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Learning and motivational impacts of a multimedia science game

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ABSTRACT

The power of a web-based forensic science game to teach content and motivate STEM careers was tested among secondary students. More than 700 secondary school students were exposed to one of the three web-based forensic cases for approximately 60 min. Gain scores from pre-test to a delayed post-test indicated significant gains in content knowledge. In addition, the game's usability ratings were a strong predictor of learning. A positive relationship between role-play experience and science career motivation was observed, which suggests a role for authentic virtual experiences in inspiring students to consider STEM careers.

1. Introduction

The types of learning possible through serious games (games primarily focused on education rather than entertainment) cover a broad spectrum. Scholars have made theoretical claims about conceptual, procedural, and declarative knowledge that result from playing serious games (e.g., Gee, 2005; Prensky, 2001; Squire, 2002). A complementary notion that games can also serve as professional apprenticeships has been advanced (Foster, 2008; Hatfield & Shaffer, 2008; Shaffer, 2006; Squire, 2006). A well-designed game experience can engage students in *professional play*, affording them the opportunity to develop a *professional vision* of themselves (Gee, 2003; Hatfield & Shaffer, 2008; Squire, 2006). Given the urgent need for more students, particularly from minority populations, to enter the STEM pipeline, serious games may provide a vehicle for accomplishing both education about and motivation for pursuing STEM careers.

The Federation of American Scientists report (2006), *Harnessing the Power of Video Games for Learning*, examined the potential for games to impact science education. More recently, a report from the President's Council of Advisors on Science and Technology (2010) suggested the need for both "preparation and inspiration" to promote an increase in recruits into STEM careers. It is possible that games can provide both elements. The examination of empirical data about the ability of a web-based science game to accomplish the dual outcomes of preparation (knowledge acquisition) and inspiration (create more positive attitudes about science and science careers) is the focus of the work presented here.

2. Study purpose

The study examined secondary students' gains in knowledge about science and attitudes toward science and science careers as a consequence of playing an online forensic science game. Key elements that support learning through serious games center on usability, satisfaction, role-play and engagement (Bourgonjon, Valcke, Soetaert, & Schellens, 2010; Malone, 1980; Squire, DeVane, & Durga, 2008). Aspects of these constructs were also measured to determine their influence on knowledge gain and motivation to engage in a science career.

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3. Background to the study

3.1. CSI: The Experience game development

The opportunity to create an online science game associated with a high profile television series occurred through a partnership with the Fort Worth Museum of Science and History. With National Science Foundation funding, the museum developed a traveling exhibit, CSI: The Experience, which has toured the United States and abroad since opening at the Chicago Museum of Science and Industry in 2007. Our challenge was to build a companion digital environment, CSI: The Experience –Web Adventures, that could be used by online visitors to achieve educational outcomes similar to those anticipated from the exhibit experience. Both instantiations strived to be consistent in their look and feel and to reflect their relationship to the television series. Fig. 1 presents the splash page for CSI: The Experience –Web Adventures.

Fig. 1. CSI: The Experience –Web Adventures splash page (http://forensics.rice.edu).

The goals of both the exhibit and the web adventures primarily focused on (a) teaching aspects of science that form the basis of forensics and (b) motivating adolescents to consider STEM careers. The hands-on approach of the museum exhibit was replaced with virtual crime scenes and virtual lab experiences. Members of the American Academy of Forensic Sciences served as consultants, ensuring the integrity of the science and providing procedural authenticity for the forensic cases. The prominence of the CSI television series and the support of CBS in using their trademarked assets helped to draw a large audience from the general public to the web adventures site with over half a million visitors a year. Many of these visitors have provided anecdotal evidence about the web adventures' impact consistently noting enjoyment, engagement and authenticity as the highlights of game play; however, in this study, we attempted to determine how these characteristics impacted outcomes with regard to knowledge acquisition and science attitude shifts among a secondary school population using a pre-post quasi-experimental design. Although the web adventures were originally designed as an informal learning (out of school) experience, schools have moved to the forefront of users composing approximately 62% of the site's visitors. These statistics, indicating the willingness of schools to adopt serious games as part of their curriculum, motivated our structured inquiry into the CSI: The Experience –Web Adventures' efficacy in secondary classrooms.

