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Science games and the development of scientific possible selves

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Abstract

Serious scientific games, especially those that include a virtual apprenticeship component, provide players with realistic experiences in science. This article discusses how science games can influence learning about science and the development of science-oriented possible selves through repeated practice in professional play and through social influences (e.g., peer groups). We first review the theory of possible selves (Markus and Nurius 1986) and discuss the potential of serious scientific games for influencing the development of scientific possible selves. As part of our review, we present a forensic game that inspired our work. Next we present a measure of scientific possible selves and assess its reliability and validity with a sample of middle-school students (N=374). We conclude by discussing the promise of science games and the development of scientific possible selves on both the individual and group levels as a means of inspiring STEM careers among adolescents.

Keywords

scientific possible selves; self-concept; science games; career development; science identity; transformative identity

Malika was assigned the game, CSI: THE EXPERIENCE, as part of her 8th grade biology unit studying DNA. Although the teacher's purpose was to present DNA analyses in a real-world context to his students, Malika and a few of her classmates were excited about the role-play aspect of the game, which provided a variety of authentic activities of forensic specialists. She was a regular viewer of television mystery shows such as *Bones*, *CSI* and *NCIS* and rated them among her favorites. Malika wrote to the game developers after playing the game stating, "This website helped me to realize what path I want to take in life. I would like to become a toxicologist. Can you tell me what schools might be best for me and what courses I should take? Thank you for helping me realize my full potential!" She also began talking to her friends about possible science careers to see if they had an interest in science. Her Facebook page reflects her new confidence in a science career in the science-related pages she has "liked." Through Facebook she has discovered that many of her friends and schoolmates have similar interests, which has helped her develop a social network of like-minded friends.

The example above illustrates the importance of exposing students to career opportunities associated with science, technology, engineering, and mathematics (STEM). Without exposure to science concepts and reinforcing experiences with concrete applications, students will be less prepared to take more mathematics and science courses in school and will lack motivation for, and interest in STEM careers. Additionally, the influence of peers who fail to view STEM careers as desirable or acceptable also play a role in determining

students' interest and motivation. Indeed, research suggests that persistence in STEM relies heavily on initiating interest and fostering engagement in science by middle school. For instance, a student's STEM career expectations by the 7th or 8th grade increase the probability of that student persisting in STEM dramatically (Tai, Lui, Maltese, and Fan 2006). A 2011 analysis on "pipeline persistence" by Adam Maltese and Robert Tai (2011) also indicates that a student's established interest and their career expectations in STEM in the 8th grade are important predictors of obtaining a college degree in STEM. Moreover, these researchers found that interest was more important than enrollment or achievement in STEM for predicting who will select a STEM major in college. Taken together, this research speaks to the importance of engaging students individually and in their peer groups with STEM content and STEM careers relatively early in their development. Skill and achievement are important, but interest and motivation also play a vital role in the selection of a science career.

But how can students, particularly those for whom there is neither mentor nor positive STEM-related experiences, acquire an interest in science? How can a prevailing peer-group attitude that doesn't consider science "cool" be shifted to see science careers as desirable goals? One answer might be through the creation of science games that provide what Allan Collins, John Brown, and Ann Holum (1991) describe as *cognitive apprenticeship* experiences such as those that teach the way professionals in a particular career think about and solve problems. Cognitive apprenticeships assume that social and environmental influences are central aspects of learning with students, mentors, coaches, and peer groups guiding the process. In game play, these social and environmental influences can be part of the game itself (Um and deHaan 2005). For instance, David Shaffer and his colleagues (Shaffer, Squire, Halverson, and Gee 2005) have used the term *epistemic games* to refer to role-playing games that simulate professional training. Epistemic games allow students to role-play careers as a form of training. In support of the potential for these types of games to influence how students think about real-world problems, Padraig Nash and David Shaffer (2011) recently examined the consequences of an urban planning game in which professionals mentored middle school players. They found that middle school players internalize and imitate the professional way of thinking modeled by mentors. Kurt Squire (2006) also described how simulation games influence identity by giving "... students the experience of being competent, independently thinking problem solvers, enabling them to develop identities in relation to a community of practice" (p. 26).

