Playing the System: Comparing the Efficacy and Impact of Digital and Non-Digital Versions of a Collaborative Strategy Game

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ABSTRACT
The present research compared the experiences and outcomes afforded by digital and non-digital games. In a randomized experiment, a sample of youth, ages 11-17, played a cooperative public health game presented in either a non-digital format (board game) or digital format (mobile app). Relative to baseline scores reported in a no-game control condition (N = 30), players of the *non-digital* version of the game (N = 28) exhibited significantly higher post-game systems thinking performance and more positive valuations of vaccination, whereas players of a nearly identical digital version (N = 30) did not. This discrepancy was accounted for by key differences in play that emerged: specifically, players of the *digital* game exhibited a more rapid play pace and shorter turn length, and discussed strategies and consequences less frequently and with less depth. The implications for the use of games to facilitate cognitive growth and learning are discussed.

Keywords
digital games, non-digital games, systems thinking, game affordances, conversation analysis, games for health, games for a purpose

INTRODUCTION
Systems thinking – an approach to problem solving that emphasizes the interconnections and interdependency between the component elements of a dynamic system – has been widely identified as a vital "21st century skill," essential for navigating an increasingly

Proceedings of 1st International Joint Conference of DiGRA and FDG

complex, knowledge-based, and technologically-driven society (e.g., Banathy 1996, 2000; Dede 2000; Jacobson & Wilensky 2006). In recent years, scholars and educators have been increasingly cognizant of the importance of systems thinking for learning in a wide range of domains, including science, engineering, and computing, as well as its applicability for solving global challenges to public health, security, and the global economy (Boardman & Sauser 2008; Trilling & Fadel 2009). Indeed, as Sterman (1994) pointed out:

> Many [philosophers and scientists] advocate the development of systems thinking – the ability to see the world as a complex system, in which we understand that…"everything is connected to everything else." If people had a holistic worldview, it is argued, they would then act in consonance with the long-term best interests of the system as a whole. Indeed, for some, the development of systems thinking is crucial for the survival of humanity (p. 291).

Thinking in terms of systems helps learners make sense of complex situations that unfold over time and formulate "mental models" to understand and explain the connections between key elements in those systems, often involving a myriad of interactions between people, resources, actions, outputs, and outcomes (Skyttner 2006).

At the same time, however, a growing body of work has revealed that systems thinking is a difficult skill to acquire and hone (Jacobson 2001; Resnick 1996; Penner 2000; Sweeney & Sterman 2007), even among well-educated adults (Cronin, Gonzalez, & Sterman 2009), prompting a recent clarion call for new and innovative approaches and educational experiences capable of improving learners' understanding of complex systems (Sterman 2010).

In response to this entreaty, there has been increasing enthusiasm in the learning science and educational research communities for the notion that games (or pedagogies inspired by games) could represent a unique alternative intervention to model and instill systems thinking skills (Federation of American Scientists,2006; Gee 2003, 2007; Kafai 2006; Squire 2006, 2010). Such claims derive from the recognition that many games present players with intricate, multi-variable systems with a central problem to solve, rules to learn, and constituent components to negotiate. To master these systems, players must devise and deploy strategies for solving challenges, negotiating risks, and maximizing rewards in the context of the game – and often revise and rethink these strategies in the event of failure or unexpected occurrences as play proceeds. Because of their complex, dynamic nature, Zimmerman (2007) has argued that games should be effective tools for teaching "systems literacy," a mode of thinking that "stresses the importance of dynamic relationships, not fixed facts." In Bogost's (2007) view, games that effectively model systems could help players "learn to reflect on the natural or artificial design of systems in the material world." Likewise, Gee (2004) considers well-designed games to be "learning machines," in part because they can facilitate systems thinking.

To date, however, these claims have not yet been supported with evidence provided by controlled, experimental research testing for a causal relationship between game play and an increase in systems thinking aptitude. To this end, the present research marks the first attempt to show that a game could produce significant improvements to students' systems thinking performance following a single game play session. This work aims to build on promising early efforts in this area, which have offered detailed descriptions of the processes used by players to master the systems modeled by a particular game (e.g., Mann 1991; Squire & Barab 2004; Torres 2009). To illustrate, in their exploration of the video game *Civilization III* (Firaxis 2011), Squire and Barab (2004) showed that as students began to master the game's model of economic, environmental, military, social, and technological systems, they exhibited a shift away from simple "one variable solutions" to problems toward solutions incorporating multiple variables and leveraging the "unique affordances" of each. While this work is undeniably rigorous, thought-provoking, and even paradigm-shifting, it is nonetheless crucial to demonstrate that a well-designed game not only can increase players' understanding of the system modeled by the game itself, but also promote growth in players' *general* systems thinking capacity that manifests in contexts outside of the game. Providing such evidence was the primary impetus for the present work.

