in a game that has the potential to modify the person's possible future self and lead to a new sense of identity in a domain (p. 40). While this importance of teacher interventions cannot be underestimated, our large-scale study required a more controlled environment, thus we elected to focus upon the impact of the simulation on "scientific possible self" absent of teacher discussion or elaboration of the content.

The Intervention

The game, *Virtual Clinical Trials* (http://vct.rice.edu), consist of three very different disease/condition specific clinical trials—Spinal Cord Injury, Teens and Depression, and Traumatic Brain Injury (Figure 1).

Figure 1. *Virtual Clinical Trials: Advances in Neuroscience* splash page (http://vct.rice.edu)

For each of the three simulations, learning objectives were created with input from high school science teachers to ensure appropriateness for the grade level and alignment with the Next Generation Science Standards (NGSS Lead States, 2013) and the Common Core State Standards (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). To gain an understanding of what high school students know about clinical trials, online surveys were given to high school students, and teachers were recruited to participate in focus groups. Designing the storyboards for the simulations also involved several rounds of review by a variety of experts to ensure accuracy. Scientists specialized in working on the medical advancement being highlighted in the simulation reviewed the neuroscience content, a panel of clinical research coordinators reviewed all clinical trials content, and high school science teachers reviewed all content for appropriateness to grade level. Prior to programming, paper prototyping with high school students identified content and usability issues.

Engaging players in the process of setting up a clinical trial exposes them to scientific research and scientific practices in a context outside of what is usually presented in a traditional school laboratory. The role-play was designed to allow players to work with a variety of clinical trial experts, understanding the rationale for their research, designing a clinical trial, and receiving guidance and feedback throughout the simulations. Many of the techniques used are elements suggested by Ghefaili (2003) as a way to translate the "cognitive apprenticeship" model into a technology environment. Throughout the simulations, players engage in embedded activities where they must decide the appropriate hypotheses, the outcome measures, the optimum inclusion/exclusion criteria, and the conclusions to be drawn from the data analysis.

Checks for understanding are incorporated throughout to support active learning and a virtual notebook is included to provide accountability for the teacher.

Three published clinical research studies were used as models to develop the simulations (Dixon et al., 1999; Emslie et al., 2002; Popovic et al., 2006). A storyline with a problem to be solved was embedded to add structure to educational content and create a situated learning context. In *Trial 1: Spinal Cord Injury*, players are given the goal of helping clinical trial experts set up a Phase 2 trial testing an electrical device for treating patients with spinal cord injury. The simulation involves a biomedical engineer, a clinical trials coordinator and a clinical trials director. In *Trial 2: Teens and Depression*, the player designs a phase 3 clinical trial testing a new antidepressant for treating teenagers with major depressive disorder. Characters in this simulation are a psychiatrist, a clinical trials coordinator and a clinical trials director. The third simulation involves the preclinical laboratory testing of two new drugs for treating traumatic brain injury in rats. The two careers portrayed are a neurobiologist and a clinical trials director. Since the third simulation involves the preclinical laboratory testing in rats rather than humans, it was not included in this study. In each simulation, the player is placed in the role of designing the trial, with the guidance of other characters that are modeling their specific career (Figure 2).