Even games designed primarily for entertainment (as opposed to education) such as *World of Warcraft*, *Grand Theft Auto*, *Star Wars Galaxies*, and *Guitar Hero* offer players opportunities to experience *projective identities* — hybrids of themselves and the avatar they assume in a game (Gee 2003). Video games that are experiential and provide a sense of agency (i.e., players feel they can operate on their environments to effect change) reflect ideas originally set forth by Jean Lave and Etienne Wenger's (1991) theory of situated learning. That is, learning takes place when people practice in authentic contexts that can generalize to real-life situations. A recent report by the MacArthur Foundation (Jenkins, Clinton, Purushotma, Robison, and Weigel 2006) further examined the video game phenomenon and its social implications. The authors, in describing the appeal of video games, wrote:

Children often feel locked out of the worlds described in their textbooks through the depersonalized and abstract prose used to describe them. Games construct compelling worlds players move through. Players feel part of those worlds and have some stake in the events unfolding (p. 24).

The idea that the role-play opportunities afforded in games influence students' feelings of agency, competence, interest in a domain, and their ideas about how that domain is relevant

to their future selves is related to Albert Bandura's (1982) notions that life's paths are shaped by "selective development of competencies, interests and affiliative preferences" (p. 135). That is, the opportunity to actively engage in a new role will provide students with mastery experiences that will contribute to their sense of agency and competence (i.e., self-efficacy), and will motivate them to learn more about the role by pursuing educational opportunities afforded by the environment. These opportunities might include developing a social network of similarly-interested peers or mentors and/or doing independent research through available resources. Increased self-efficacy, interest, and motivation will lead to the development of scientific *self-concept* (e.g., I am someone who is interested in science) and to the development of scientific *possible selves* (e.g., I hope to become a scientist one day; Foster 2008).

Possible selves are thoughts about what we hope to become, what we expect to become, and what we fear becoming that develop through personal experiences and environments (e.g., through cultural norms, friends, teachers, parents, and the media; Markus and Nurius 1986). Joey Lee and Christopher 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). These authors use the term *identity* to refer to a person's self-image, or mental model of the self. Possible selves can be considered to be future-oriented aspects of identity. That is, possible selves are focused on what the person will become.

Possible Selves and Self-Concept

Self-concept is defined as a person's self-perceptions of their abilities in a domain (e.g., "I am good at math;" Marsh 1990a) and is an important influence on motivational processes such as goal setting and self-regulation (i.e., maintaining focus on goal achievement; Carver and Scheier 1982). Self-concept is relevant across a wide range of domains (e.g., social, athletic, academic; Shavelson, Hubner, and Stanton 1976) and formed through experiences within a domain and interpretations of a person's environment (e.g., reinforcers in the environment and the actions and attitudes of significant others such as parents, teachers, and classmates; Guay, Marsh, and Boivin 2003). Self-concept is also related to interest in a domain, which leads to initial experiences that are reinforced by feedback provided in the environment (physical, cultural, social).

In the example above, Malika's initial interest in forensic science is expressed by her new-found confidence and behaviors. At a social level, she is talking with her peers in class and using social media to find friends and resources that support her interest. This behavior translates to the development of a positive self-concept in the domain of science. This science self-concept in turn, is predictive of Malika's ability to visualize herself in a science career and enact strategies in order to achieve it. As suggested in the example above, academic self-concept is a useful theoretical framework for understanding motivation, self-regulation, and school achievement (Marsh 1990a). Theories of self-concept, however, are not explicitly future-oriented: that is, they do not consider what people hope to become, what they expect to become, and what they fear they will become. In the example above, Malika's hope for a future career in science is a manifestation of one of her *possible selves* (Markus and Nurius 1986).

Similar to self-concept, possible selves are thought to derive in part from initial interest and past experiences in a domain and the environment in which a person operates. Unlike self-concept, however, which is related to the assessment of a person's current abilities in a

domain, possible selves are manifested in a person's thoughts about who he or she ideally hopes to become, who he or she realistically expects to become in the short-term, and who he or she fears becoming (Markus and Nurius 1986). Possible selves encompass a person's enduring goals, aspirations, motives, fears, and threats and are thought to direct future-oriented behavior. It is perhaps important to note that fear in this theory is related to concern about failure to achieve one's goals.

