Youth science identity, science learning, and gaming experiences

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ABSTRACT

This study explored the relationships between identity, science learning, and gaming. A survey of 1502 teenagers assessed gaming preferences, habits, science learning, science and gamer identities. Hierarchical regression analyses revealed that enjoyment of problem-solving games and identifying as a gamer were the strongest predictors for teens’ science understanding. Teen preferences for games with science-related features, and competence in problem-solving games were significant predictors of teens’ understanding of science. Teens who preferred collaborative social games over science-oriented games were less likely to understand the nature of science. Teens with a stronger science identity were more likely to negatively evaluate their gaming groups, preferred problem-solving games, and claimed greater competence in games with science-related features when compared to those who do not self-identify as science thinkers. Results suggest that games that seek to support those who do not feel successful in science learning should focus on social interaction and involve activities and experiences that could be utilized in the real world rather than problem solving games. Results suggest that science-focused games may reinforce perceived self-efficacy and sense of competence in real world scientific reasoning situations for those already predisposed to feel confident as science thinkers.

1. Introduction

The Pew Internet and American Life Project reported that over 92% of youth play video games teens report playing for at least an hour during each gaming session, and most Americans teens play five or more genres of games (Lenhart et al., 2008). Gaming genres played by teens vary widely and include rhythm-based games, puzzle/card games, sports games, and first-person shooter games, with teens reporting that they play these games more frequently each year (Lenhart, Purcell, Smith, & Zickuhr, 2010; Lenhart et al., 2008). Recent research has begun to explore both the positive and negative consequences of game play. Consequently, there is mounting evidence of science reasoning in gaming environment such as Quest Atlantis, River City, Wolf Quest, Environmental Detectives, and Martian Boneyards (Asbell-Clarke et al., 2012; Barah, Thomas, Dodge, Carteaux, & Tuzun, 2005; Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005; Klopfner & Squire, 2008). Furthermore, recent research has suggested that youth game-play has the potential to contribute to their science learning (i.e. Clark, Nelson, Sengupta & D’Angelo, 2009; Gee, 2007). However, research is still needed to explore whether/how teens construct their science identity through these gaming environments to determine how teen identity development might be enhanced and/or hindered through immersion in video game worlds.

1.1. Science identity and gaming

Acknowledging that identity is socially constructed, Carlone and Johnson (2007) theorize that identity development occurs through interpersonal experiences, has impacts on learning, predicts behaviors, and relates to one’s understanding of the self. Science identity contains three dimensions: (1) competence and mastery with science-related content and activities, (2) social performance with science-related content when interacting with others, and (3) recognition or validation from oneself and others as a science person (Carlone & Johnson, 2007). The gaming environment provides an immersive space for science-learning that has the potential to develop, modify, and/or limit one’s notion of their science identity (Shaffer, Squire, Halverson, & Gee, 2005). Furthermore, an individual’s differentiation and integration within a group structure shape the individual’s identity development as it relates to and influences their group identity (Adams & Marshall, 1996). Through formal education, teens are given increasing opportunities to modify and expand their identities to incorporate...
conceptualizations of themselves as science people (Beier, Miller, & Wang, 2012). However, Carlone and Johnson’s identity model has not yet been applied to gamers’ perceptions of themselves as science people, specifically in relation to their game-play experiences and their interactions with their peer gaming groups. Gaming may represent one area of exploration in which youth compartmentalize other parts of their sense of self (Fraser, Gupta, & Rank, 2013; Sylvan, Asbell-Clarke, Fraser, Gupta, & Rowe, 2013). Video games provide a context by which youth engage in new forms of identity that may differ from their offline expressions of themselves (Przybylski, Weinstein, Murayama, Lynch, & Ryan, 2012). Current research is beginning to suggest that youth experiences on digital environments greatly influence their identity development (Dodge et al., 2008). However, research is needed to identify how teens are experimenting with their science identity to determine how their identity is modified, maintained, and/or determined by their video game engagement and their engagement with peers through video game platforms.

1.2. Science learning and gaming

Egan (1997) argues that by pushing their limits, youth construct meaning based on their pre-existing knowledge. When immersed within specific gaming worlds, youth may receive opportunities to incorporate this previous knowledge into the game, while expanding on this knowledge by creating meaning from the gaming experience. The nature of science (NOS) field of knowledge, as defined by previous researchers (Lederman, 1992), represents one potential area of pre-existing knowledge in which youth can build upon through video games. NOS has been described as the understanding of science as a way of knowing, or the values and assumptions that are inherent in the development of scientific knowledge (Lederman, 1992). Expanding upon Lederman’s definition, Schwartz and Crawford (2004) identified three essential factors for NOS learning – reflection, context, and perspective, all of which align to how gaming might encourage synthesis of content knowledge to hypothetical conditions.