3.2. Games as effective learning tools

Our prior work on testing the efficacy of online science games demonstrated that after as little as 30 min of exposure, the knowledge gains from pre- to a delayed post-testing were significant (Miller, Moreno, Estrera, & Lane, 2004; Miller, Moreno, Willcockson, Smith, & Mayes, 2006; Miller, Schweingruber, Oliver, Mayes, & Smith, 2002). The game environment also affords students of the net generation different learning strategies and preferences that are well suited for 21st century skills (Ito et al., 2008; Oblinger & Oblinger, 2005; Prensky, 2001). In some sense, serious games share similar traits of problem-based learning (PBL). Research surrounding PBL speaks to the design and engagement of learners in authentic problems (Walker & Shelton, 2008).

3.3. Games as STEM career motivators

CSI: The Experience –Web Adventures provide players the opportunity to take on the roles of particular professionals in order to solve a crime. The three existing games (Cases) that form the CSI Web Adventures were conceived of as "possibility spaces," to provide experiences similar to those afforded through the museum exhibit (Squire, 2006).

Since the first case was launched in May of 2007, many players and teachers have emailed comments as to their perceptions of the games. (Comments are posted on the website http://forensics.rice.edu under the Reviews tab.) Some examples relating to career inspiration are provided below:

- *I thought I might like to be a forensic scientist – and today I got to "be" one.*
- *I totally want to become a forensic scientist after this.*
- *I am thirteen years old and always wanted to be involved with forensics. This activity gave me the opportunity. Thank you.*
- *I am a freshmen college student in nursing prep, and thinking of getting my BA in forensic science after I become a RN. I have been looking online for games and tools to help me and this is the only one I have found very helpful!*
- *I realize this is what I want to do for my career!!! This is awesome!!!!*
- *I love this site. It's exactly what I was looking for. I am thinking about studying this as a major and this is great help.*
- *I introduced my summer school students to this site today. I think it actually sparked the interest in some of them to inquire about future careers in the forensic field. Keep up the good work!*

The nature of these comments prompted our interest in measuring the affective impacts resulting from STEM role-play, in addition to assessing science content outcomes. Hatfield and Shaffer (2008) describe "professional play" that is often part of epistemic games, and Brown, Collins, and Duguid (1989) refer to role-playing experiences as "virtual apprenticeships." The CSI games have been designed in a way that students learn to work (and thus to think) as different forensic specialists. The three CSI Cases not only introduce the actual work of crime scene investigation, but also engage players in forensic lab work including toxicology and DNA analysis, medical examination, analysis of firearms and tool marks, and facial reconstruction. Could this role-play exposure be an important method for influencing students' perception of themselves as scientists or changing their attitudes toward science and science careers? As Foster (2008) hypothesized regarding game play, by experiencing authentic events in such a concrete way, students may develop intrinsic interest in science. The role-playing games expose students to professional roles that they typically do not encounter in school. With the exposure to those roles, students commit to them, inhabit them and may create projective identities that are a melding between themselves and the roles (Squire & Jan, 2007). Earlier work by Turkle (1995) has suggested that "life on the screen" allows us to inhabit identities far different from our normal selves. Schools, by adopting well-designed serious games, are poised to expose students to future or *possible selves* (Foster, 2008; Markus & Nurius, 1986). The game environment allows players to take risks without serious consequences and engage in careers that may or may not be deemed "cool" by their peers. Adolescents, in particular, can be presented with science personas that allow them to identify their interests and strengths.

4. Research methods

4.1. Study design and sample

Participants, consisting of secondary school students, were recruited through an online solicitation sent to science teachers asking for involvement of their intact classes in a three-session research study. As an incentive, $100 were offered to teachers. From among the teachers' applications, the final selection was made to ensure a distribution of students that reflected different geographic regions. Classes in 13 schools from 12 states participated, as reflected in Table 1.

Table 1
Field test population by grade, assigned case, and location.

Grade	State	Case assigned	Environment
Middle school ($N = 385$)			
6	NC	1	Rural
7	MO	1	Rural
6	AZ	2	Urban
7–8	TX	2	Suburban
6-8	CA	3	Urban
6–8	WI	3	Urban
High school ($N = 350$)			
9–10	KY	1	Suburban
10–12	MS	1	Urban
9–12	NY	2	Urban
9–12	TX	2	Rural
10–12	MI	3	Suburban
10–12	MI	3	Suburban
10–12	Virgin Islands	3	Rural

$N = 207$, Case 1; $N = 202$, Case 2; $N = 326$, Case 3.