As is self-concept, possible selves are also related to a range of domains including social, athletic, and academic (e.g., students may hope to become Olympic athletes and may fear becoming delinquents). The pool of possible selves that are made salient for any person will be a function of the sociocultural context in which he or she operates, and includes both the opportunities provided by the person's immediate social environment as well as the images and models provided by the media (Markus and Nurius 1986). In the example above, Malika's hope to become a forensic scientist is influenced by her immediate success in the computer games she plays, the media she prefers to watch, and by her peers who are likewise interested in science. Additionally, these aspirations are reinforced by the images of scientists she sees on the television shows she watches and her interactions with real scientists if she happens to know any. In this way, possible selves derive through both individual experiences and social identity (e.g., comparisons with others). They are distinctly social in nature.

The importance of social components (operationalized as peer group) on the development of possible selves has been researched by Daphna Oyserman, Deborah Bybee and Kathy Terry (2006) with a sample of low-income minority teens. They found that interventions, which focused on making academic possible selves salient by highlighting academic achievement and skills and by influencing perceptions of the importance of academics to the peer group, strengthened individual academic possible selves. The increase in academic possible selves positively affected academic initiative, standardized test scores, and grades (i.e., academic possible selves mediated the effects of the intervention on these outcomes), and these effects were sustained over a 2-year period (i.e., over the length of the study).

Possible selves provide a link between self-concept and future-oriented goals and behavior and can include selves that represent a short-term reality (i.e., expected self), selves that should be approached (i.e., hoped for), and selves that should be avoided (i.e., feared). Daphne Oyserman and Hazel Markus (1990) posit that possible selves will have their maximum effect on motivating future-oriented behavior when there is a balance between the expected and feared selves. That is, fears about what one might become are motivating when they are offset by a relevant expected-self that can provide strategies for avoiding the feared state. Similarly, positive expected-selves will be motivating when they are offset by fear of what one might become if the expected or hoped for state is not realized. For instance, the activities associated with the expected self as a high-school graduate (e.g., doing homework and studying) are potentially derailed by daily distractions such as hanging out with friends. Motivation for these distracting activities may be diminished when the student fears what would happen if they do not achieve their expected end-state. Positive longer-term goals (e.g., the hoped-for self) will also enhance motivation for activities that can help achieve goals, but longer-term outcomes may be too distal to have a major impact on the strategies that influence daily goal-related behavior. As such, connecting possible selves to strategies that provide roadmaps for how goals will be achieved is an essential component of the motivation derived from possible selves.

Research conducted by Daphna Oyserman, Deborah Bybee, Kathy Terry, and Tamera Hart-Johnson (2004) describes the importance of linking possible selves to specific behavioral strategies as necessary for maintaining self-regulation while striving for a desired possible

self. For example, a person will presumably be more likely to maintain a fitness regimen with strategies that include walking daily and eating right when these strategies are linked to a hoped-for self who is healthy, and an expected self who can reasonably anticipate achieving some improvement in current health in the short term, and a feared self who is unhealthy. Strategies are one means of breaking down larger, long-term goals into more specific goals that can be accomplished.

Social cognitive theory discusses the value of having short-term or proximal goals, which are discrete performance accomplishments that are aligned with more distal goals, which are cumulative performance accomplishments (e.g., attaining a college degree, becoming a scientist). According to social cognitive theory, distal goals can be less advantageous than proximal goals for influencing daily behavior because they do not provide guidance to develop strategies for goal attainment. Moreover, when a person focuses only on distal goals rather than proximal goals and strategies, there is little opportunity for interim rewards throughout goal striving (Bandura and Schunk 1981). Similarly, focusing on a hoped-for self without consideration of realistic expectations or short-term strategies may not be effective.

The multiple influences on the development of possible selves (i.e., both the individual and social context) make this construct especially relevant for increasing interest in careers in STEM fields. That is, it may not be sufficient to focus on developing an individual's self-image; it may also be important to impact the individual's social network in order to make interest in STEM careers acceptable among peers. This duality of personal and social dimensions of possible selves fits particularly well with the notion of serious scientific games offered within the social context of a science classroom. Could the elaborative rehearsal involved when playing high-quality STEM-related games across a school/class (social network) result in individual possible selves and group possible selves becoming more aligned with images of STEM careers and motivation to study science? This is a broad question and an initial step requires the construction and testing of valid ways to capture such change. Below we present a science game and player comments that provided inspiration for the development of a measure of possible selves.