The gaming world could provide youth learners with opportunities to use each of these skills, in addition to affording youth with opportunities to critically examine and apply science topics in an effort to solve problems embedded in video games (Squire, Barnett, Grant, & Higginbotham, 2004). Previous studies have found that video games can facilitate scientific inquiry, data analysis, and theory-building skills (Asbell-Clarke et al., 2012). There is a growing body of research suggesting that gaming environments can enhance youths’ learning (Barab et al., 2005; DeFreitas, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2010; Gee, 2007; Ketelhut, 2007; Lenhart et al., 2008; Steinkuehler & Duncan, 2008), and video games can be leveraged as environments that promote learning processes (Harpe, Myers, & Aleven, 2013). However, research is needed to determine the processes by which video games can be used to enhance learning experiences for youth (McClarty et al., 2012).

Video games can provide youth with opportunities to develop situated understandings, effective social strategies, personal and varied identities, share values with peers, and engage in communities of practice (Shaffer et al., 2005). Gaming worlds provide contexts in which learners can explore situated concepts (Gee, 2007), where object-relationships can be understood by hypothesizing, experimenting, and inferring from the manipulation of such objects. Gee (2007) originally identified four specific aspects of games that are relevant to positive learning outcomes: (1) display of problem-solving or mastery; (2) learning from failure to eventually win; (3) competition as a social event; (4) design features such as interactivity (players’ ability to influence the progress of the game), sequencing (clarity of the connections between early and later parts of the game); and (5) role-playing potential. While all of these attributes likely contribute to learning outcomes, the theoretical focus in the science-learning game research has tended to treat gamers as an undifferentiated mass, occasionally considering gender as a discriminatory tool. The research has neglected to explore potential psychographic variations that may influence learner genre preference. The authors hypothesize that a game’s genre may pre-determine who will prefer and play the game, and then what learning might be achieved given the gamer’s specific preferences.

Not surprisingly, students prefer learning science through the use of video games (Marino, Israel, Beecher, & Basham, 2013). The consistent, non-social rewards (e.g. level changes, accumulated coins) available in video games serve to motivate youth, enhance youth interests, and increase their overall engagement in the game (Garris, Ahlers, & Driskell, 2002). Once youth are engaged in science-based games, studies have found numerous benefits for the player such as enhanced understanding of complex science phenomena (Kafai, Quintero, & Feldon, 2010; Klopfer, 2008; Plass et al., 2013; Squire et al., 2004; Steinkuehler & Duncan, 2008), and improved spatial reasoning skills (Greenfield, Brannon, & Lohr, 1994).

Similarly, strategic video game play has been directly linked with teen’s increased problem-solving abilities and overall academic performance (Adachi & Willoughby, 2013). Video games are vivid, interactive environments in which gamers can engage in learning environments that bring to life abstract concepts and ideas embedded in more traditional curriculum (Evans, Anderson, Chang, Deater-Deckard, & Bacle, 2013). The active involvement elicited by video games, the goals presented, and the visual representations of complex science concepts may be related to science learning, however, many of these items have not been empirically tested. Despite the growing recognition of video games as effective instructional tools, the exact mechanisms by which they impart science learning has yet to be determined (Evans et al., 2013). Furthermore, there is limited research on how teens’ preconceptions of themselves as science thinkers might influence the degree to which science-learning games or genres are useful for teens’ science learning.

1.3. Social self

Situated within a scaffolding approach to learning (Vygotsky, 1987), Salomon and Perkins (1998) suggest that learning is not an individualized process nor is it a completely social process, but learning is instead a combination of individual and social processes. In a review of the learning literature, Salomon and Perkins identify how individual learning can be socially mediated. Individual learners may participate in a collective group where learning is distributed in the group more than in the individual, and the individual and social dimensions of learning interact in a “reciprocal spiral relationship.” Consequently, teens’ learning processes should be considered as embedded within social constructions.

In the context of the gaming world, it is likely that the group dynamics of the gaming experience may serve as an influential factor, contributing to students’ understanding of science (Squire et al., 2004). Indeed, previous research has suggested that the social aspects of video games are attractive for youth players (Frosting-Henningsson, 2009; Jansz & Martens, 2005; Trepte, Reinecke, & Juechens, 2012). These video games represent a modern tool that can be used to inculcate new cultural norms and practices through shared environments, shared learning, and practice within a group setting (Shaffer et al., 2005). Research has indicated that the virtual, social component of video games can significantly improve learners’ engagement and motivation with learning material (Plass et al., 2013). Video game worlds may satisfy socialization
needs, where players feel satisfied, accomplished, and content after playing the game (Hoffman & Nadelson, 2010). As a unique attribute of games, competition and cooperation through video games have the potential to bring players together in a social community of players (Shaffer et al., 2005).