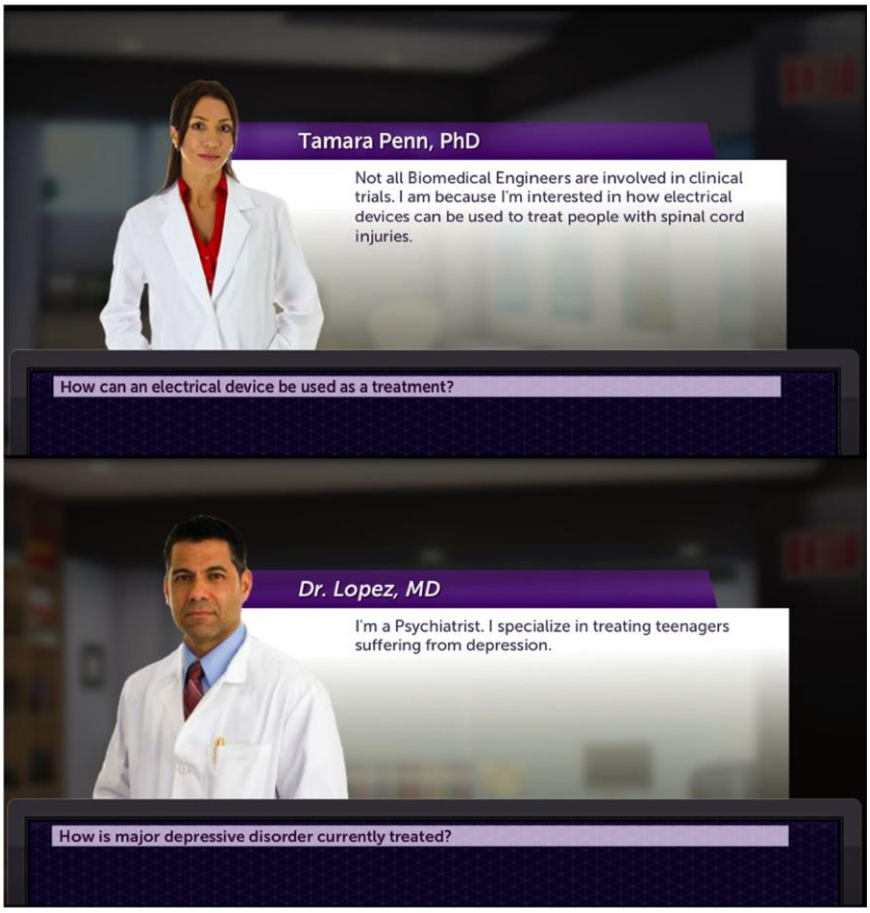

Figure 2. Screen capture from *Trial 1: Spinal Cord Injury* (top image) and *Trial 2: Teen and Depression* (bottom image) showing dialogue with the biomedical engineer and psychiatrist.

Methods

Focus groups conducted with high school teachers revealed that the content contained within *Virtual Clinical Trials* simulations aligned best with Anatomy and Physiology (A&P) classes. Preliminary evaluations of the *Virtual Clinical Trials* simulations focused on testing learning gains and clinical trials attitude change after exposure to one simulation. The randomized controlled trials demonstrated that students who played one simulation gained more knowledge about the experimental design process than control students who did not play the simulation; however, no changes in attitudes toward clinical trials were found (unpublished data). It is well established that exposing learners multiple times to content leads to higher gains in knowledge (National Research Council, 2000). One could argue that one exposure to an educational game is not enough to confer mastery, and that more extended play is necessary to witness substantial changes in knowledge and attitudes (National Research Council, 2011). This lead to the question whether a "dose effect" could influence the dependent variables of knowledge of the experimental design process, attitudes toward clinical trials, attitudes toward pursuing a career in clinical trials, and hope for pursuing science careers.

Hypotheses for this study were: Exposure of A&P students to two *Virtual Clinical Trials* simulations compared to students exposed to only one simulation will produce greater pre-post shifts in:

a) Knowledge of experimental design concepts within a clinical trial context;
b) Attitudes toward clinical trials;
c) Attitudes toward pursuing a career in clinical trials research; and
d) Hope for pursuing science careers.

Study Design

A three-arm study (N=525) was conducted to test the "dose effect" of playing two simulations vs. playing only one simulation (Table 1). Teachers selected the study arm they wanted to be in based on the amount of time they had to dedicate to the study and whether science content contained within the simulation had yet to be covered in class. Three teachers were in each study arm. Some teachers provided more classes than others leading to study arm three having a larger number of subjects than arms one and two.