Case Study of Forensic Games

At the Rice University Center for Technology in Teaching and Learning (CTTL) we have developed several science education games to provide students with authentic game experiences that would not only teach science content, but result in career motivation. One example is the freely available forensics game, *CSI: THE EXPERIENCE* (<http://forensics.rice.edu>), which incorporates the same principles of situated learning discussed above and helps to develop a student's sense of agency in science through authentic role-play. Funding by the National Science Foundation, participation of CBS (owners of the CSI television franchise), and the advice of practicing members of the American Academy of Forensic Sciences proved invaluable in designing a high-profile game highlighting modern day forensics. The web adventure splash page makes clear the association of the TV show, while at the same time stating that players will be called upon to "learn forensic science and apply your knowledge." The home page for *CSI: THE EXPERIENCE* is shown in Figure 1.

CSI: THE EXPERIENCE consists of three related games with scaffolded forensic science content, beginning with Rookie Training and proceeding to two cases, one at the intermediate level and the other at the expert level. The cases provide virtual experiences with increasing complexity by incorporating forensic specialties such as toxicology, firearms and tool mark analysis, medical examination, DNA analysis, forensic odontology, and digital forensics. The game heuristics involve players acquiring tools, interviewing suspects,

collecting evidence and analyzing evidence for clues. Final justification for the selection of a suspect must be based on the analyzed data.

In the most complex of the three cases, *Case Three: Burning Star*, the scene begins with a burned out car discovered in the desert. A body is found inside the car. Answers must be found as to the identity of the body, the cause of death, whether foul play was involved and, ultimately, who was responsible. There are multiple paths a player may take in the process of collecting and analyzing evidence, questioning suspects, and securing clues. For example, at the crime scene there are footprints in the sand, a liquor bottle potentially with fingerprints, and skeletal remains. Figures 2, 3, and 4 are illustrative of the type of real-world analysis that occurs when evidence is processed for this case. The processing techniques serve as examples of procedural learning.

Schools are integrating these types of serious science games into the curriculum and studies are revealing positive impacts on learning outcomes. Research we have conducted on *CSI: THE EXPERIENCE* suggests that this game is effective at teaching declarative and procedural knowledge (Miller, Chang, Wang, Beier, and Klisch 2011). Effect sizes for learning in a pre-post test design are large (i.e., a standard deviation or more) even after a delay from the time a student plays the game to when they are tested on what they have learned.

Our findings that students learn about forensic science through game play on *CSI: THE EXPERIENCE* (Miller et al. 2011) are encouraging; however, we believe that succeeding in a science-focused game (web adventure) has other longer-term outcomes beyond the acquisition of science content (declarative knowledge) and science process skills (procedural knowledge). Anecdotal evidence that we have collected suggests that serious scientific games affect motivation for careers in science. Recent emails from adolescent and adult players suggest strong motivational forces that share characteristics with the theory of possible selves (Markus and Nurius 1986). Table 1 presents a sample of the types of comments (unsolicited and unedited) that are suggestive of the possible selves theory at work in this immersive, single player game. Although most of the unsolicited comments we receive are related to the facet of possible selves reflecting what players hope to become as opposed to how they expect to do in science classes and what they fear becoming, the comments suggest that game play provides a sense of self-efficacy and agency that piques player interest in becoming scientists. These comments, and others like them, served as the impetus for our research to develop a measure that could assess shifts in scientific possible selves.

Measuring Scientific Possible Selves

Researchers have typically used open-ended responses from participants to assess possible selves (e.g., Oyserman and Markus 1990). These responses describe how people choose among and pursue actions in order to reach desired end-states and avoid undesired end-states. Questionnaires examining possible selves have also assessed the strategies people use to achieve their goals. We developed a measure of scientific possible selves designed to assess how students perceive their futures in science careers. This measure was created based on the research described above (e.g., Oyserman and Markus 1990) and focus groups with middle school students to assess their ideas about science careers. Student focus groups provided content for the measure and ensured that the items realistically reflected middle-school attitudes and could be easily understood by this audience.

The scientific possible selves measure was designed in a closed-response format. The closed-response nature of the measure necessarily limits how respondents completed the measure; however, a closed-response measure has the advantage of being more efficient and

easy to use than the free-response measure. Because empirical evidence to support the impact of games on the development of possible selves is scarce, we thought it was important that the measure we created be easy to use. The measure included three subscales to target scientific possible selves: the hoped-for scientific possible self, the expected scientific possible self, and the feared scientific possible self. Strategies and plans of action were also assessed to determine whether students were taking action to attain their hoped-for and expected states.