Many video games also provide individuals with a range of social rewards that include praise for one’s game-playing, belongingness in a community of gamers, and validation and approval of one’s actions (Olson, 2010). Tarrant et al. (2001) found that adolescent boys identified their peers’ “skill” in video games as the second most desirable characteristic (after being “fun”), further highlighting the social rewards that can be found in video games. Gamers’ perceptions of themselves and the gaming identities they develop through their participation in the virtual world are linked with the social environment embedded in many forms of video game play (Shaffer et al., 2005).

2. Current study

The current study explored associations amongst science identity, science understanding, and teens’ gaming preferences. This study also examined whether teens’ game play, in the context of their social selves, might relate to their understanding of the nature of science. Furthermore, researchers were interested in understanding how teens transfer knowledge from their game play into the non-gaming environment, and whether this knowledge might be leveraged to enhance teens’ learning from educational games.

3. Material and methods

3.1. Participants

A sample of 1502 teenagers from across the U.S. were recruited through Qualtrics, an online survey panel supplier. The research team sent requests to parents who had opted into the survey system and had registered their household as having a teen between 14 and 18 years in their household. Parents were emailed information about the survey and were asked to give their consent for their teen to complete an online survey by forwarding the URL link to the survey to their child or to directly ask their child to complete the survey linked from the parent’s email. To prevent non-teens from taking the survey, participants were initially asked to confirm they were between the ages of 14 and 18. Demographic asked participants to identify their gender, location, and the year they were born. To attain a stratified sample, age groups were capped at 375 participants per birth year.

3.2. Measures

An online survey was used to assess teens’ video game habits, preferences, and competitiveness as they may relate to science identity and learning. Both forced-choice and open-ended questions were used to uncover teen game-playing experience, preference and attitudes, assessments of science identity, gamer identity, and test questions to uncover participants’ factual understanding of the NOS, concepts that are central to most science curricula in the U.S.

3.2.1. Gaming habits

Two sets of questions asked about the frequency of teens’ engagement in video game play, where the game play occurs, and the platforms they used. Teens were asked to indicate all the platforms (such as cell phones, consoles, and computers) they had used to play games in the last two weeks, and could indicate that they had not played any of the platforms listed. A second set of items asked about the frequency of game playing in seven general locations. Items response were given on a Likert scale ranging from 1 (Daily) to 7 (Never).

3.2.2. Game preferences and experiences

A list of 15 game types was developed based on existing taxonomies and modified to reflect the current gaming literature (Lenhart et al., 2008; Phan, 2011). Teens were asked to indicate the types of games they liked (with a dichotomous variable coded as 1 = they checked it, or 0 = they did not) from a list of games that (a) related to science learning (e.g., building cities or conducting scientific investigations), and/or (b) those that involved overcoming physical (e.g., racing) or mental (e.g., word puzzles) challenges. Teens were asked to indicate their level of game play ranging from 1 (Professional) to 5 (Beginner). Items also asked about recent game play, game sites visited, favorite games, and what the teen liked about their favorite game, while open-ended questions assessed the games played most recently, game sites teens visited, their favorite game, and what they liked most about their favorite game.

3.2.3. Knowledge of games

Teens were asked whether they play games on their own, play with others in the same room, and/or play with others online. To assess their engagement and interaction within their gaming communities, two items asked about the teen’s use of gaming blogs and/or online forums, and their contribution to content on the blogs and/or online forums. Participants were asked to rate these items on a seven-point Likert scale ranging from 1 (Strongly disagree) to 7 (Strongly agree).

3.2.4. Social game play

Teens were asked whether they play games on their own, play with others in the same room, and/or play with others online. To assess their engagement and interaction within their gaming communities, two items asked about the teen’s use of gaming blogs and/or online forums, and their contribution to content on the blogs and/or online forums. Participants were asked to rate these items on a seven-point Likert scale ranging from 1 (Strongly disagree) to 7 (Strongly agree).

3.2.5. Collective self-esteem

The Collective Self-Esteem Scale (Luhtanen & Crocker, 1992) was used to assess individuals’ self-evaluations based on group memberships. This 16-item scale includes four subscales assessing evaluations from their close affiliation with groups (membership), evaluation of the groups’ status based on their personal perception (private), evaluation of the groups’ status based on their perception of others’ assessment (public), and the extent to which group membership is important to their self-concept (identity). Participants were asked to rate these items on a seven-point Likert scale ranging from 1 (Strongly disagree) to 7 (Strongly agree).