Intact classes were randomly assigned to one of the three CSI Cases. The original sample consisted of 783 students. Forty-eight had missing data either on the pre-test or post-test and, therefore, were excluded from analysis. The final sample included 735 students (385 middle school students and 350 high school students). Among them, 207 played Case 1 (68% male), 202 played Case 2 (47% male), and 326 played Case 3 (40% male). All measures were administered with students working at individual computer workstations. Session 1 included the administration of the demographic and computer experience measures and the pre-test of content knowledge (approximately 25 min). Session 2 was scheduled three days after Session 1 and included playing the assigned case (approximately 60 min). Session 3 (approximately 30 min) included assessment of satisfaction, usability, role-play experience, science career motivation, and the post-test of knowledge. Session 3 was scheduled three days after the assigned case was played. Teachers were instructed to avoid pre-teaching the content of the website before the pre-test and to refrain from providing a recap of content included in the game before the post-test.

4.2. Intervention

In the process of developing three CSI Cases, we consulted individual members of the American Academy of Forensic Science who stressed the importance of communicating, more accurately than on television, the nature and scope of forensic disciplines. A more complete description of the development process and the content is described elsewhere (Miller, Chang, & Hoyt, 2010). To summarize briefly, in Case 1 players train as "rookies" learning how to process DNA, analyze ballistics and tool marks, conduct toxicology tests and perform an autopsy. Upon completion of each training segment the player earns tools (swabs, magnifying glass, tweezers, and pipette) that become part of their field kit. In Case 2, titled *Canine Caper*, a dog handler is found dead at the Las Vegas Dog Show; in Case 3, *Burning Star*, a burned car contains an unrecognizable body. Players are challenged to explore the crime scene and to determine the perpetrator of the crime and how the crime was committed.

The discovery process allows the player to gather clues by clicking on objects that are suspected as relevant to the crime, to use tools to analyze evidence, to interview suspects through dialogues, to move among different locations, and ultimately to present his/her conclusion with supporting evidence to the CSI chief. All of the activities require the player, using the virtual environment and mouse manipulations, to assume the role of a forensic specialist. The meaning making occurs as players discover the science behind different analyses (e.g., DNA vs. mtDNA or identification of whorl, loop and arch features in fingerprints), and perform the procedures for correct evidence analysis.

Positive and negative feedback were built into each interactive segment. The characters from the CSI television series are used as "intelligent agents" throughout the game and players can "ask" the characters for advice and suggestions by clicking on them, if needed. Quizzes are woven throughout the segments as checks for understanding to guard against the accretion of incorrect facts or assumptions. Fig. 2 provides a screen capture illustrative of a check for understanding and the feedback given by a CSI character.

4.3. Data sources and instrumentation

Participants provided information regarding their gender, grade in school, ethnicity, and experience with computer games. Two questions assessed computer gaming experience: *On average, how much time do you spend PER WEEK on playing games on the computer?* Participants reported the number of hours per week on a scale from 1 = less than 1 h, 2 = 1–4 h, 3 = 5–10 h, and 4 = 10 h or more. Game