The study described below was designed to assess the reliability and validity of the scientific possible selves measure. To this end, the scale was administered with other scales that have been established as related to academic achievement generally and achievement in science specifically (e.g., vocational interests and self-concept). In general, we expected positive relationships between the new scale of scientific possible selves and these existing measures and we expected the relationships to be greater in magnitude when the existing measures were specifically related to science achievement.

Testing a Measure of Scientific Possible Selves

Participants in our study were 415 middle-school students recruited through an on line solicitation to their science teachers. The solicitation asked for the involvement of intact science classes in a two-session research study. Data were missing for 13 students who did not participate in Time 1 assessment, and 28 students who did not participate in Time 2. Of the remaining 374 students (190 girls; 184 boys) 98 were in the 6th grade, 165 were in the 7th grade, and 111 were in the 8th grade. Student assent and parental consent were acquired for each student participant. Teachers received a stipend of \$100 for their involvement.

Measures Examined

Scientific possible selves

The scientific possible selves inventory had four sub-scales: (a) the hoped-for scientific possible self, (b) the expected scientific possible self, (c) the feared scientific possible self and (d) an assessment of strategies and plans (see Table 2). The instructions for all sub-scales told students that “Each of us has some images of what we hope to be like, what we think we will be like, and what we want to avoid being like in the future” and then asked students to think about each of these ideas for each sub-scale. Instructions for the hoped-for possible self scale asked students to think about what they hoped they would be like some day in the future, regardless of how likely it would be. Instructions for the expected possible self scale asked students to think about next year and imagine what is most likely to be true of them. Instructions for the feared possible selves scale asked students to think about what they do not want to be like in the future, and focused on fear of failure in science. Instructions for the strategies and plans scale asked students to endorse those strategies or plans they have for attaining their goals in science. For each of these scales, participants were asked to indicate the extent to which they agreed or disagreed with each statement on a Likert-scale where 1 = strongly disagree and 5 = strongly agree.

Vocational interests

Investigative vocational interests were assessed using the 15-item measure in the Unisex Edition of the American College Testing Interest Inventory (UNIACT – Lamb and Prediger 1981). Investigative interest is the facet of John Holland’s (1973) taxonomy of vocational interests that is most related to interest in science (Ackerman and Heggestad 1997). Participants were asked to “consider whether you would like or dislike an activity rather than whether you have the ability to do it” and they responded on a 6-point Likert scale

where 1 = strongly dislike and 6 = strongly like. Example items are “Study biology” and “Learn how the brain works.”

Self-concept

Two facets of academic self-concept were measured using the Academic Self-Description Questionnaire II (ASDQII; Marsh 1990b). Participants rated how well statements described them on an 8-point scale where “1 = definitely false” and “8 = definitely true.” Example items for the 8-item science self-concept measure are “I get good grades in science class” and “It is important for me to do well in science class.” Reading self-concept was assessed using an 8-item measure from the ASDQII. We replaced the term “English” with “reading” to be consistent with language used by middle schools in the United States. Sample items are “I get good grades in reading classes,” and “Compared to other students my age, I am good at reading.”

Procedure for Data Collection

To control for participant fatigue in completing the questionnaires, data were collected over two sessions (each lasting no more than 20 minutes) during science classes. Both sessions took place during the same week, but exact timing was left to the discretion of the teacher. The possible-selves questionnaire and demographic measures, which required participants to select from gender categories (male/female) and grade levels (6th, 7th, or 8th), were collected during Session 1. Session 2 included assessment of the self-concept and vocational interest measures.

Reliability and Validity Evidence for a Measure of Scientific Possible Selves

Means, standard deviations, correlations, and internal consistency reliability estimates for all measures are shown in Table 3. The table also shows that reliability estimates for all measures were good (e.g., above .75). Of note in the table is that the means of the scientific possible selves scales (which were measured on a five-point scale) suggest that students were more likely to agree with statements about short-term outcomes (e.g., the expected selves) more than they were to agree with the other scales. This is not surprising given that the question of obtaining a short-term outcome may seem more concrete to students relative to the long-term goals referenced in the hoped-for self scale (e.g., “I think I can get good grades in my science classes.” versus “It is very likely that I will get a job in science one day.”).