Moreover, in response to recent appeals among learning scientists for more nuanced, rigorous research identifying the features of games that have the greatest impact on learning (e.g., Foster 2008; Wilson et al. 2009), the research to be presented explored how one of the most fundamental components of a game – namely, its technological platform – might influence its efficacy and impact. In particular, the present work sought to answer one overarching research question: would translating a non-digital board game to a digital format affect players' game play experience and, consequently, the game's effectiveness as a tool for promoting learning and cognitive growth? Somewhat surprisingly, no empirical work to date has systematically explored the effect of technological platform on the dynamics or consequences of a game play experience; the present work aimed to take an initial step toward filling this noteworthy gap in the games and learning literature.

In addition, the present study aimed to investigate whether any divergences in learning and attitude change outcomes produced by the digital and non-digital game implementations would be accounted for by differences in the game play experience, in particular the amount and depth of communication and decision making exhibited by players of the two game variations. With this focus on analyzing the communicative activity of players, the present work takes it place alongside provocative and innovative work that has demonstrated the importance of analyzing the content and context of inter-user conversations in domains such as human-computer interaction (e.g., Dybkjaer, Bernsen, & Minker 2004), computer-mediated communication (e.g., Carenini, Ng, & Zhou 2007), and social media platforms (Chen, Nairn, & Chi 2011; De Choudhury et al. 2009). Collectively, this body of research has shown that capturing and analyzing the dialogue that occurs between users (or players) can provide valuable insights into the social dynamics and decision making processes that are evoked by particular communication modalities. In contrast, empirical investigations of the communication dynamics that occur within games, with a few notable exceptions (e.g., Aylett et al., 2006; Cheung, Chang, & Scott 2012; Drachen & Smith 2008; Ducheneaut & Moore 2004; Nardi & Harris 2006), are largely absent from the literature. The present study aimed to help fill this void by offering the first direct comparison of the conversational patterns exhibited by players of digital and non-digital game variations – and linking those patterns with players' ultimate success in mastering the system modeled in the game.

To address these questions, the present research compared two different versions of *POX: Save the People* (hereafter referred to simply as *POX*), a collaborative public health strategy game designed to model the role that vaccines play in preventing disease spread:

(1) *Non-digital POX*: a board game utilizing a realistic narrative of disease spread (see Figure 2) and (2) *Digital* POX: a nearly identical digital translation of the *POX* board game created for the Apple iPad (see Figure 1). This game was designed by the team at Tiltfactor Laboratory at Dartmouth College, and the impetus for this work was to investigate whether the two instantiations of the game (which originated as a board game and subsequently ported to a digital app) would yield divergent player experiences or outcomes.