3.2.6. Enjoyment of science-related gaming features

A set of 14 items assessed the extent to which teens enjoyed video game features that facilitated science learning. These items were based on game features theorized to facilitate science learning (Gee, 2007). Features included those that necessitated problem-solving or mastery, learning from failure, competition as a social event, design features that enabled impacting the progress of the game, connecting early and later parts of the game, and role-playing potential. Participants were asked to rate these items on a three-point Likert scale ranging from 1 (Not very much) to 2 (A little) to 3 (A lot), and there was an option for 1 don’t know. An
additional item asked about aspects of games that the teen believed to have application for real life.

Four items assessed teens’ preference for games with science learning potential according to Gee’s (2007) theory. Items were rated on a scale ranging from 1 (Strongly disagree) to 5 (Strongly agree), asking teens’ preference for games where they get a chance to figure out game rules, use a demo or tutorial, or use trial-and-error methods to accomplish game tasks. Additionally, one item asked about perceived competence in problem-solving games.

3.2.7. Applications of games to real life

Three items asked how participants conceptualized the relationship between the games they played and the real world. Participants were asked how games did or did not comply with real world rules, the perceived impact the participant experienced from game play, whether game play was relaxing during and after playing, and whether the teen experienced boredom from accomplishing game tasks quickly. Responses were rated on a seven-point Likert scale ranging from 1 (Strongly disagree) to 7 (Strongly agree).

3.2.8. Understanding of science and science identity

To measure understanding of the NOS, items were modified slightly from the scale instruments developed and tested by Tobin and McKibbin (1997), to more closely align items with video games. Responses were rated on a five-point Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree). Carlone and Johnson’s (2007) model was used as the basis of a new 14 item scale to measure teens’ science identity. Three aspects of science identity were assessed – competence with science-related content knowledge (e.g., I am successful at science-related activities), the importance of science identity to the self (e.g., Doing science-related activities is important to who I am), and the social validation of identity from important people in the teens’ lives (e.g., It is important that others see me as a science person). Responses were given on a five-point Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree).

4. Analytic plan

4.1. Quantitative data analysis

Both item-level and scale-level descriptive data was run for all of the quantitative analyses. Each construct was analyzed for validity, predictive strength, and correlations amongst the items in the measure. Further correlation and regression analyses were also used to explore relationships amongst the variables. To identify differences amongst teens with a high and those with a low understanding of the nature of science, median-split groups were used with each group.

4.2. Qualitative data analysis

The qualitative natural language semantic analysis software Leximancer was used to undertake a primary analysis of the open-ended responses to game preference questions. The software conducts automatic content analysis of text to uncover themes from the connections between words used in phrases and sentences. By ranking words based on their frequencies and then assessing their co-occurrence with other words generated specific concepts for each set of words that were semantically close. These concepts were organized into broader themes that depict the data in ways that allowed knowledge building based on these responses. Leximancer was used to produce a visualization of the thematic analysis of the survey question “What do you like about your favorite game?” using both automated and user-defined settings. Colors indicate the primacy of central concepts noted as hierarchically important or relevant across more responses, indicated by centrality and the colors red, orange, and yellow. Green, blue, and purple represented themes that were accorded lesser importance in responses and tended to be identified by a lower number of participants.

5. Results

5.1. Participant demographics

A total of 1502 participants were recruited (667 male and 835 female). Nearly half of the participants lived in a suburban area (46.5%, n = 698), 22.2% in a rural area, and 31.4% in an urban area. Birth date confirmed the even distribution with twenty-five percent (n = 375) claiming 1994 as their birth year, making most of them 18 at the time the study was administered.

5.2. Gaming habits and preferences

Only 6.1% of teens reported that they had not played a game in the past few weeks. The remaining youth reported playing all seven types of digital media listed, with the majority of game play on a console, such as XBox (n = 1077), computer (n = 1009) or cell phone (n = 942). Most teens indicated playing games at home either daily (57.3%, n = 861) or two to three times a week (21.1%, n = 317). The frequency in which teens played digital games at friends’ houses was evenly distributed between 8.6% and 19.7%, where 20.8% of respondents reported that they never played at friends’ home.

The mean number of types of game activities “liked” by teens was 5.12 (SD = 2.94). The most popular games were solving puzzle and word games (52.3%), racing with obstacles and challenges (51.4%), playing or making music/dancing (48.4%), engaging in battles (47.9%), and first person shooter games (45.7%; N = 1502). Almost half (48.4%, n = 727) considered their gaming skills to be intermediate, with almost a third of the respondents above the intermediate level. Only 14.4% of teens reported playing games that feature scientific investigations, with the strongest correlation being with activities that involved “learning” (r = .284, p < .001). When teens were asked open-ended questions about the games they had played in the last three weeks, the most-played game was the Call of Duty series. The Sims, Halo, Mario, and the Madden series games were the next most frequently played. When asked to name their favorite game of all time, the Call of Duty series was the most frequently reported.