The correlations among study variables also showed evidence of convergent and discriminant relationships. Not surprisingly, expected-self was negatively related to feared-self ($r = -.22, p < .01$), indicating that the better one expects to do in the short-term (e.g., this year in school), the less fear they have about succeeding in science. Expected-self was also positively related to hoped-for self ($r = .38, p < .01$), suggesting that those who report that they will do well in the short-term in science are more likely to have long-term goals for science careers. It is also interesting to note that strategies for achieving success in science were highly related to the hoped for self ($r = .66, p < .01$), and also related to the expected self ($r = .30, p < .01$), suggesting that those who dream of becoming scientists one day and also who expect to do well in science in the short-term are also more likely to say they plan to engage in activities related to science now (i.e., in middle school).

The correlations among the scientific possible selves and the self-concept and interest measures (also in Table 3) show convergent and discriminant relations in the expected directions. Investigative interests were positively related to the hoped for self and expected self (r 's = .44 and .29, p 's < .01 respectively), and also positively related to strategies ($r = .$

53, $p < .01$). Correlations between science self-concept and the possible selves scales were also greater in magnitude (r 's = .34 for hoped for self, .61 for expected self, -.37 for feared self, and .27 for strategies) than the correlations between reading self-concept and the possible selves scales (r 's = .15 for hoped for self, .34 for expected self, -.19 for feared self, and .09 for strategies). Tests for significant differences between dependent correlation coefficients confirmed that the relationships between science self-concept and scientific possible selves were indeed significantly greater in magnitude than the relationships between reading self-concept and scientific possible selves (for hoped-for self, $t(371) = 6.94$, $p < .01$; for expected self $t(371) = 4.29$, $p < .01$; for feared self $t(371) = 9.24$, $p < .01$; for strategies $t(371) = 7.70$, $p < .01$).

In general, we did not find large gender differences in scientific possible selves, with the exception of a small correlation for feared possible selves ($r = .11$, $p < .05$), suggesting that girls were more likely to express concern over doing well in science. Girls also reported higher reading self-concepts than boys ($r = .13$, $p < .05$), but there were no differences in science self-concept or investigative interests. Similarly, there were no evident differences in scientific possible selves related to grade level, although students in higher grade levels were likely to endorse more strategies relative to students in lower grade levels ($r = .11$, $p < .05$). This may be a function of the types of science related activities that are available to students at higher levels.

Implications and Potential use of a Scientific Possible Selves Measure

The scientific games that we have developed encourage players to explore and discover science through the role of scientist. Players' comments suggested that the opportunity to explore a virtual scientific environment helped them develop a sense of agency and self-efficacy that might manifest in the development of their possible selves. In sum, virtual experiences with games may shape players' ideas about what they hope for, expect, and fear about their future, and their ideas about the strategies that they need to follow to achieve their goals. The systematic investigation of possible selves necessitates a focus on measuring the construct.

The goal of this study was to examine the reliability and validity of a measure of scientific possible selves that we developed. Our results are aligned with our expectations in that the subscales of scientific possible selves had high internal consistency reliability estimates and showed convergent and discriminant relations. For instance, expected self was positively related to hoped-for self and negatively related to feared self. The relationships between the subscales of the scientific possible selves measure and other measures of academic self-concept and scientific vocational interests were also as expected: Scientific possible selves were positively related to interest in science and more highly related to science self-concept than reading self concept. In sum, this study suggests that the scientific possible selves measure examined here will be a valuable addition to research aimed at understanding the determinants of careers in STEM.

We acknowledge that the specific conditions of the research environment (e.g., a classroom environment supervised by a teacher and the order of the tests administered the questionnaire) may limit the external validity of our findings. Nevertheless, our study is an important first step in the systematic measurement of scientific possible selves. The next step in our research program will be to use the scale that we have developed to examine the determinants of the development of scientific possible selves. That is, how do activities such as engaging in serious scientific games lead to hopes, expectations, fears, and strategies for pursuing careers in STEM? What are the elements of games that may contribute to the development of scientific possible selves? For instance, we believe that virtual experiences

provided through role play in computer games can make play more engaging and realistic for students and will pique their interest in science education and careers. Games can also provide students with strategies for reaching their career goals, by including information about the requirements for specific jobs in STEM.

In addition to the attributes related to the design of serious science games, we are also interested in examining social and cultural aspects that contribute to the development of scientific possible selves. How do peer groups influence the development of scientific possible selves? Can virtual gaming communities influence interest in science and what is their effect relative to immediate peer groups? How important are the resources afforded by one's environment in the development of possible selves? Another important question related to the social context of games is whether the delivery of science content through a game can make science "cool" to a peer group, and how much these peer group judgments influence individual scientific possible selves. In sum, the development of scientific possible selves at both the group and individual levels is ripe for future research. Measuring scientific possible selves in a valid and reliable way is an important first step.