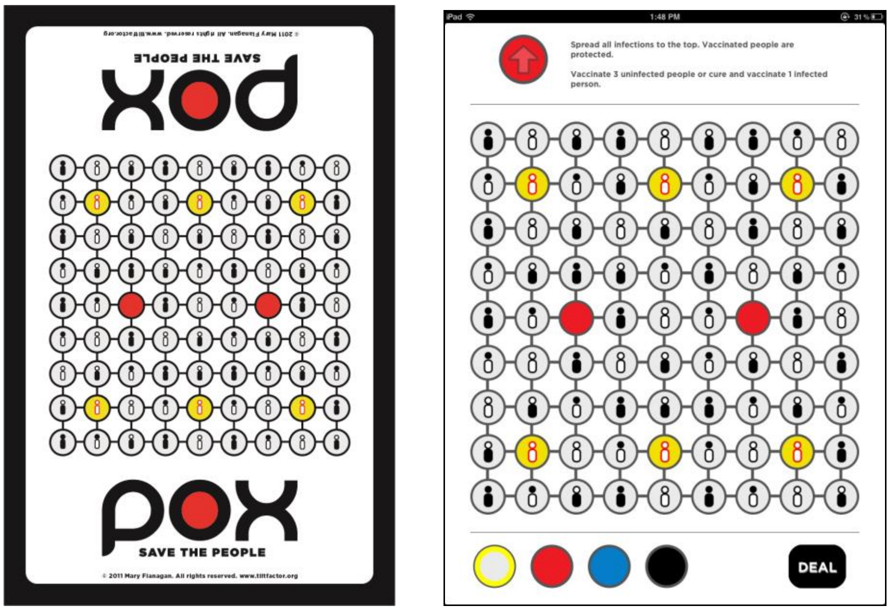


Figure 1: Non-digital (left) and digital game screen (right) for *POX*.

POX Rules and Gameplay

The design of the *POX* games was guided by the foundational belief that by modeling the impact of individuals' health and vaccination statuses on other members of their community, the game could effectively promote a general understanding of systems dynamics among players. The game is played on a grid of 81 (9x9) spaces, with each space representing one person in a community in which a communicable disease is beginning to spread. At the start of the game, two people are infected with disease; they are represented by two red spaces near the center of the board. As in real life, people with susceptible immune systems (e.g., pregnant women, babies, HIV+ individuals, cancer patients) cannot be vaccinated. These immunocompromised individuals, represented by six yellow spaces on the board/screen, are especially vulnerable. Thus, the game's "system" consists of a community of people whose vaccination, infection, and vulnerability statuses constantly affect one another – and the system as a whole – and thus drive players' decisions during the game.

Game play proceeds as players alternate drawing cards from the *POX* deck. Each card provides two pieces of information. The first tells players how the disease will spread during the current turn; the second describes the public health resources that are available to be deployed. As the game progresses, players must effectively allocate public health resources to obstruct, and ultimately halt, the disease's progress. In this way, the game models fundamental public health decisions and dynamics around which players must collaboratively attempt to form a winning strategy to stem the spread of the disease.

The game features two types of events that might occur each turn: "Spread Cards" describe the way the disease spreads from those infected, while "Outbreak Cards" reveal new manifestations in the disease. Spread Cards direct players to spread the disease in either one or two directions from those spaces that are already infected. For example, if players draw a card that instructs them to "spread all infections to the right" they must place a red chip (which signifies infection) on every non-vaccinated person to the right of an already infected person Once all new infections have been placed, players must decide either to vaccinate three uninfected people on the board, or to cure one infected person (see Figure 2). If an Outbreak Card is drawn, this means the disease has manifested in a previously healthy person who is not adjacent to an already infected person. Working within the constraints specified on the card, players must select a person on the board to infect. After an outbreak occurs, players are able to vaccinate one uninfected person (see Figure 3).

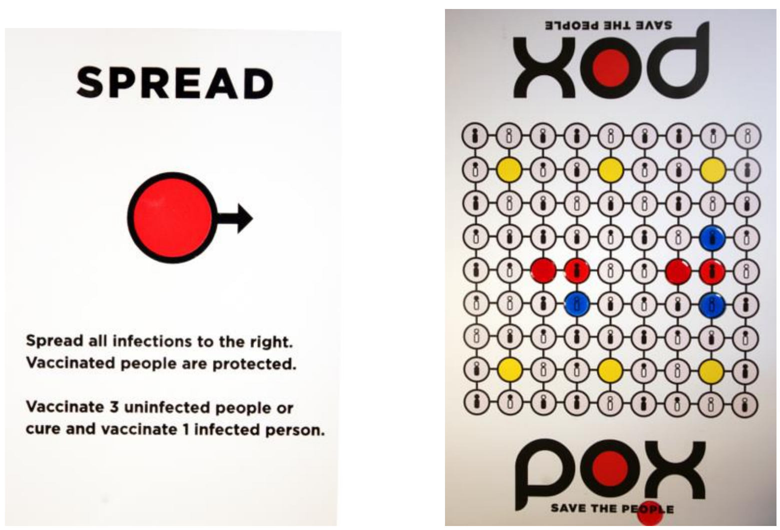


Figure 2: If this Spread Card were drawn to begin the game, both initial infections would spread to the right. In this case, the players have decided to vaccinate three uninfected people.

