The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/2398-5348.htm

Defining perplexity and reflective thinking in a game-based learning environment

Ekta Shokeen, David Weintrop, Anthony James Pellicone, Peter Francis Moon, Diane Ketelhut, Michel Cukier and Jandelyn Dawn Plane
(Author affiliations can be found at the end of the article)

Received 11 October 2022
Revised 3 February 2023
Accepted 1 March 2023

Abstract

Purpose – The purpose of this paper is to understand the role of perplexity in young players' experiences within an educational videogame and how reflective thinking can help them to get out of perplexing scenarios.

Design/methodology/approach – We used a constructivist grounded theory approach and the lenses of Dewey's conceptualization of perplexity and reflective thinking to examine young players' in-game experiences.

Findings – We find that perplexity in gameplay is an experience that occurs when players encounter uncertainty about where to go or what to do next in the game. Findings reveal that while playing an educational game players engaged in two forms of perplexity – exploration-based and puzzle-based. Additionally, we unpack how players overcome these perplexing scenarios by reflecting on the information provided in the game.

Research limitations/implications – While in a state of perplexity, reflecting on the in-game information aids players to think and make meaning, thus supporting learning. We provide suggestions for how to better utilize perplexity as an in-game design mechanism to encourage young players to reflect on in-game information.

Originality/value – This empirical study is original in its context of studying the phenomenon of perplexity in videogames and young players' in-game reflection experiences.

Keywords Perplexity, Reflection, Reflective thinking, Learning, Videogame

Paper type Research paper

Introduction

Research on game-based learning (GBL) finds that navigating in-game environments enhances students' problem solving, reasoning, decision making and computational thinking abilities (Adachi and Willoughby, 2013; Gee, 2003; Zhao and Shute, 2019). Learning is inherently situated in gameplay experience (Shute and Wang, 2015; Williams-Pierce, 2019), and students learn by responding to their failures within in-game challenges (Juul, 2013; Slovák *et al.*, 2017; Cox *et al.*, 2012; Nordin *et al.*, 2014; Koster, 2013). Further, in-game challenges motivate students to find solutions (Adachi and Willoughby, 2017; Hamlen, 2018). Recent research indicates that attending to players' in-game reflection can improve learning opportunities for players (Iacovides and Cox, 2015; Khaled, 2018; Mekler *et al.*, 2018). It is well known that due to a lack of knowing what to do next in the game, students

The authors acknowledge the funding support of the [Anonymized]. Also, The authors thank the students who participated in this study for sharing their experiences with us.

Information and Learning Sciences
© Emerald Publishing Limited
2398-5348
DOI 10.1108/ILS-10-2022-0112

experience "pleasant frustration" while playing games (Gee, 2003). However, sometimes students experience unproductive frustration while solving in-game challenges (Odgers *et al.*, 2020; Shokeen *et al.*, 2021). Currently, little is known about why some in-game challenges bring productive frustration while others bring unproductive frustrations. It is unclear what game elements make players productively reflect during gameplay and what game elements do not promote this type of productive reflection. Therefore, there is a need to further examine students' in-game interactions to improve their learning opportunities within games. It is this gap in the literature that we seek to fill by examining students' experiences of in-game perplexity and reflective thinking experiences. Specifically, this work pursues the following research questions:

RQ1. What forms does perplexity take for youth in a videogame-based context?

RQ2. What does it look like for learners to employ reflective thinking to resolve in-game perplexity?

To answer these questions, we used a constructivist grounded theory approach to analyze 17 middle-school students' experiences playing an educational game called *HEX of the Turtle Islands* (hereafter referred to as *HEX*). We focus on understanding middle school students' gameplay experiences as this is a critical age for cognitive development (Ellis, 2014; Hazar and Hazar, 2018). To develop the construct of perplexity within the GBL, we utilized Dewey's lenses of perplexity and reflective thinking (Dewey, 1933). We related in-game challenges, a state of pleasant frustration in-game, to *perplexity* and *reflective thinking* as a way to get out of the perplexing scenario in videogames. Our findings indicate *what* the construct of perplexity looks like within gameplay and how a systematic reflective thinking cycle can be used as an analytical lens for understanding how players resolve perplexing experiences within gameplay.

This work presents a promising avenue of research for educators and designers by discussing how perplexity can be situated within a game to encourage students to reflect on the ideas presented in the game. Thus, this work contributes to GBL in two ways. *First*, it provides implications on how perplexity-inducing experiences can be designed within a videogame. *Second*, it suggests how designers, researchers and educators can scaffold students' reflective thinking processes by identifying where and how they might be struggling in the perplexing scenarios within games. These findings show how well-designed perplexity-inducing experiences within a videogame allow players to employ the process of reflective thinking and, as a result, serve as generative learning experiences.