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Biographies

Margaret E. Beier is an associate professor of psychology at Rice University in Houston, TX, U.S.A. Her research focuses on motivation, learning, and intellectual development throughout the lifespan. She is on the editorial board of *Journal of Experimental Psychology: Applied* and she has authored numerous book chapters and journal articles. Her work has appeared in *Psychological Bulletin*, *Journal of Educational Psychology*, and *Computers and Education*.

Leslie M. Miller is executive director of the Rice University Center for Technology in Teaching and Learning. Her research focuses on the design and evaluation of serious games for science education. Through grants from the National Institutes of Health and the National Science Foundation, a variety of web adventures have been created (webadventures.rice.edu) and aspects of their impacts published. Her work has appeared in the *Journal of Educational Multimedia and Hypermedia*, *Cell Biology Education*, and *Computers and Education*.

Shu Wang is a Ph.D. student in psychology at Rice University in Houston, TX, U.S.A. Her research focuses on the predictors of learning and success in educational environments and she has evaluated the impact of serious scientific games in terms of both learning outcomes and attitude change. Her research has appeared in *Computers and Education*.

Figure 1.

Home page for the *CSI: Web Adventures* (<http://forensics.rice.edu>) website.

Figure 2.
Procedure for making mold of shoeprint taken from *Case Three: Burning Star* in *CSI: Web Adventures*.

Figure 3. Evidence received after completing a facial reconstruction taken from *Case Three: Burning Star* in *CSI: Web Adventures*.

Figure 4. Microscope activity to compare tool marks made by a hunting knife taken from *Case Three: Burning Star* in *CSI: Web Adventures*.

Table 1**Unsolicited and Unedited Comments from Players Illustrative of Possible Selves Phenomena**

i love this it helps me learn i want to be a csi but i havent started school yet and i want to prepare myself by the time i start i know at least a little about what am going to be studying this site really helps thank you

I really liked your website. It helped me with CSI investigations. I now wanna be a CSI person.

well I've finished the second one again you should put way more games into the websute more and more people would join i would get all my friends to join and then you would be a popular site because its the most popular tv show in the uk and the usa so you should put more games on it.

this is awesome!! gave me alot of insight of what they go threw as an everyday job and im actually interested so im goin to see about goin to school for criminal science.

I've always dreamed of being a forensic scientist this is the next best thing thankyou!

I like this.. to me feels like im in the labs with all the characters ... love this game.

It may sound silly but I have three kids 16,10 & 3. My 16 year old wants to be a doctor. In the last two days since we found this site she has decided to major in chemistry. says, "being a CSI is just as important mom I still get to help people just some of them are dead." she says she can always become a doctor later :) We all play together (even my 3 year old) We've always enjoyed watching the shows and trying to figure out "who done it" before they tell you. I think this site is a wonderful in site into what goes on behind the scenes to solve crimes.

I think that this is an excellent site, especially for students like me that is interested in this type of career. I will only be a freshman in college but i can already see myself taking part in csi.

This CSI experience is awesome!!!! Not only it teaches you, but it's fun to do it. It can inspire people to make that as a career.

I thought this stuff was interesting. I like forensics now!:(

I'm a Sophmore in high school and my dream career is to work in a toxicology lab. i really loved this web adventures. i learned A LOT of cool stuff one here. thanks.

I'm a junior in high school and I want to go to college to become a forensic pathologist. How do I go about this...does my major has to be biology.

Hi there, I just wanted to say that it was a great idea to set website like this, that we can use to learn and practice on. I myself want to become a CSI in the future and next year I'm going to college in the Netherlands to study forensics. But this website has encouraged me more to become a CSI. Thank you!