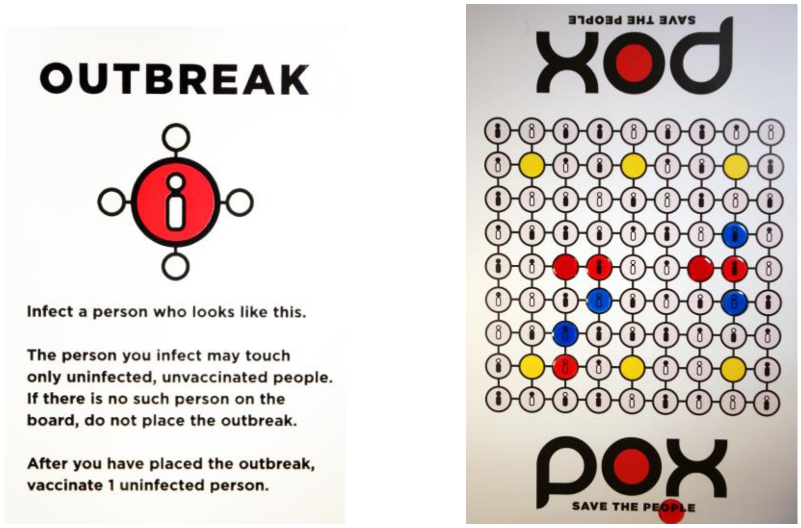


Figure 3: With this Outbreak Card having been drawn, players have chosen where to place the new infection and selected one new person to vaccinate.

The mechanics of *POX* aim to illustrate how quickly disease can spread, especially if players opt not to prioritize vaccinating the uninfected over the alternative of curing the infected, when given the choice. Players win the game if they are successfully able to surround infected people on the board with vaccinated people, so that the disease can no longer spread in any direction, before a pre-determined number of characters die (see Figure 4). In the game, death occurs in one of two ways: (1) an infected person is surrounded on all possible sides by other infected people or (2) the disease spreads to any immuno-compromised person.

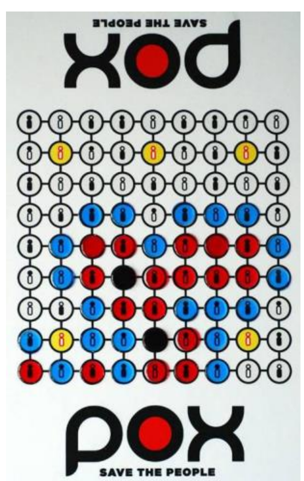


Figure 4: A game win state: infected people are surrounded on all sides by vaccinated people.

To master the system successfully, players must learn to navigate the game system's constantly fluctuating state (due to changes in vaccinations, infections, and deaths that occur with each new Spread and Outbreak Card that is drawn). Thus, players who understand the system well would be able to recognize the impact of their play decisions and strategies (e.g., the choice to vaccinate versus cure, the optimal location to place outbreaks, the need to protect vulnerable community members, etc.) on the rate and direction of the changes to the system that occur.

Overview of the Present Research

The present research aimed to determine whether varying the platform of *POX* would affect the game play tendencies of players as well as the game's efficacy in achieving its aims to promote a growth in players' systems thinking ability and greater prioritization of vaccination as a strategy to curb disease spread. To ensure a fair and systematic comparison, the two versions of the game used in the present study were designed to be *as similar as possible* in appearance, rules, and content. Specifically, the *only* differences between *Non-digital POX* and *Digital POX* were those dictated by their respective platforms. In place of the card deck, the digital version featured a "Deal" button, which players tapped to reveal the next event card, and displayed the card text at the top of the screen. In all other respects, the game's graphics were identical. Likewise, in lieu of the physical chips used in the non-digital version of the game, the digital version featured color-coded circles, which players could tap to select chips and then place them. In addition, the same pre-determined sequence of event cards was used for all three versions of the game.

METHOD

Participants

Eighty-eight U.S. students (23 females and 16 males, ages 11 to 17) were recruited with flyers distributed in middle schools and high schools. The provision of written consent from both students and their parents or guardians was a prerequisite for participation. Study sessions took place at students' school facilities, with participant pairs comprised of previously acquainted students from the same class.