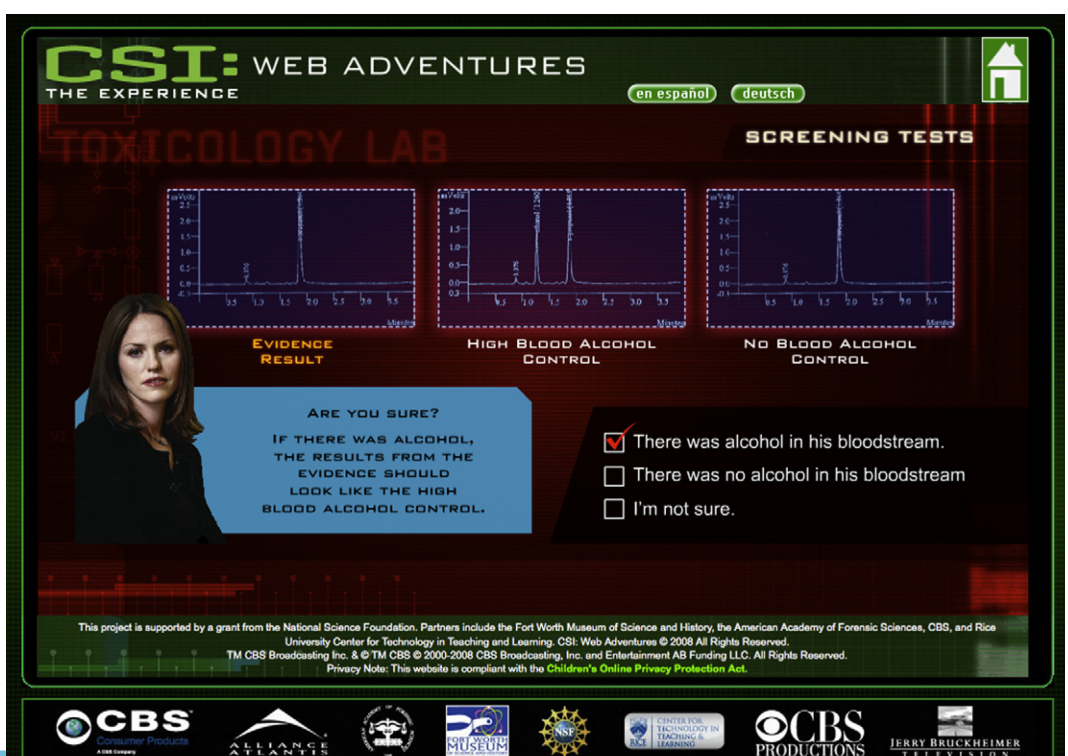

Fig. 2. Example of a check for understanding and feedback in the CSI: The Experience –Web Adventures.

experience was also assessed on a four-point scale where 1 = not at all, 2 = somewhat, 3 = experienced, and 4 = very experienced. These two items were combined to create a measure of game experience, with a reliability estimate of .58 (using the Spearman-Brown Prophecy formula on the correlation between these two items, $r = .41$).

We constructed science knowledge tests specific to each case based upon the concepts or procedures introduced in the case. All knowledge items were presented in a multiple-choice format with four response options. Identical tests were used for pre- and post-tests: Case 1 had 22 items, Case 2 had 21 items, and Case 3 had 20 items. One knowledge item example is *What equipment do investigators use to analyze striations on bullets?* (Answer: Comparison microscope). The Appendix contains the specific post-intervention items for Case 1. Knowledge items were similar in nature for Cases 2 and 3.

Additionally, we created post-attitude questions consisting of four scales measuring satisfaction, usability, the role-play experience, and motivation toward science careers. For each scale, participants read statements and rated their level of agreement on a 5-point Likert-scale from "strongly disagree" to "strongly agree." The satisfaction scale contained five items to assess how well participants liked the game. One satisfaction example item is *I would recommend this CSI web-adventure to my friends*. The usability scale consisted of three items. A usability example is *Using the game features (such as tools and dialogues) was easy*. We assessed the extent to which the role-play element of the game was realistic and engaging with a three-item scale. A role-play example item is *My role as a CSI agent seemed realistic in the game*. Participant motivation toward science careers was assessed with a five-item scale. A career-motivation example item is *The CSI game increased my interest in having a job in science*. Internal consistency reliability estimates (Cronbach's α; Cronbach, 1951) were .92 for satisfaction, .67 for usability, .75 for the role-play element, and .88 for the career motivation scale.

5. Results and discussion

The overall approach involved examining the differences between pre-tests and delayed post-test results on the content knowledge. For the variables of satisfaction, usability, career motivation, and role-play, for which there are post-test only measures, we examine the differences among the three cases. Finally, we conducted multiple regression analyses to determine which of the variables contributed to post-test performance on knowledge and career motivation.

5.1. Content knowledge gain

To assess learning from the game, we compared pre-test and post-test performance on the content knowledge tests using *t*-tests for dependent means. The means, standard deviations, results of the *t*-tests and effect sizes (*d*-scores) are shown in Table 2. We found a significant change in content knowledge across all three games. The magnitude of the effect was consistently large (e.g., *d*-scores around .80 or over; Cohen, 1988). With testing occurring three days after finishing a case, the gains ranged from 10.8% for Case 1 to 8.7% for Case 2 and 14.2% for Case 3.