Students who returned informed consent documents participated in three or four computer sessions depending on the study arm. During Session One (approximately 30 minutes), students were asked for their assent, an identification number assigned by the teacher so students' identities could not be matched to data, basic demographic information (e.g., grade, gender, ethnicity), and their responses to nine multiple choice knowledge questions, eight clinical trials-related attitudinal questions, eight career interest questions, and six scientific possible selves hoped for self questions. During Session Two, scheduled a minimum of three days after session one, students in study arm one and three played *Trial 1: Spinal Cord Injury* (approximately 45 minutes total) and students in study arm two played *Trial 2: Teens and Depression*. After an additional three day delay, students in study arm one and two completed a post-test in Session Three (approximately 30 minutes), which contained the same questions that were in the pre-test. In addition, students were asked to rate their satisfaction and engagement with the simulation. The minimum three-day time delay between game play and post-testing was purposely planned to test the persistent effects of the game beyond the immediacy of the intervention. Students in study arm three played *Trial 2: Teens and Depression* (45 minutes) during Session Three. In Session Four, scheduled at

least three days after Session Three, students in study arm three completed the same post-test as completed by study arm one and two (approximately 30 minutes total).

Table 1

Study arms, number of students participating, and activities in each session of the study

	Study arm one (122 students)	Study arm two (148 students)	Study arm three (255 students)
Session one	Pre-test	Pre-test	Pre-test
Session two	*Trial 1: Spinal Cord Injury*	*Trial 2: Teens and Depression*	*Trial 1: Spinal Cord Injury*
Session three	Post-test	Post-test	*Trial 2: Teens and Depression*
Session four	X	X	Post-test

Participants

Approval to conduct this study was given by the University's Institutional Review Board. We recruited high school A&P teachers through an online solicitation sent to teachers who had attended various *Virtual Clinical Trials* workshops. A stipend of $200 or $300 was offered to teachers depending on the amount of work involved in a particular study arm (collecting informed consent forms, scheduling computer lab time, etc.). Teachers were required to meet the following criteria in order to qualify for the field test: permission from school principal, at least two A&P classes with 11th and/or 12th graders of academic equivalence, guarantee of at least 20 students in each class, access to a computer lab or classroom laptops for up to four class periods, and collection of informed consent document signed by both parents and students. In accordance with the State of (deleted to maintain blind review process) age of consent, students who were 18 years old were not required to obtain a parent's signature.

The final sample included students from nine volunteer teachers' classrooms. To validate the representation of socio-economic status diversity, students in the sample were assigned to one of three economic groups as operationalized by free/reduced lunch percentages of the total school population, ranging from low disadvantage (less than 29% of students receive free-reduced lunch), to middle disadvantage (between 29-59% of students receive free-reduced lunch), and high disadvantage (more than 59% of students receive free-reduced lunch). All study demographics are listed in Table 2.

Table 2
Sample demographics (N=525)

Category	Percentages
n	525
Grade	1 9th (0.5%) 8 10th (1.5%) 164 11th (31%) 352 12th (67%)
Gender	161 Male (31%) 364 Female (69%)
Ethnicity	237 Caucasian (45%) 127 Hispanic/Latino (24%) 70 African America (13%) 68 Asian/Pacific Islander (13%) 3 Native American (0.6%) 20 Other (4%)
Socio-economic status	223 low disadvantaged (42.5%) 42 middle disadvantaged (8%) 260 high disadvantaged (49.5%)

Measures

Measures for this study included a knowledge scale and five attitudinal scales. See Supplementary Materials for the full measures and Table 3 for example items and reliabilities (Cronbach's α).

Knowledge. Content knowledge items were developed with and reviewed by a high school science teacher and clinical trials experts to ensure scientific accuracy and appropriateness for grade level. For the scale, 12 pilot questions assessing experimental design concepts within a clinical trial context were developed. All items were multiple-choice with three response options and consisted of recall and application questions. To refine the content knowledge pilot scale, the items were tested with 164 students in six A&P classes. Item difficulty and discrimination analysis of the pilot data (Kehoe, 1995) narrowed down the scale to nine items. The nine items were used in the evaluation to measure gains in knowledge relating to experimental design concepts presented within a clinical trials context. The internal consistency reliability was .598 for the content knowledge pre-test and .685 for the post-test.