Literature review

First, we review the GBL literature related to in-game challenges and theoretical framing of *perplexity* and *reflection* for this study. Second, we review how the concept of reflection has been used in prior gaming research and provide an updated version of reflective thinking used in this study.

In-game challenges in game-based learning

Games are built on adaptive levels of challenge for players that require them to think, which makes them a powerful learning tool (Gee, 2003; Squire, 2006). Failure in games is considered an opportunity for players to learn from their mistakes using continuous feedback provided to them on their failures (Juul, 2013; Williams-Pierce, 2019; Zhao and Shute, 2019). A wide variety of game genres provide in-game challenges in the form of puzzles for players (Shute and Wang, 2015; Scozzi *et al.*, 2017; de Freitas, 2018). Puzzles often

provide "pleasantly frustrating" experiences that both challenge and reward the player (Gee, 2007). However, sometimes players are reported to have negative experiences during gameplay which leads to unproductive frustration (Gibson *et al.*, 2022; Anonymized, 2021). Thus, the design of in-game challenges and supports can contribute to productive or unproductive frustration among students during gameplay (Shokeen *et al.*, 2020; Anonymized, 2021). Thus, there is a need to identify the moments and design mechanics which provide unproductive frustration to improve the design of games.

For this study, we adopt Dewey's conceptualization of perplexity, from educational philosophy, as a psychological process of cognitive growth (Berlyne, 1960; Dewey, 1933). Dewey (1933) defines *perplexity* as a temporary situation in which the learner gets disturbed and confused. Related, *reflection* is conceptualized as an:

> Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends (Dewey, 1933; p. 9).

In states of perplexity, a learner's mind is challenged, and the process of reflective thinking begins which is categorized as an ability to direct the course of subsequent experiences by adding meaning to the experiences (Dewey, 1933; Rodgers, 2002). Berlyne (1960) further clarifies Dewey's use of perplexity as one kind of conceptual conflict by having several mutually exclusive beliefs with no way of knowing for certain which is true, different factors simultaneously support and inhibit each of the alternative beliefs. According to this theoretical framing, perplexity in gameplay can be related to a temporary state of confusion when students experience an uncertainty about how to proceed and what to do next in the game. These perplexing moments can be related to the "pleasant frustrations" due to "in-game challenges" which require students to *reflect* on their actions in reference to the information provided to them in the games. Combining perplexity and reflection provides insight into students' meaning-making processes in-games. In the context of a single player education game, reflection needs to happen during students' interactions with the game. In this sense, perplexity can be considered the beginning of challenging students to reflect on their actions in games. Thus, by attending to when students feel perplexed in the game and how they make sense of in-game information, designers and educators can create in-game experiences to support their learning about both gameplay and the conceptual information embedded within that gameplay.

Reflection in game-based learning

GBL research suggests games can be useful for reflection in the context of social-emotional learning (Slovák *et al.*, 2017). Prior studies show that performing postplay debriefing sessions (such as a blog discussion) can push players to reflect on the required learning outcomes (Crookall, 2010; Choontanom and Nardi, 2012; Marsh and Costello, 2013). While these forms of reflection are generative for the player, they are external to the gameplay, and it is unlikely that all games inspire players to engage in these forms of reflection. Iacovides and Cox (2015) found two types of reflection that occur in games – a reflection that occurs within the moment of play (reflection in-action) and reflection that occurs after a gameplay session (reflection on-action). This kind of categorization of reflection focused on times *when* players reflect in the game (whether it is during the gameplay or post-gaming) rather than *how* players reflected; it lacks insight into the process of reflection in the gameplay. Shute *et al.* (2016) provided a quantitative assessment tool for measuring players' moves and actions within gameplay, yet there is still a lack the understanding of the relationship between players' specific moves and the process of reflection taken during the game.

In regard to promoting reflection in game design, previous work suggests that several game design mechanics can facilitate reflection such as deliberately subverting players' expectations of what constitutes a game; narratives and roleplaying (Khaled, 2018; Ortiz and Harrell, 2018). Adult players' experience of reflection (e.g. dialogic, transformative) in commercial gameplay indicates that the levels of reflection cannot be conflated with the benefits of reflection (Mekler *et al.*, 2018). Based on prior literature claims in-game reflection can be both measured and designed for; however, little is known about the processes of youth in-game reflection in the GBL.

Building on prior work on reflection in GBL, a recent study proposed a breakdown of the process of reflective thinking into six distinct phases to better understand the process of reflection in GBL (Shokeen *et al.*, 2022). These distinct phases are useful to identify where a student might be struggling to complete their reflection of in-game actions. As discussed above, perplexity is the origin of reflection for students in GBL. Therefore, to understand how students deal with the moments of perplexity in-games, we utilized these phases of reflective thinking to analyze young players' reflective experiences within the gameplay. These six phases are:

(1) *Phase 1:* Initial Interaction: players' initial interaction with the game.