5.2. Differences in attitude variables

For each of the four attitude dimensions, the scale ranged from 1 to 5 (with 5 being the most positive). Twenty-one items across four dimensions were culled from prior work or developed for this study. An exploratory factor analysis using principal axis factoring and a varimax rotation was conducted to ensure that each item clustered with the other items selected for that dimension. In addition, an item analysis for each of the four dimensions was conducted. Results of the factor and item analysis suggested that five items were problematic (e.g., did not load cleanly on any one factor) and were not used in the scales.

The remaining sixteen items comprise the following dimensions: satisfaction (five items), usability (three items), role-play (three items), and career motivation (five items). Items and factor loadings for the 16 items used in this study are shown in Table 3. The largest factor loading for each item was on its designated scale. There is also evidence of some cross loadings especially for items in the Role Play, Science and Career Motivation, and Game Satisfaction scales. Nevertheless, we felt that each of the scales was conceptually and empirically unique enough to warrant treating them separately in further analysis.

An ANOVA revealed significant differences among the three cases in the variables of usability and role-play (Table 4). Tukey post-hoc tests revealed significant differences in usability means for all three cases (p's $< .01$). For role-play, there were significant differences between Case 1 and the other two cases (p's $< .01$), but no significant difference between Case 2 and Case 3 ($p < .05$). This is also somewhat aligned with expectations in that Case 1 is an orientation in which players visit different forensic experts and train with them (hence the title, *Rookie Training*), whereas in Cases 2 and 3 players are in the role of a CSI agent responsible for solving a case.

Table 2
Descriptive statistics, *t*-tests, and effect sizes for comparing pre- and post-tests of content knowledge.

	Pretest			Posttest			*t*-test	df	d
	M	SD	α	M	SD	α			
Case 1	8.55	2.85	.71	10.93	3.70	.82	10.70**	206	1.05
Case 2	7.14	2.48	.67	8.97	3.44	.67	7.67**	201	.78
Case 3	9.44	2.92	.78	12.27	3.71	.78	17.03**	325	1.36

*$p < .05$, **$p < 01$. $N = 207$, Case 1; $N = 202$, Case 2; $N = 326$, Case 3.
Note: Effect sizes (*d*-scores) adjusted for pre- and post-test correlations (i.e., test of dependent means). Pre- and post-test correlations are .54 for Case 1, .39 for Case 2, and .61 for Case 3.

Table 3
Exploratory factor analysis of attitude items.

	Factor loadings			
	1	2	3	4
Science career motivation				
Playing this CSI web-adventure made me want to learn more about forensics.	**.692**	.368	.111	.155
Doing the virtual labs increased my motivation to learn science.	**.688**	.379	.163	.110
After playing the game, working as a forensic specialist seems more interesting.	**.662**	.264	.166	.306
The CSI game increased my interest in having a job in science.	**.667**	.198	.164	.162
I think I can be good at the kind of work done by the forensic specialists in the game.	**.639**	.227	.150	.165
Satisfaction with the game				
I liked playing this CSI web-adventure.	.357	**.738**	.266	.210
I would recommend this CSI web-adventure to my friends	.404	**.740**	.179	.212
This CSI web-adventure was boring. *(Reversed)*	.236	**.664**	.216	.290
Learning forensic science through this CSI web-adventure was fun.	.467	**.570**	.180	.262
If there were more CSI web-adventures, I would play them.	.428	**.702**	.160	.227
Game usability				
Using the game features (such as tools and dialogues) was easy.	.272	.131	**.570**	.158
I felt like I needed hints on how to play this web-adventure.	.001	.094	**.558**	.020
It was easy to find out what to do next while playing the game.	.190	.173	**.721**	.015
Role-play experience				
I did NOT feel like I was a part of the crime solving team in the game. (*Reversed*)	.207	.281	.082	**.692**
My role as a CSI agent seemed realistic in the game.	.393	.292	.064	**.605**
Role-playing games about other science careers would be interesting to me.	.292	.341	.109	**.533**

Note: Factor 1 = Science career motivation; Factor 2 = Satisfaction with the game; Factor 3 = Game usability; Factor 4 = Role-play experience. Highest factor loadings for each item are shown in bold-face type.

Table 4
Means, standard deviations, and differences in mean attitude values by case.