Attitudes. For attitudes, five scales were used: attitudes toward clinical trials, interest in pursuing a career in clinical trials, possible selves hoped for self, satisfaction with the simulation, and engagement in the simulation. For each scale, participants read statements and rated their level of agreement on a five-point Likert-scale from 1 = "strongly disagree" to 5 = "strongly agree".

To develop a scale for assessing attitudes toward clinical trials, several rounds of pilot testing were conducted. Sixteen pilot items were originally developed based on an existing scale for assessing community attitudes toward participating in biomedical research (Frew et al., 2010) and our assumptions students may have about clinical trials. Factor analysis and item-by-item analysis of pilot data narrowed

down the scale to eight items with high internal consistency estimates. The internal consistency reliability was .745 for the pre-test and .826 for the post-test.

To measure student interest in clinical research careers, ten pilot items were adapted from an existing used and validated scale (Miller et al., 2011). Factor analysis and item-by-item analysis of pilot data identified eight items suitable for inclusion in the evaluation. The eight items were then used to measure shifts in interest in clinical research careers. The internal consistency reliability was .843 for the pre-test and .888 for the post-test. To assess students' "scientific possible self", six previously used and validated hoped for scientific possible self-items were included (Beier, Miller, & Wang, 2012). The internal consistency reliability was .972 for the pre-test and .978 for the post-test.

Post-test only measures included a satisfaction and engagement scale. The satisfaction scale consisted of four previously used and validated items (Bowling et al., 2013; Klisch, Miller, Beier, et al., 2012; Klisch, Miller, Wang, et al., 2012; Miller et al., 2011). For the engagement scale, four items were adapted from a previously used and validated scale (Fredericks, Blumenfeld, Friedel, & Paris, 2005; Klisch et al., 2013). The internal consistency reliability was .850 for the satisfaction scale and .784 for the engagement scale (both post-test only).

Table 3

Number of items, examples, and reliabilities (Cronbach's α) of measures

Scale	Number of items	Example item	Cronbach's α	
			Pre-test	Post-test
Experimental design knowledge	9	"*Which statement below is true about clinical trials and experimental treatments?*" (correct answer = Not all clinical trial participants receive the experimental treatment)	.598	.685
Attitudes toward clinical trials	8	"*People who participate in clinical trials contribute to the discovery of improved medical treatments*"	.745	.826
Clinical trial career interest	8	"*I have a good feeling about a career related to clinical trials research*"	.843	.888
Hoped-for possible selves	6	"*I have always hoped to have a job in science one day*"	.972	.978
Satisfaction	4	"*The simulation was an interesting way to learn about the clinical trials process*"	NA	.850
Engagement	4	"*The simulation grabbed my attention*"	NA	.784

Results

To determine the effect of simulation dose on the dependent variables of knowledge gain for concepts related to clinical trials, attitudes toward clinical trials, clinical trials career interest, and hoped for scientific possible selves, study arms one and two were first compared to determine if students exposed to a single simulation differed in their performance on the variables being tested. A one way repeated measures ANOVA with a between subjects factor (study arm) found no significant differences in gains between the two groups (knowledge: (F(1,268) = 0.024, p = .878); clinical trials attitudes: (F(1, 268) = 2.28, p = .132); clinical trials career interest: (F(1, 268) = 1.28, p = .260); hoped for scientific possible selves: (F(1, 268) = 0.66, p = .416)). This allowed data from study arm one and two to be consolidated and compared with study arm three for all variables. For these subsequent analyses, a one way repeated measures analysis of variance with a between subject factor was also conducted, this time comparing the number of simulations students completed.

Because this study employed a quasi-experimental design, pre-intervention scores across study arms were compared to assess baseline equivalence. One-way ANOVAs confirmed that students in the three arms began the study with similar knowledge and attitudes: knowledge: (F(2, 522) = 1.29, p = .276); clinical trials attitudes: (F(2, 522) = 1.45, p = .237); clinical trials career interest: (F(2, 522) = 0.40, p = .273); hoped for scientific possible selves: (F(2, 522) = 1.45, p = .235).