5.3. Characteristics of favorite games

Leximancer was used to explore the characteristics of teens’ favorite games. The graphics and storyline emerged as important when teens were asked to explain why their favorite games were their favorite (Fig. 1). Graphics were often mentioned with other concepts, such as characters and protagonists in addition to multiple skill levels, interfaces with maps, and the potential to explore worlds for an indefinite period of time.

The second theme that emerged was appreciation for how the game is connected to real life, labeled relation to reality. Some teens felt that their favorite game could, “teach [them] to solve problems quickly and that these skills can be applied to real life.” Other teens liked the game because it simulated real life or activities from real-life, such as football. A great many of these responses indicated that simulation to real life was satisfying because it offered the gamer an element of control, whereby they could actively learn new information, engage in strategic thinking, and create or build something relevant to their life. These statements seemed linked to identity ideation and an exploration of self-hood. For example:
Teens most enjoyed the problem solving and mastery features of games ($M = 2.49$, $SD = .44$, $n = 1478$), where 74.7% of respondents reported that they like to achieve success a lot ($n = 1122$; Fig. 2). Similarly, 60.3% teens reported that they liked being able to choose their skill level ($M = 2.56$, $SD = .64$, $n = 1409$; Fig. 2). The four gaming features that facilitated science learning as articulated by Gee (2007) were all significantly different from one another with the exception of design features and social aspects of gaming. The remaining three factors teens reported as liking in declining order: design features ($M = 2.42$, $SD = .54$; Fig. 2), social aspects of gaming which was apparent from qualitative analyses as well ($M = 2.39$, $SD = .66$; Fig. 2), and learning from mistakes ($M = 2.32$, $SD = .58$; Fig. 2).

A regression analysis was conducted to understand how the types of games teenagers played related to their understanding of the NOS. Predictors in the analysis were demographics (age, gender, area of residence), competence in science-related game features, experience playing video games, and the different types of games played. Enjoyment of problem solving and mastery features of games was the strongest predictor of high NOS ($\beta = .21$, $p < .001$; Table 1). Science understanding was also predicted by teens’ competence in games that involved science features, acknowledgement that games can relate to real life, and enjoyment in the social aspects of games ($\beta = .15$, $p < .001$), their acknowledgement that games can relate to real life ($\beta = .11$, $p < .001$), and enjoyment in the social aspects (such as collaborations and competition) of a game ($\beta = -.09$, $p = .001$).

Means of median split groups for those with a high and low understanding of science were compared across the variables assessing frequency of play in various locations. Low means indicate more frequent game play. Teens who had a limited understanding of the NOS reported more frequent game playing at school ($M = 5.54$ for low NOS; $M = 5.85$ for high NOS), during after-school programs or camps ($M = 5.55$ for low NOS; $M = 6.25$ for high NOS), and through formal library programs ($M = 5.9$ for low NOS; $M = 6.49$ for high NOS). Preferences for gaming platforms were similar for the low and high NOS groups, with the most common platforms including consoles such as Xbox or PSP (67.4% of low NOS group; 76% of high NOS group), computers (62.2% of low NOS group; 72.2% of high NOS group), and cell phones (60.9% of low NOS group; 64.6% of high NOS group).

One of the few differences found between the low and high NOS groups were expressed in game type preferences. Those high in NOS played more race games ($\chi^2 (1, N = 1502) = 24.56$, $p < .001$), word puzzles ($\chi^2 (1, N = 1502) = 21.62$, $p < .001$), battle games ($\chi^2 (1, N = 1502) = 22.09$, $p < .001$), and first person shooter games ($\chi^2 (1, N = 1502) = 11.33$, $p < .001$). Teens that preferred first person shooter games also had higher NOS scores ($\chi^2 (1, N = 1502) = .078$, $p = .002$).

5.4. Nature of science understanding

The NOS measures were internally consistent (17 items, $x = .843$), with average responses having a moderate understanding of science ($M = 3.73$, $SD = .50$, $n = 1502$). Teens reported the highest ratings for items that acknowledged the gaps in knowledge that science has to address ($M = 4.16$, $SD = .88$), the tentative nature of science knowledge, its testability ($M = 4.06$, $SD = .82$), and the need to revise it over time ($M = 3.95$, $SD = .89$). The average youth respondent agreed that, “there are still many unresolved issues that need to be solved in science” ($M = 4.06$, $SD = .82$) and that “scientific laws, theories and concepts are continually being tested” ($M = 4.06$, $SD = .82$).
playing games on their own were less likely to play with friends in person, online, or with strangers online, as indicated by the weak correlations shown in Table 2.

Most respondents (78.2%; \( n = 1175 \)) learned about new games from friends. Almost half the respondents said they found out about new games from game sites (48.2%; \( n = 729 \)) and approximately 42% of respondents looked to family members or TV.