Variable	Case	*N*	M	SD	df (btwn, win)	*F*
Satisfaction	1	207	3.80	.89	2, 732	.10
	2	202	3.85	.96		
	3	326	3.83	.95		
Usability	1	207	3.76	.73	2, 732	39.22**
	2	202	3.36	.80		
	3	325	3.13	.84		
Career Motivation	1	207	3.54	.89	2, 732	1.74
	2	202	3.56	.84		
	3	326	3.44	.85		
Role-play	1	207	3.40	.92	2, 732	10.97**
	2	202	3.71	.89		
	3	326	3.74	.80		

*$p < .05$, **$p < .01$. $N = 207$, Case 1; $N = 202$, Case 2; $N = 326$, Case 3.

5.3. Correlations

Correlations among all study variables by case are shown in Table 5. The correlations could not be compared with one another directly given that students were randomly assigned to play only one of the three cases. However, we did observe some interesting patterns across the three cases as follows:

Pre- and post-test content knowledge scores were highly related to the affective variables in all three cases. In all three cases, experience with games was not significantly related to performance on the pre-test or post-test content knowledge measures, suggesting that it was not important for performance on the knowledge tests. However, experience with games was a significant predictor of attitudes for Cases 2 and 3, but not for Case 1, which may be a function of the more tutorial nature of Case 1. Less exploratory behavior on the part of the player is required in Case 1 so a non-gamer could easily adapt to the play schema.

5.4. Hierarchical regression analyses

Although zero-order correlations provide information about the relations among the constructs of interest, they do not take into account the multi-colinearity among predictors. To examine the independent contribution of the predictors of learning and of career motivation, we conducted a series of hierarchical regressions.

The first set of analyses examined the determinants of content learning for each of the three cases. Multiple-regression analyses are preferred over difference score methods for examining change over time (e.g., learning) due to problems with the reliability of difference scores (Cronbach & Furby, 1970). In the first regression analysis, post-test content knowledge performance was the criterion variable. Pre-test content knowledge performance and game experience were entered as the first step, essentially controlling for prior knowledge before playing the game and individual's game experience. In a second step, we entered the additional predictor variables (satisfaction, usability, and role-play). The pattern of results from this analysis is shown in Table 6, and is identical across all three cases: After controlling for gaming experience and pre-test performance, only usability was a significant predictor of post-test performance. This makes sense when

Table 5
Correlations between study variables by case.

	1	2	3	4	5	6	7
Case 1							
Pre-test	1.00						
Post-test	.54**	1.00					
Satisfaction	.08	.11	1.00				
Usability	.07	.23**	.33**	1.00			
Career motivation	.18*	.16*	.76**	.31**	1.00		
Role-play	.07	.09	.69**	.25**	.69**	1.00	
Game experience	.09	.09	.10	.11	.08	.11	1.00
Case 2							
Pre-test	1.00						
Post-test	.39**	1.00					
Satisfaction	.07	.32**	1.00				
Usability	.14*	.35**	.48**	1.00			
Career motivation	.17*	.32**	.69**	.43**	1.00		
Role-play	.14*	.34**	.68**	.40**	.68**	1.00	
Game experience	.02	.04	.24**	.15*	.10	.21**	1.00
Case 3							
Pre-test	1.00						
Post-test	.61**	1.00					
Satisfaction	.17**	.25**	1.00				
Usability	.12*	.26**	.49**	1.00			
Career motivation	.18**	.27**	.74**	.39**	1.00		
Role-play	.16**	.25**	.73**	.39**	.67**	1.00	
Game experience	.05	.07	.19**	.20**	.18**	.13*	1.00

*$p < .01$, **$p < .05$. $N = 207$, Case 1; $N = 202$, Case 2; $N = 326$, Case 3.

one considers that those who find the game to be easier to use would be more likely to learn from it (i.e., elements of the game did not impede their learning).

The second hierarchical multiple regression analysis examined the predictors of career motivation, which was the criterion in this analysis (Table 7). Game experience, and pre- and post-test performance on content knowledge were entered into the regression in the first step as control variables; self-reported satisfaction, usability and role-play experience were entered in the second step.

Table 6
Regression of post-test content knowledge performance on attitude variables controlling for gaming experience and pre-test content knowledge performance by case.