Materials and Procedure

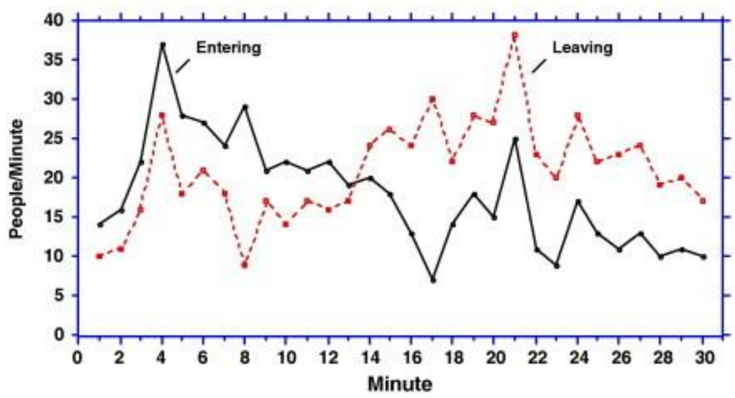
Participants were randomly assigned to one of three experimental conditions, represented by the two versions of *POX* – *Non-digital POX* versus *Digital POX* – and a control condition, in which participants completed the dependent measures (described below) prior to playing the non-digital version of *POX*. In the two game conditions, participants played their assigned version of *POX* in pairs, seated side by side in front of the game board or iPad, with a researcher explaining the rules of the game from a pre-scripted set of instructions. All game play sessions were audio-recorded, with the consent of participants and their parents or guardians, for later transcription and analysis.

The following measures were administered to participants individually in a paper-and-pencil questionnaire. Full instructions for completing each measure were provided within the questionnaire.

Systems Thinking Aptitude

Participants first completed the Department Store Task (Sterman 2002), a validated instrument used to assess respondents' systems thinking performance. This measure presents a pair of line graphs depicting the inflow and outflow of shoppers in a store during every minute of a 30-minute interval and poses four specific questions to respondents (see Figure 5). The first two questions – "When did the most people [enter/leave] the store?" – assess respondents' ability to understand the graph and successfully differentiate between inflow and outflow. The third and fourth questions – "When were the [most/fewest] people in the store?"– evaluate the extent to which respondents can infer the relationship between the two key components of the system: the inflow and outflow of customers. This measure was selected for the present study as a strong test of players' ability to transfer their understanding of the system modeled by the game to the novel system depicted in the instrument's graph. That is, higher post-game scores on this task would indicate a growth in players' general ability to understand and navigate complex systems.

The graph below shows the number of people *entering* and *leaving* a department store over a 30-minute period.



Please answer the following questions.

Check the box if the answer cannot be determined from the information provided.

1. During which minute did the most people enter the store?

   Minute ________ ❑ Can't be determined

2. During which minute did the most people leave the store?

   Minute ________ ❑ Can't be determined

3. During which minute were the most people in the store?

   Minute ________ ❑ Can't be determined

4. During which minute were the fewest people in the store?

   Minute ________ ❑ Can't be determined

Figure 5: The Department Store Task (Sherman, 2002)

Subjective Valuation of Vaccination

As an indicator of participants' relative valuation of vaccinating versus curing as a strategy to quell disease spread, participants were asked to imagine that they were the head of the World Health Organization and to respond to the following hypothetical scenario:

> *You just received a $10,000 donation to help combat a deadly disease. You must decide how much of that $10,000 to give toward* ***finding a cure for the disease*** *and how much to give toward* ***vaccinating uninfected citizens against the disease****. What would you do??*

Participants were instructed to write their respective allocations for finding a cure and vaccinating uninfected citizens on separate lines on the questionnaire. Similar allocation measures have been widely used in fields such as economics, judgment and decision making, and psychology, as a valuable tool for assessing the subjective value individuals place on particular alternatives (for a review, see Ajzen & Driver 1992; Fischoff 1991).

RESULTS

Because participants were run as dyads, and it is impossible to rule out the possibility of nesting (i.e., higher correlations between participants' responses and performance outcomes in each dyad compared to the outcomes that would have emerged had participants been run individually), we averaged the scores between each dyad's members and analyzed all results with the *dyad* as the unit of analyses (resulting in k = 15 pairs in the digital game condition and no-game control condition and k = 14 pairs in the non-digital game condition).