Knowledge

Means and standard deviations for knowledge items are listed in Table 4 for consolidated study arms one and two and study arm three. Students answered the same number of questions at baseline, but students exposed to two simulations answered one additional question on the post compared to the average two-thirds of a point gain among the one-simulation group. To establish the effect of simulation dose on knowledge gain, a repeated-measures analysis of variance was conducted. There was a main effect of time on performance (F(1,523) = 151.31, p < .001, effect size (partial eta squared) = .224), indicating that students in both conditions improved on the outcome measure. Furthermore, the interaction of time and dosage was also significant. Students who were exposed to two simulations performed significantly better on items about experimental design concepts within a clinical trial (F(1,523) = 13.22, p < .001, effect size (partial eta squared) = .025). The effect size is considered small according to standard interpretations (Middlemis Maher, Markey, & Ebert-May, 2013). This confirms the hypothesis that exposure to two simulations will produce greater pre-post shifts in knowledge of experimental design concepts within a clinical trial context than exposure to one simulation.

Table 4

Means and standard deviations for experimental design knowledge (max score = 8) by amount of simulation exposure

Condition	*n*	Pre Test		Post Test	
		M	SD	M	SD
One simulation (Study arm one and two)	270	5.63	2.03	6.28	2.10
Two simulations (Study arm three)	255	5.63	2.06	6.82	1.98

Attitudes Toward Clinical Trials

A repeated measures ANOVA was performed to measure the effect of simulation dose on clinical trials attitudes. The analysis revealed a main effect of time on attitudes ($F(1,523) = 52.58$, $p < .001$, effect size (partial eta squared) = .091). A small, significant interaction of time and dosage condition ($F(1, 523) = 10.28$, p = .001, effect size (partial eta squared) = .019) indicated that exposure to two clinical trial simulations produced additional gains in positive attitudes to clinical trials than exposure to one simulation. It should be noted that there was a slightly positive attitude toward clinical trials prior to exposure (Table 5). This confirms the hypothesis that exposure to two simulations will produce greater pre-post shifts in attitudes toward clinical trials than exposure to one simulation.

Table 5

Means and standard deviations for clinical trials attitudes by amount of simulation exposure

Condition	*n*	Pre Survey		Post Survey	
		M	SD	M	SD
One simulation (Study arm one and two)	270	3.72	.43	3.79	.52
Two simulations (Study arm three)	255	3.66	.42	3.85	.54

Note: Minimum score = 1, Strongly Disagree; maximum score = 5, Strongly Agree

Clinical Trials Career Interest and Hoped for Scientific Possible Selves

After consolidating study arm one and two for comparison with study arm three, a repeated measures ANOVA detected no interactions of time and dosages with regard to shifts in clinical trials career interest or hoped for scientific possible selves across any of the groups (career interest: $F(1, 523) = 0.06$, $p = .805$; possible selves: $F(1, 523) = 0.16$, $p = .899$). This data does not support the hypothesis that exposure to two simulations will produce greater pre-post shifts in clinical trials career interest and hoped for scientific possible selves than exposure to one simulation. The analyses did, however, detect a small but significant main effect of time for the possible selves variable across the two simulation conditions ($F(1, 523) = 13.01$, $p < .000$, effect size (partial eta squared) = .024). In other words, students exposed to any simulation slightly increased their perceptions of possible selves, but exposure to two simulations did not confer any additional benefits.

Regression Analysis

Multiple regression analyses was conducted to identify predictors of post-simulation knowledge and attitudes. The model included a game satisfaction variable investigated in our prior research studies (Klisch, Miller, Beier, et al., 2012; Klisch, Miller, Wang, et al., 2012). A simulation engagement variable was also added that had been included on pilot tests.

Regression analyses for predicting knowledge change (Table 6) were conducted. After controlling for pretest scores, exposure to two simulations significantly predicted performance on the post-test for knowledge questions. There was also significant associations between students' satisfaction and engagement with the simulations and their performance on the post-test.