Predictor	Case 1		Case 2		Case 3	
	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	.29**		.15**		.38**	
Game experience		.04		.03		.04
Pre-test		.53**		.39**		.61**
Step 2	.04*		.13**		.04**	
Game experience		.02		−.06		−.01
Pre-test		.52**		.33**		.58**
Satisfaction		.01		.12		.04
Usability		.19**		.19*		.15**
Role-play		.00		.16		.08
Total R^2	.33**		.28**		.42**	

*$p < .05$, **$p < .01$. $N = 207$, Case 1; $N = 202$, Case 2; $N = 326$, Case 3.

Table 7
Predicting career motivation with affective variables, controlling for gaming experience and performance on pre- and post-test content knowledge measures.

Predictor	Case 1		Case 2		Case 3	
	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	.04*		.11**		.10**	
Game experience		.06		.08		.16**
Pre-test		.13*		.05		.03
Post-test		.08		.30**		.24**
Step 2	.63**		.47**		.49**	
Game experience		−.02		-.10*		.04
Pre-test		.11*		.08		.02
Post-test		−.01		.01		.05
Satisfaction		.57**		.41**		.50**
Usability		.07		.08		.01
Role-play		.31**		.38**		.28**
Total R^2	.67**		.58**		.58**	

*$p < .05$, **$p < .01$. $N = 207$, Case 1; $N = 202$, Case 2; $N = 326$, Case 3.

As shown in Table 7, satisfaction with the game, the role-play experience and usability as a whole accounted for a significant amount of variance in science career motivation but only satisfaction and the role-play experience showed significant predictive power. This pattern of results was observed in all three cases.

6. Conclusions

The goals of this evaluation were to examine the effectiveness of online forensic games as learning tools as well as science career motivators, and to understand the potential determinants of the games' impacts. The results reported reveal knowledge acquisition occurred from a 1-h exposure to one CSI Case after a three-day delay in testing. The observed learning was of large effect size and reliable. Typically, game exposure would be preceded or followed by classroom discussion, assignments, and hands-on activities. One would hypothesize that science content knowledge would be increased further if additional instructional components were provided. These findings suggest that the CSI games are efficacious in school environments. If used as either stand-alone assignments or part of a learning cycle that involved other types of instructional experiences, CSI Cases offer evidence of knowledge acquisition and motivational effects.

We further found that the usability rating was a strong predictor of learning in all three cases after controlling for computer gaming experience. In other words, students who reported that CSI game play did not present difficulties for them were likely to learn more from them. The results confirmed previous findings that a serious game's impacts are, at least partly, influenced by its usability (Markopoulos & Bekker, 2003; Mayes & Fowler, 1999).

It was also shown that post-intervention career motivation was related to satisfaction with the game and the ratings of role-play experience. The fact that satisfaction with the game was predictive of career motivation after playing the game may be driven and explained by a third factor – a general interest in science. A measure of general interest in science or forensic science in particular could be added to determine how this pre-disposition may relate to the outcomes. What is clearer is the positive relationship between role-play experience and science career motivation. This is promising because it highlights the effectiveness of virtual experiences, at least in the case of a forensic game, not only in promoting learning, but also in influencing choices for careers in science. Games afford students the apprenticeship or situated learning that may not be accessible to them in the real world. They can work (and think) authentically in a particular role. As such, they are likely to explore more about careers outside the game world and change their attitudes toward STEM careers. Attitude change may motivate students to engage in strategies that would facilitate achieving the desired career. For example, students could take actions such as seeking real apprenticeships or pursuing more courses related to the career goal.

Among groups of teens, STEM careers may not enjoy a positive social status. The nerd or serious student label could deter interest and likewise impact behavior. Games may offer an inroad to reaching entire classes of students and accentuating the "coolness" of STEM careers, in turn, overcoming preconceived career stereotypes. A study on a broader scale and over a longer sustained period of time and with other types of science careers could answer questions about the power of science games to modify STEM career attitudes and strategies to achieve STEM careers during the middle school years and across multiple environments. If science-related identities can be created and developed through authentic and engaging games, this may motivate students to take actions to further build their competence and pursue a particular discipline. Research to determine the generalizability of these findings to other careers and other games is a next step, but the preliminary results suggest that it is possible to both "prepare and inspire" students through serious game interventions.

Appendix. Supplementary materials

Supplementary data related to this article can be found online at doi:10.1016/j.compedu.2011.01.016.

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