Systems Thinking Aptitude

Dyads' scores on the four items of the Department Store Task were summed to form a composite measure of systems thinking aptitude (with possible scores ranging from 0 to 4). A planned contrast revealed that participants in the *Non-digital POX* condition (M = 2.58, SD = .79) significantly outperformed participants in the no-game control condition (M = 1.53, SD = 1.13), t (43) = 2.61, p < .02, d = 1.08. Participants in the *Digital POX* condition (M = 2.14, SD = 1.02) also earned a higher average score than did participants in the control condition; however, this difference was *not* statistically significant, t (43) = 1.57, p < .13, d = .56. Thus, relative to the baseline scores exhibited by the control group, the board game implementation of *POX* produced markedly better systems thinking performance from participants, whereas the digital implementation of the game did not.

Subjective Valuation of Vaccination

For purposes of analysis, a difference score was calculated for each participant's designated allocations by subtracting the dollar amount devoted to curing from the amount devoted to vaccinating; thus, positive values indicate a higher amount allocated to vaccinating versus curing. Planned contrasts showed that, compared to participants in the control condition, who, on average, allocated slightly more money to curing versus vaccinating (M = -76.92, SD = 2100.06), participants allocated significantly more money to vaccinating in the *Non-digital POX* condition (M = 3928.57, SD = 4047.11), t (43) = 2.68, p < .02, d = 1.24. In contrast, the difference between the mean allocation for participants in the control condition and the *Digital POX* condition (M = 1485.71, SD = 5121.13) was not significant, t (43) = 1.04, p < .30, d = .86. This finding replicates the pattern of results for participants' systems thinking performance, reported above, and shows that the non-digital version of the game, but not the digital version, significantly increased participants' prioritization of vaccination as a more resource-efficient strategy to curb disease spread.

In order to investigate whether participants' play patterns and tendencies might help explain this striking difference in the efficacy of the non-digital and digital versions of the game, the game play sessions in the two game conditions were compared on a number of key dimensions. To do so, the audio recordings of all play sessions were transcribed, with each game turn time-stamped and all spoken dialogue that occurred between players included in the transcribed file. For purposes of analysis, the game start time and end time were designated, respectively, as the point in the game when players drew the first card and the point when players acknowledged a win or loss state. In addition, in order to assess the volume and content of the conversation that occurred between players, any instance of a player simply reading the text of an event card verbatim was omitted from the transcription file.

Game Outcomes

Despite the fact that nearly all of the game particulars (such as the card sequence, player seating arrangement, etc.) were held constant between conditions, there nonetheless emerged a clear difference in the success rate of players of the two versions of the game. Specifically, whereas 5 of the 6 pairs of *Digital POX* participants *lost* the game (i.e., they did not successfully contain the spread of the disease before 5 deaths had occurred), 4 of the 6 pairs of *Non-digital POX* participants *won* the game (i.e., they successfully contained the spread of the disease). Next, the game play session transcriptions for each condition were coded and analyzed to determine whether this divergent rate of success in the game could be explained by the amount of dialogue and depth of strategizing displayed by players.

Game/Turn Length

A one-way analysis of variance (ANOVA) revealed that, on average, game play was significantly shorter in duration in the *Digital POX* condition (M = 9.65 minutes; SD = 2.31 minutes) compared to the *Non-digital POX* condition (M = 15.32 minutes, SD = 1.96 minutes), F (1, 28) = 21.01, $p < .002$. In addition, the average turn length (i.e., the time between drawing a card and implementing all actions and decisions dictated by the card) was significantly shorter among players of *Digital POX* (M = 55.44 seconds; SD = 12.73 seconds) than it was among players of *Non-digital POX* (M = 81.96 seconds; SD = 13.67 seconds), F (1, 28) = 12.09, $p < .007$. At the same time, the average number of turns did not significantly differ between the two conditions ($M_{Digital}$ = 10.5, $SD_{Digital}$ = 1.87; $M_{Non\text{-}digital}$ = 11.33, $SD_{Non\text{-}digital}$ = 1.37), F (1, 10) = .78, p = .40. Thus, despite the fact that players won (or lost) the game after a similar number of event cards in both conditions, the rate of play was significantly faster, and the length of play significantly shorter, among participants who played the game in the digital format.