### Table 1

<table>
<thead>
<tr>
<th>Suburb-Dummy code</th>
<th>( B )</th>
<th>SE (( B ))</th>
<th>( \beta )</th>
<th>( t )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural-Dummy code</td>
<td>.097</td>
<td>.026</td>
<td>.081</td>
<td>3.09</td>
<td>.002</td>
</tr>
<tr>
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<td>.032</td>
<td>.045</td>
<td>1.91</td>
<td>.057</td>
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<td>.007</td>
<td>.085</td>
<td>3.41</td>
<td>.001</td>
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<tr>
<td>Perceived gaming skill level</td>
<td>.036</td>
<td>.025</td>
<td>.007</td>
<td>2.50</td>
<td>.012</td>
</tr>
</tbody>
</table>

**Collective gaming self-esteem**

| Membership | .061 | 0.015 | 0.123 | 3.60** | 0.000 |
| Private    | .090 | 0.017 | 0.166 | 4.79** | 0.000 |
| Public     | .049 | 0.019 | 0.075 | 2.40   | 0.016 |
| Identity   | -.095| 0.012 | -.196 | -8.05**| 0.000 |

### Table 2

<table>
<thead>
<tr>
<th>Enjoyment of science related game features</th>
<th>( B )</th>
<th>SE (( B ))</th>
<th>( \beta )</th>
<th>( t )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem solving and mastery</td>
<td>.240</td>
<td>0.037</td>
<td>0.212</td>
<td>6.54**</td>
<td>0.000</td>
</tr>
<tr>
<td>Learning from failures</td>
<td>-.037</td>
<td>0.025</td>
<td>-.043</td>
<td>-1.51</td>
<td>.122</td>
</tr>
<tr>
<td>Social aspects (competition or collaboration)</td>
<td>-.070</td>
<td>0.021</td>
<td>-.092</td>
<td>-3.26**</td>
<td>0.001</td>
</tr>
<tr>
<td>Design features</td>
<td>-.010</td>
<td>0.029</td>
<td>-.031</td>
<td>-0.35</td>
<td>.724</td>
</tr>
<tr>
<td>Application to real life</td>
<td>.065</td>
<td>0.013</td>
<td>0.121</td>
<td>4.89**</td>
<td>0.000</td>
</tr>
</tbody>
</table>

**Note:** \( R^2 = .267 \).

\( ^* p < .05 \).

\( ^{**} p < .005 \).

5.6. **Collective self-esteem and understanding of the NOS**

The Collective Self-Esteem Scale remained reliable (16 items, \( \alpha = .760 \)) and paired t-tests of each pair of subscales indicated differences between all pairs of subscales, except between Membership and Private. Teens’ personal identification with their gaming groups was the lowest compared to the other subscales (\( M = 3.71, SD = 1.02 \)), indicating that although teens may think of
themselves as successful gamers in the gaming community, this factor contributes least to their sense of self as a gamer in other parts of their life.

Most of the subscales of collective gaming self-esteem were significantly correlated with at least one type of gaming device. The strongest correlations were between the membership subscale \((r = .280, p < .001)\), private regard \((r = .271, p < .001)\), and public regard \((r = .220, p < .001)\) with gaming consoles. Those more experienced with video games were more likely to positively evaluate their gaming groups. However, those who felt gaming mattered to their identity indicated the weakest correlation with experience \((r = –.141, p < .001)\), while the strongest correlation with experience was acknowledging personal contribution to their identity as a gamer in other parts of their life. Those who felt gaming was acknowledging personal contribution to their identity indicated the weakest correlation with evaluate their gaming groups. However, those who felt gaming experienced with video games were more likely to positively regard the NOS – one with the game types racing and battle games, and the other with word puzzles and building cities. In each of these moderation analyses, the interactive effect of each collective self-esteem subscale \(\text{(Member, Private, Public, and Identity)}\) and each of the two game sets were entered, resulting in eight interaction variables. Similarly for the second moderator analysis, the interaction variables were between the collective esteem subscales, and build cities and word puzzles.

For the first analysis, the interactions between the Private subscale and battle games \((b = .081, p < .019)\), and between the Identity subscale and race games were significant \((b = .046, p < .049)\), both positively predicting understanding of the NOS. In the second analysis, the interactions between the Identity subscale and word puzzle games were significant \((b = .082, p < .001)\), positively predicting teens’ understanding of the NOS. To identify the nature of the interactive effect, means for median-split groups of those high and low in collective self-esteem were calculated and compared for those who did and those who did not play each of the games. Fig. 3 illustrates that NOS understanding was higher for teens that held a positive regard for their gaming group, especially those that played battle games.

5.7. Science identity and gaming preferences

Only 38% \((n = 559)\) of respondents thought of themselves as science people, and only 33.3% \((n = 784)\) reported that doing science-related activities was important to their identity. However, 49.5% \((n = 781)\) of teens agreed that knowledge and skills in science helped them contribute to important issues.