I really liked this Web Adventure thing because I am thinking about being a forensic scientist when I grow up and this helped me learn more about the different fields, because I'm not completely sure which one I want to pursue. I still don't know, but it helped me hear more about each one, now I think I like toxicology. :)

THIS GAME WAS REAL FUN ...SOME PARTS...ANYWAY THIS HAS MADE ME WANT TO BE A CSI PERSON WHEN I GROW UP.SO FROM 1-10 I GIVE IT A 9...SO ANYWAY YOULL HAVE ALOT OF AS FUN LIKE HOW MUCH I DID

I really like this website. When i grow I already wanted to be a medical examiner. Seeing this website it brings closer and closer to what I need to succed this dream even more. THank even though im on my first episode i want to see more.

i am writing to let you know that i love this site i am amazed with forensic science and hope to make it my job in the next couple of years i am 17 years old and im looking into colledge courses for forensics i love this site pleasewrite me if you have any advise

i think that this website is educational yet fun... it teaches you alot about crime scene investigation & helps you to understand about the work that is involved.

pretty cool stuff. It makes me want to be a csi the game teaches you alot of stuff of what the csi does thanks

I love all the CSI series and I just wanted to see if there's any way I could play a CSI game or learn about how being a CSI is! I cracked all 3 cases and learnt things I'd never sit and read about on my own! I loved it! Nice job!

what kind of programs i can get into to help me furhter my career in csi work with me being only 13 years old? what are some programs in New Orleans that i can get in to help me with csi work?

This is awesome. This website made me want to be a forensic scientist. I love it and have shown it to my siblings and dad.

I LOVE the show! I am fourteen and I know what I want to do for my career! I had so much fun with the different cases on the website.

What colleges do you go to, to learn about forensic science becuase i'm really interested in that stuff. like toxicology, cloning, fingerprints, etc

I love this website! I'm so glad my biology teacher gave us this assignment! I have always been very interested in forensics, and this website has already taught me a lot more than I previously knew. Thanks!

I like it alot it is making me think about becoming a csi person doing the finger print and stuff like that

I love this site so much. I have always loved forensics. This website helped me to realize what path I want to take in life. Thank you for helping me realize my full potential!

Table 2**Scientific Possible Selves Scales and Items.**

Hoped for Self

- 1 I have always hoped to have a job in science one day.
- 2 Having a job in science one day is very important to me.
- 3 I expect to go to college and get a degree needed for a job in science.
- 4 It is very likely that I will get a job in science in the future.
- 5 I am sure I will do well in a job in science.
- 6 I expect to have a strong professional career in science in the future.

Expected Self

- 1 I am confident that I can get better grades than other students in science classes.
- 2 I think I can get good grades in my science classes.
- 3 I think I have what it takes to do well in science.

Feared Self

- 1 I worry that I will not get good grades in science classes.
- 2 I think about how I don't do as well as others in my science classes.
- 3 I am concerned about falling behind in science classes.
- 4 I worry that I won't be able to get a science-related degree.
- 5 I am afraid that I won't be able to get a job in science in the future.
- 6 I am afraid people will think it is odd or strange to have a job in science.

Strategies

- 1 I want to take as many science classes as possible next year.
 - 2 If possible, I would get involved with a science club.
 - 3 If possible, I would want to attend a science camp.
 - 4 I would be interested in participating in a science fair.
 - 5 I read science and science-related stories during my free time.
 - 6 I try to learn more about jobs in science that I am interested in from all possible sources (e.g., TV shows, books, people who have that job, etc.)
-

Table 3

Means, Standard Deviations, and Correlations for Scientific Possible Selves Scales, Self-concept, Vocational Interests, Gender, and Grade Level (N = 374).

	M	SD	1	2	3	4	5	6	7	8	9
1. Hoped for self	2.79	1.05	(.92)								
2. Expected self	4.09	.74	.38	(.75)							
3. Feared self	2.29	.92	.04	-.22	(.82)						
4. Strategies	2.57	.94	.66	.30	.07	(.85)					
5. Investigative Interests	3.65	1.00	.44	.29	.02	.53	(.91)				
6. Science Self-concept	6.35	1.21	.34	.61	-.37	.27	.33	(.91)			
7. Reading self-concept	6.25	1.25	.15	.34	-.19	.09	.26	.51	(.91)		
8. Gender	--	--	.02	-.04	.11	-.02	.03	-.07	.13	--	
9. Grade	2.04	.75	.09	.06	.06	.11	.00	.05	-.10	.04	--

Note. Gender coded 1 = boys and 2 = girls. Grade coded as 1 = 6th, 2 = 7th, and 3 = 8th. Correlations greater than .11 in magnitude are significant at the $p < .05$ level; correlations greater than .14 in magnitude are significant at the $p < .01$ level. Internal consistency reliability estimates are on the diagonal.