Conversation Analyses

The amount and depth of between-player dialogue was analyzed in several ways. First, the average number of words spoken by participants to each other during each turn was calculated. This measure revealed that participants in the *Digital POX* condition spoke significantly fewer words per turn (M = 79.35, SD = 16.54) compared to participants in the *Non-digital POX* condition (M = 157.01, SD = 33.53), F (1, 28) = 25.89, $p < .001$. Closer inspection of the session transcriptions revealed a clear divergence in the content of players' conversations in both conditions. Specifically, players of the non-digital version of the game frequently engaged in discussion about the viability and possible consequences of alternative strategies, as the following dialogue sample illustrates:

> P2: I feel like we need to save the yellow because they're so weak.
> P1: So which should would we do?
> P2: Do you want to give this one up and just see if it takes him over and try to survive the other spreads or keep alive the other ones?
> P1: So basically just sacrifice him?
> P2: Okay, so let's put three surrounding this guy.
> P1: We don't need three because he's going to be safe with just two here and here.
> P2: No, we don't…um…but if you put one here, I think he's also safe, right? Or almost safe…
> P1: Unless we get another spread up, but we can take our chances…

In contrast, such exchanges occurred relatively infrequently among players of the digital version of the game who, instead, more often than not converged on the first solution offered by either player during each turn rather than engage in lengthy debate or deliberation. This pattern is evidenced by the greater frequency of affirmative utterances in the digital, compared to the non-digital, game condition. The word count analysis revealed that players of the digital variation of the game, compared to players of the non-digital variation, more frequently uttered words such as "yeah" (N = 194 vs. 69) and "okay" (N = 141 vs. 64), but less frequently used the word "because" (N = 15 vs. 47) in their conversations. These patterns support the general conclusion that participants who played the game in its digital form appeared to make their game decisions with greater haste (in the interest of seeking more immediate consensus) and with less consideration of the reasons or ramifications for those decisions.

As a more rigorous analysis of the depth of players' decision making, the conversations that took place during each turn of the play sessions were coded for the presence or absence of between-player discussion regarding the strategies and consequences for their chosen chip placements (for outbreaks and vaccinations/cures). Specifically, each turn in a given game was coded "0" if there was no evidence of discussion (i.e., players settled on the locations for chip placements without discussing alternatives and/or consequences) and "1" if the turn involved at least one utterance that referred to the reasons or effects of a chosen chip placement. This analysis revealed that a significantly higher proportion of turns featured between-player discussion in the non-digital game condition ($M = .59$, $SD = .11$) than in the digital game condition ($M = .43$, $SD = .13$), $F(1, 28) = 5.17$, $p < .05$.

DISCUSSION

Interpretation of Findings

Few learning scientists have systematically studied the psychological and educational impact of technological platform on engagement and learning, and, likewise, few game scholars have directly compared the play styles and game outcomes evoked by digital versus non-digital variations of the same game. Thus, the present study takes an important step toward demonstrating key differences in play tendencies (such as the speed of play, extent of deliberation, and need for "closure" for in-game decisions) prompted by nearly-identical digital and non-digital versions of a collaborative strategy game Moreover, the stark differences in conversation patterns (particularly in regard to the amount of between-player discussion and consideration of alternative strategies within the game) that emerged between the digital and non-digital game conditions were strong indicators of player success or failure in the game, reflecting a key platform-driven divergence in players' ability to master the complex system presented by the game.

To explain the significant differences in play and performance that emerged between the digital and non-digital games in the present study, the distinct affordances of each platform must be taken into account, particularly in regard to the cognitive processes triggered by digital and non-digital experiences. Specifically, the two platforms may automatically activate distinct mindsets of mental "scripts" or schemas that influence how users approach and experience digital and non-digital games. For instance, players of digital games, and users of technology more generally, may be more accustomed to solitary use (i.e., interacting with the technology without a fellow user or co-player alongside them) and a faster pace of action and information delivery requiring a lower level of sustained attention or concentration.

In contrast, players of non-digital games may be more inclined to expect an experience shared with at least one other player (and, consequently, one involving more between-player conversation) that is more slowly and deliberately paced. Moreover, the use of physical objects (e.g., chips or tokens) in a non-digital game might serve as a game equivalent to a "talking stick," permitting clear and embodied assignation of roles between players. The use of actual physical tokens in the hand may have thus slowed down play and allowed more turn taking in conversation, creating less rush and more room for each player to engage in thoughtful discourse (Ranzijn & McConnochie 2012). To the extent that thoughtful, meaningful deliberation and between-player collaboration are essential ingredients for successful game play with games like *POX*, which present fairly complex systems to players, these divergent play styles and mindsets could explain why participants who played the digital version of the game were less successful in negotiating and mastering its intricacies.