The three subscales of science identity were all significantly different from one another. The average respondent believed they had a higher competency in science activities when it was compared with the importance of their science identity to themselves; the mean difference was \(--.47 (SD = .63, n = 1485)\) and the need for social validation of a science identity was \(M = .70 (SD = .79, n = 1477)\). The mean difference between the importance of identity to the self and social identity was .23 \((SD = .50, n = 1482)\). A regression analysis was conducted with identity as a science person as the outcome variable; the ten predictors accounted for almost 20% of the variance \((R^2 = .20, F(16, 1416) = 22.95, p < .001; \text{Table 3})\). The strongest predictor of teens’ science identity was preference for games with science-related features, while problem solving and mastery and competence in games with science-related features also predicted science identity \(\text{(Table 3)}\).

5.8. Transfer of gaming to real life

When asked about the application of games to real life, almost half of the teens (46.4%; \(n = 698\)) disagreed that games frustrated them when they did not follow real world rules. Teens were neutral about whether games helped them with school \((M = 4.03, SD = 1.50)\) and neutral about applying games to the real world \((M = 3.87, SD = 1.61)\). However, more than a third \((41.5%; n = 623)\) disagreed that games had no connection to the real world, and 33.4% \((n = 502)\) agreed with the statement. Almost 40% \((n = 59)\) of teens reported that what they learned through games helped them in school. Over half of the teens \((61.3%; n = 920)\) reported feeling more relaxed during game play, and 56.1% \((n = 843)\) reported feeling more relaxed after game play.

6. Discussion

This study provided both descriptive and relational information on teen gaming preferences as they relate to NOS understanding, social aspects of gaming, collective self-esteem, and science identity. This data suggests that gaming preferences are linked to perceived self-efficacy in different social and behavioral domains. While game theorists have suggested that games can promote science learning, and a growing body of data has demonstrated that this learning can achieve significant advances in science learning if implemented in controlled settings, our results suggest that these science learning games are more likely to be preferred by those youth who already engage in higher academic achievement, and also likely have a higher level of science literacy.

6.1. Gaming preference and NOS

Open-ended responses about teens’ gaming preferences highlight the significance of satisfaction and feedback, which are both components of identity exploration that youth pursue during their teen years. Given the quantity of time and ubiquity of gaming in youths’ lives reported here, it seems that one cannot underestimate the contribution these experiences may have on teens’ future conceptualizations of themselves science learners.

The following were other significant predictors of NOS understanding: (1) preference for battle games, racing games, building cities and environments, and word puzzle games, (2) teen’s competence in games that involved science-features, (3) enjoyment of the social aspects of games, and (4) acknowledgement that games can relate to real life. Teens’ preferred gaming features parallel the learning objectives and learning environments most suitable for science learning, which are also categorized as essential features for positive learning outcomes \(\text{(Gee, 2007)}\). This study explicitly highlights the multi-dimensional relationships amongst teens’
understanding of science concepts and their video game habits and preferences.

6.2. Gaming and science identity

Although few of the teens in this study thought of themselves as science people, science identity was related to evaluations of gaming groups, preferences for specific genres of video games, and gaming experience and skillset with these genres. Teens with a weaker science identity more positively evaluated their gaming group, suggesting that those that have not yet developed a science identity may feel better about the gaming groups they belong to. It may be that teens view their developing science identity as in conflict with their gaming affiliations, and subsequently in conflict with their gaming peer groups. This conflicting relationship should be explored further in future studies to disentangle how science identity and peer evaluations develop over time.

Valuing one’s membership in their gaming group and identifying strongly with that group was related to a stronger science identity, supporting Olson’s (2010) description of gaming environments as opportunities for teens to receive social rewards through peer praise, belongingness from a community of gamers, and validation of their behaviors. Teens’ personal contributions to gaming groups, as they related to their identification as science people, illustrated a significant relationship between group affiliation and science identity. Teens’ science identities were most strongly predicted by teens’ preferences for games with science-related features, in addition to problem-solving and mastery and competence with science-related features. Not only were teens’ science identities related to how much they enjoyed problem-solving games, but was also related to their level of competence in that skillset. It is likely that teens’ with strong science identities are drawn towards games that favor these abilities. Similarly, teens with these science identities are likely reinforcing these identities, or developing them further by engaging with science-related concepts such as problem-solving skills available in certain genres of video games. The science-related features available in games, and teens’ subsequent engagement with the games may function in a continuous cycle that reinforces teens’ science identities. These results affirm Shaffer et al. (2005) suggestion that specific gaming environments allow for science learning and science identity development, and that youth identity development may be influenced by the digital environments in which they engage (Dodge et al., 2008). However, further research is need to identify the processes by which these science identities develop, and how identity may be socially constructed (Carlone & Johnson, 2007) through these video game environments over time.