Consistent with the repeated-measures ANOVA analysis, the regression analyses indicated that exposure to two simulations significantly predicted changes in clinical trials attitudes but not shifts in clinical trials career interest or hoped for scientific possible selves. After controlling for pretest knowledge and prior attitudes, data revealed small, statistically significant associations between knowledge and clinical trials attitudes. In other words, the more students learned about concepts related to clinical trials, the more favorable their attitudes. This may mean that learning about clinical trials improves students' attitudes slightly, or that knowledge and attitudes develop concurrently. Significant associations were also found between students' satisfaction for and engagement with the simulations, and their attitudes toward clinical trials and clinical trials career interest. In fact, the two variables proved to be second and third-strongest predictors of clinical trials attitudes and clinical trials career interest. Only engagement, not satisfaction, predicted possible selves attitudes.

Table 6

Regression analysis summary for predictors of post-test knowledge and attitude outcomes (N = 525)

	Beta Values, by Outcome Variable			
Predictor Variable	Experimental Design Knowledge	Clinical Trials Attitudes	Clinical Trials Career Interest	Hoped for Scientific Possible Selves
Dosage (i.e., exposure to two simulations)	.142**	.085**	.018	-.001
Pre experimental design knowledge	.628**	.025	-.001	-.001
Post experimental design knowledge	--	.150**	-.018	.013
Pre clinical trials attitudes	--	.489**	--	--
Pre career interest	--	--	.628**	--
Pre possible selves	--	--	--	.858**
Satisfaction	.093*	.284**	.144**	.006
Engagement	.099*	.092*	.127**	.085**
Adjusted R^2	.456	.531	.535	.773

*$p < .05$, **$p < .01$.

Gender and ethnicity were explored to determine if there was a moderating effect of demographic characteristics on pre-post knowledge, attitude change, and reactions to the simulations (Table 7). Collectively, male and female, and minority and non-minority students, all benefitted from the simulations, but there were some small differences between demographic groups. Female students enjoyed the simulation a little more than their male counterparts (Male: $M = 3.50$, $SD = 0.67$; Female: $M = 3.75$, $SD = 0.74$, partial eta squared = .027) and Minority students reported slightly higher levels of engagement with the simulation than White students (Non-minority: $M = 3.43$, $SD = 0.66$; Minority: $M = 3.56$, $SD = 0.63$, partial eta squared = .027).

Table 7
Repeated-measures analysis of variance results by gender or minority status on knowledge and attitude outcomes (N = 525)

	F (1, 523)	*p*
Experimental Design Knowledge		
Time x minority	2.67	.103
Time x gender	0.07	.790
Positive Attitudes		
Time x minority	0.41	.521
Time x gender	0.64	.426
Career Interest		
Time x minority	2.92	.088
Time x gender	1.16	.281
Possible Selves		
Time x minority	1.43	.233
Time x gender	0.03	.856
Satisfaction		
Time x minority	1.03	.310
Time x gender	14.24	.000
Engagement		
Time x minority	5.42	.020
Time x gender	2.00	.158

Discussion

The results of this study indicate that high school Anatomy and Physiology students who were exposed to two simulations performed significantly better on knowledge items about experimental design concepts within a clinical trial than students exposed to only one simulation. Performance on post-test was also influenced by students' satisfaction and engagement with the simulations. The two different, but complementary, simulations perhaps gave players a more in-depth view of the clinical trials process, thus accounting for the "better knowledge" outcomes with two exposures. Overall, *Virtual Clinical Trials* simulations have evidenced success in teaching experimental design concepts. This online tool could prove valuable to other science classrooms and individuals seeking to comprehend elements of clinical trials.

Another outcome, focused on attitude change, indicated that exposure to two clinical trial simulations produced more positive attitudes toward clinical trials than exposure to one simulation. Regression analysis further established a significant association between knowledge gain and attitude change, suggesting that the more students learned through the clinical trials simulations, the more positive their attitudes were regarding clinical trials. Similar to post-test knowledge performance, post-test attitudes were also influenced by satisfaction and engagement with the simulation. It is important to note that students already had high pre-test attitudes toward clinical trials. This could be due to the fact that this study was conducted with Anatomy and Physiology students, which is an elective subject in most high schools. Students taking this class may already have a high pre-disposition toward science, which could lead to a ceiling effect. There are currently no other studies examining the influence of game-based learning on changing attitudes toward clinical trials so more research is needed in this area to determine the viability of this approach beyond high school Anatomy and Physiology students. Of further interest would be the degree to which the general public and younger, more novice science students could benefit from the simulations in both the knowledge and attitude domains.