Follow-up studies are underway to explore and disentangle these various hypotheses for the cross-platform divergences observed in this study. This research has revealed, as the present findings themselves imply, that individuals who were assigned to read information on a digital device exhibited a lower level of cognitive construal (i.e., a more concrete and less abstract interpretive focus) compared to individuals who were assigned to read the same information in a non-digital format (Kaufman & Flanagan 2016). That is, the tendency in the present research for players of the digital version of the game to favor immediate, localized solutions to the game's disease spread events – and to be less inclined to consider the downstream consequences of their decisions – appears to be due at least in part to the generalized tendency for digital platforms to activate more concrete and less abstract mindsets and processing styles.

Applications of Findings

In addition to being the first empirical study to demonstrate a game's ability to foster improved systems thinking performance, the present research adds to a growing body of work that has demonstrated the general value of games as effective tools for education, revealing significant gains for learners in subjects ranging from mathematics (e.g., de la Cruz, Cage, & Lian 2000; Ke & Grabowski 2007; Kebritchi, Hirumi, & Bai 2011; Peters 1998) and vocabulary (e.g., Din & Calao 2001; Yip & Kwan 2006), to engineering (e.g., Coller & Scott 2009) and computer science (Papastergiou 2009), resulting from game play. Such results attest to the use of games in both formal and informal learning contexts as a worthwhile supplement to traditional instructional techniques by demonstrating that games not only can increase players' understanding of important and timely issues, such as the role of vaccination in public health, but also promote an increase in their general cognitive abilities. At the same time, the striking cross-platform differences in game play patterns and subsequent learning outcomes that emerged in the present study suggest that the choice of game – and platform – must be considered thoughtfully and with consideration of the potential impact of this choice on the game's intended efficacy and impact.

How might designers of digital games, and human-computer interactions more broadly, apply the findings from the present study, particularly in the creation of games or learning experiences that involve complex systems or mechanics? The reported results demonstrate that simply changing the platform of the game had a significant impact not only on player experience but also on player outcomes. It seems clear that variables such as the time spent formulating strategizing and conversing are vital to understanding and mastering the intricacies of such games and, thus, are inextricably tied to effective problem solving and successful game completion. With this in mind, designers may wish to consider ways to build in opportunities to facilitate deliberation, encourage patience, and moderate the pace of play. For example, the use of pre-game instructions or in-game prompts for reflection or deliberation and timed "decision periods," game mechanics or events that facilitate the scaffolding or shepherding of inter-player communication and discussion, and reminders or reinforcements at game end, are some potentially fruitful methods that our team will be testing in future research.

CONCLUSION

In addition to being the first study to provide empirical evidence for a game's ability to improve players' systems thinking ability, the present investigation also demonstrated a host of striking differences in the play experience and outcomes evoked by digital and non-digital game implementations. The reported findings should signal to educators, policymakers, and practitioners alike that games can be effective tools for enhancing higher-level forms of cognition and learning, as well as for augmenting health and wellness programs and campaigns. At the same time, these results point to the need for further investigation into the efficacy of digital games in learning domains; the present work represents just the first step toward understanding the constraints and affordances that are unique to digital versus non-digital platforms. Going forward, the intersecting fields with a vested interest in games for impact needs a better understanding of the instinctive, unconscious practices that are invoked by digital game platforms as they are increasingly being utilized and implemented in both formal and informal learning settings. This study offers several novel contributions that advance this understanding. First, it is the first systematic comparison of conversations across digital and non-digital versions of the same game. Second, it provides a link between those conversation and decision making patterns to game performance and game system mastery. These results demonstrate that between-player communication can be both a predictor of success and a cue for designers and educators alike for predicting player experience and game play outcomes. The simple translation between digital and non-digital formats can dramatically change play dynamics, speed of play, depth of player conversation, game success, and, ultimately, learning.

ACKNOWLEDGMENTS

We acknowledge the contributions of our team of research assistants at Tiltfactor Laboratory for their invaluable efforts in collecting, coding, and analyzing the data.

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