6.3. Social interaction in games and NOS

This study began to disentangle prior reports suggesting that all teens are drawn to the social aspects of gaming (Frostling-Henningsson, 2009; Jansz & Martens, 2005; Trepte et al., 2012) to satisfy their socialization needs (Hoffman & Nadelson, 2010). The majority of teens in this study indicated that they were solo players, but also indicated that their gaming knowledge developed in a social context, where they learned about games from friends, family, and gaming websites. It appears that game preferences may be constrained and influenced by the cliques and cultural sub-groups that are common among youth. Youth may gravitate towards peers with similar skills and interests as part of their identity and overall development. Although it was not explicitly identified, it is likely that enjoyment of the social interaction through gaming involves enjoying the opportunity to play games with friends and membership within a gaming community.

Results from this study suggest that gaming contexts offer opportunities for social interaction that might be better leveraged to facilitate science learning processes if teens are willing to engage in these social interactions via the gaming environments. Expanding on the previous studies that have identified the importance of gaming environments for science inquiry (Greenfield et al., 1994; Kafai et al., 2010; Klopfer, 2008; Plass et al., 2013; Squire et al., 2004; Steinkuehler & Duncan, 2008), this study found similarities, but also unique patterns of gaming preferences for teens with a greater and those with a lesser understanding of NOS. Since both groups most preferred race, battle, and word puzzle games, Educators and video game designer might leverage these types of games to facilitate science learning for teens with varying levels of science learning. However, the high NOS group appeared to be playing all of the game genres more frequently, suggesting overall that more frequent video game play and consistent engagement with these games is linked (directly or indirectly) with teens’ understanding of the NOS.

6.4. Transfer of gaming to offline environments

Teenagers in this study recognized the utility of gaming activities and concepts as they were applicable to offline environments.
This specifically addressed Biddell and Fischer’s (1994) concern about the lack of knowledge transfer between different contexts, primarily formal education and more informal settings. In some cases, explicit references were made to activities and strategies used within the gaming world that had applications beyond the game. Teens specifically identified that their favorite games could relate to reality. As such, this finding corroborated Egan’s (1997) argument for leveraging children and youth’s fantasy worlds as potential arenas that can be used to advance learning processes, where youth can explore their limits and extremes within the gaming world as a method of meaning construction that builds on their pre-existing ideas and knowledge of the offline world.

Teenagers in this study indicated that their video gaming environments involved activities and experiences that they felt could be utilized in the real world. There appeared to be a level of ownership and active control of how the lessons from the video game world might be used outside the games. Consequently, this study further supports the idea that video games can be conceptualized as potential learning contexts or mediums that might be designed and leveraged by game designers and educators to advance teens’ learning (Egan, 1997; Gee, 2007).

7. Conclusions

Learning about science and enhancing one’s understanding of science through a video-gaming context is likely the result of a complex system of preferences, enjoyment, competence and social feedback. In this study, the skill at which games were played was associated with a stronger sense of identity as a science person, and a general disinterest in being in a social collaborative learning world. In effect, self-identified science youth may retreat from online collaborations, but find themselves within an elite, solitary learning world. Results highlight that the collaborative social nature of video game play to support science learning, and suggest that this may be an avenue to broaden STEM literacy efforts to a wider range of learners.

Beyond simple patterns of preference, results from this study suggest that game design has the potential to support the development of science thinking among youth, the transfer of science content to real world settings, and might offer a digital medium that supports increased understanding of the NOS. Unfortunately, our evidence suggests that this support will most likely accrue for those who are already succeeding, possibly even increasing the success gap as science-oriented youth invest more time in out-of-school science gaming, while those already lagging behind focus on games that do not offer them the same learning support. Implications from this study suggest that game designers should focus their efforts on reaching and engaging underserved communities into the gaming community rather than finding success in areas where success appears to be likely. It appears that educators and game designers cannot take the, “if we build it, they will come” approach to game design for teen audiences.

Furthermore, the social nature of video-games might attract teen audiences. Evidence suggests that social gamers are more likely to derive support from one another in their potential development of mastery in a game. We believe this is a hopeful sign since these youth are more likely to benefit from social negotiation of meaning to develop their science understanding. We cannot claim this study to be definitive proof of the range of learning preferences in youth, but this national data suggests that the next wave of game development research should look closely at methods designed to engage youth who find themselves falling behind their peers in school. Science learning games have the potential to create virtual worlds that allow peer-to-peer collaborative science learning in social environments that can increase perceptions of self-efficacy and offer engaging opportunities to support mastery of NOS principles that might be recognized by peers.

Conflict of interest

No competing financial interests exist.

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References


NeoPiagetian theories of cognitive development.