Although the number of STEM related jobs in the U.S are projected to continue growing (Langdon, 2011), there is an observed gradual loss of students pursuing STEM degrees in college (Chen, 2013). This highlights the need for research examining the ability of games and simulations to influence STEM career interest. This study showed no change in attitudes in regards to clinical trials career interest after exposure to two simulations. There was a small, but significant shift in scientific possible selves when students were exposed to any simulations, though completion of two simulations did not provide added benefits as hypothesized. While the desired shift in clinical trials career interest that were anticipated based on the results from the forensics simulations were not achieved, the possible selves results are promising because it confirms the potential for the clinical trials simulations to influence future desired science careers. The exact reason for these results are hard to explain, but one might consider the higher visibility of forensic careers in the media and the engagement potential of "solving a crime" versus the more cerebral endeavor of testing hypotheses to advance medical treatments. It is also possible that students entered the CSI simulations with some prior knowledge about forensic careers. Students may need additional exposure and opportunities for reflection to change their perceptions of clinical trials careers. They were probably much less familiar with clinical trials research careers and needed to acquire some basic knowledge about them before determining their ongoing, persistent interest. More research is needed in order to determine if providing additional resources on clinical trials careers in combination with the simulations would produce a positive shift in clinical trial career interest.

It is important to note that this study was conducted without teacher intervention. The teacher playing a greater role in helping students make sense of clinical trials and associated careers presented may have a greater impact on knowledge, attitudes, and produce a higher shift in possible selves. Incorporating games into a curriculum requires more than just playing a game in isolation. As explained by Foster & Shah (2016), providing a chance for teacher led reflection and discussion during and after the game play process could provide a greater change in possible selves and knowledge It would be beneficial to evaluate the efficacy of *Virtual Clinical Trials* simulations in affecting knowledge gain and attitude change with a combined teacher intervention such as reflection and discussion. This more teacher-centric intervention would require case study approach, not within the scope of this first phase of research.

Demographic factors are worthy of consideration when evaluating educational games since research suggests differences among individual learners influences how they learn from games and simulations (National Research Council, 2011). The analysis indicated that students regardless of gender

or ethnicity equally benefitted from the simulations; however, female students were more satisfied with the simulations and minority students were more engaged. Additional studies conducted by us (Bowling et al., 2013; Klisch et al., 2013; Klisch, Miller, Beier, et al., 2012; Klisch, Miller, Wang, et al., 2012) and others (Epstein, Collins, Thomas, Pancella, & Pauley, 2007; Joiner et al, 2010) have similarly found games and simulations to be beneficial to students regardless of gender. This is important given the existing gaps in science achievement for minority students (National Science Board, 2012) and the fact that male students are more likely to be interested in STEM majors and careers than females (STEM Connectors and My College Option, 2013). The existing research results combined with the fact that most schools have computers with broadband access (U.S Energy Information Administration, 2016), highlights the potential of games and simulations as excellent resources in helping overcome the obstacles observed with minorities and females in the STEM field and underscores the importance of creating resources that are appealing to both genders and minorities.

At this time, this study serves to reassure teachers that content learning goals, attitude change, and the development of science identity are consistently achievable through simulations, but shifts in STEM career interest are not as dependably realized. The potential to move the dial on science knowledge and attitudes involving possible selves suggests that *Virtual Clinical Trials* could be a potent tool in classrooms, especially when combined with teacher-led reflections and discussion, but further research is needed to test its efficacy among broader audiences.

Acknowledgements
Support for this research and the creation of the simulations were funded by the National Institutes of Health (Blueprint for Neuroscience Research Science Education Award) and administered by the National Institute on Drug Abuse through Grant Number R25 DA033009. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Institute of Drug Abuse or the National Institutes of Health.

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