(2) *Phase 2:* Spontaneous interpretation: players spontaneously make an interpretation based on their initial interaction with the game such as what is going to happen next and how the game mechanics and dynamics will work.

(3) *Phase 3:* Identifying the problem(s): players identifying and naming the problem(s) arising from their experience. It may require players to move from an impressionistic "sense" of things to articulating ideas based on evidence from experiences.

(4) *Phase 4:* Generating possible explanations: players synthesize some potential explanation of the meaning derived from current experiences for the problem(s) that they have identified in Phase 3.

(5) *Phase 5:* Hypothesis: players develop their explanation generated in Phase 4 into a fully developed hypothesis based on their current understanding of the problem. It provides players a platform of reasoning and understanding from which they can take an action in the next step.

(6) *Phase 6:* Testing: players test their hypotheses by taking an action and the result of testing can be success or failure. If a player fails, then they may start another cycle of reflection to iterate their action until they succeed. If a player succeeds, then we can say that that player learned something about the game by engaging in reflective thinking using the information given to them in-game.

To summarize, the prior GBL literature recognized the relevance of promoting players to reflect on their in-game challenges and provided useful insights into how reflection may relate to the player experience to improve their learning opportunities in the games. Also, it is important to consider that most of the prior game studies on reflection are done on adult players in the context of commercial games (Mekler *et al.*, 2018; Ortiz and Harrell, 2018), and there has been little prior work done to unpack the process of reflective thinking in GBL with young players. There is still a lack of understanding on how we can encourage students to engage in reflective thinking during gameplay. Therefore, we focus on examining what perplexity looks like in gameplay experiences and how students employ reflective thinking to resolve in-game perplexity. Next, we discuss our method and the context for the study.

Methods

Context of the study

This empirical study is a part of a larger design-based research project study which uses GBL for introducing youth to the field of cybersecurity. Figure 1 describes the primary gameplay scenarios of the version of the game used in this study.

Description of the game

HEX is a single-player, two-dimensional adventure videogame that combines a rich narrative, exploration, and gameplay scenarios and puzzles rooted in cybersecurity concepts. The player takes on the role of a student on a work-study trip with an adult crew who is investigating ecological changes around a remote island chain called the Turtle Islands. During their research mission, their ship gets attacked by pirates who kidnap the adult crew. The player is tasked with saving the crew while also investigating a larger conspiracy involving an evil corporation. Throughout the gameplay, the player must solve problems to find out what is happening, rescue the crew, and help to save the world in the process.

There are three main mechanisms – narrative, exploration and puzzle – designed in the *HEX* to engage students with the various dimensions of the field of cybersecurity. For instance, a rich narrative is threaded in the design of *HEX* to immerse the player in the role of the main character in the ecological storyline. The narrative is unfolded to players through the mechanics of exploration embedded throughout the game to make players understand the various roles and responsibilities involved in the field of cybersecurity. During exploration, players interact with various non-playing characters located in various places in the game which guides them to the multiple challenges. Puzzles are also embedded in the narrative and exploration in a way that after solving the puzzle, players unlock new area in the game for exploration to proceed with the narrative of *HEX*. There are two types of puzzles – conceptual and exploratory – included in *HEX*. Conceptual puzzles are designed to introduce cybersecurity concepts (e.g. decrypting codes in Door puzzle, computational logic in the Wire puzzle) and exploratory puzzles (e.g. Box puzzle) to increase engagement with the game. The puzzles are designed with direct feedback, whereas the design of exploration had indirect feedback and limited guided information (e.g. arrows, highlighted paths, etc.) to instil in players a sense of freedom and choice to explore in the game environment.

Data collection

For this study, we recruited 17 participants (7 girls, 10 boys) in the age-group 12–15 years through a list-serve from a university located in a greater metropolitan area on the American East Coast, as well as via advertisements in local public libraries. The data was collected from 17 racially (3 Black or African American; 3 Asian or Pacific Islander; 7 White; 4 Not reported) diverse participants with varying levels of prior videogame experience – 2 *seldom* (rarely play videogames), 8 *occasional* (play once or twice a week) and 7 *frequent* players (play daily).

The data was collected through Zoom video calls hosted by a researcher, students shared their screen, and then played *HEX* while the researchers observed and asked questions. Each gameplay session was recorded. During each gameplay session, two or three researchers were present with one researcher leading the session and the other researcher(s) observing and taking field notes. After each session, both the lead facilitator and observers debriefed and combined field notes. All procedures were approved by a university Institutional Review Board. Parental consent and child assent were received from each

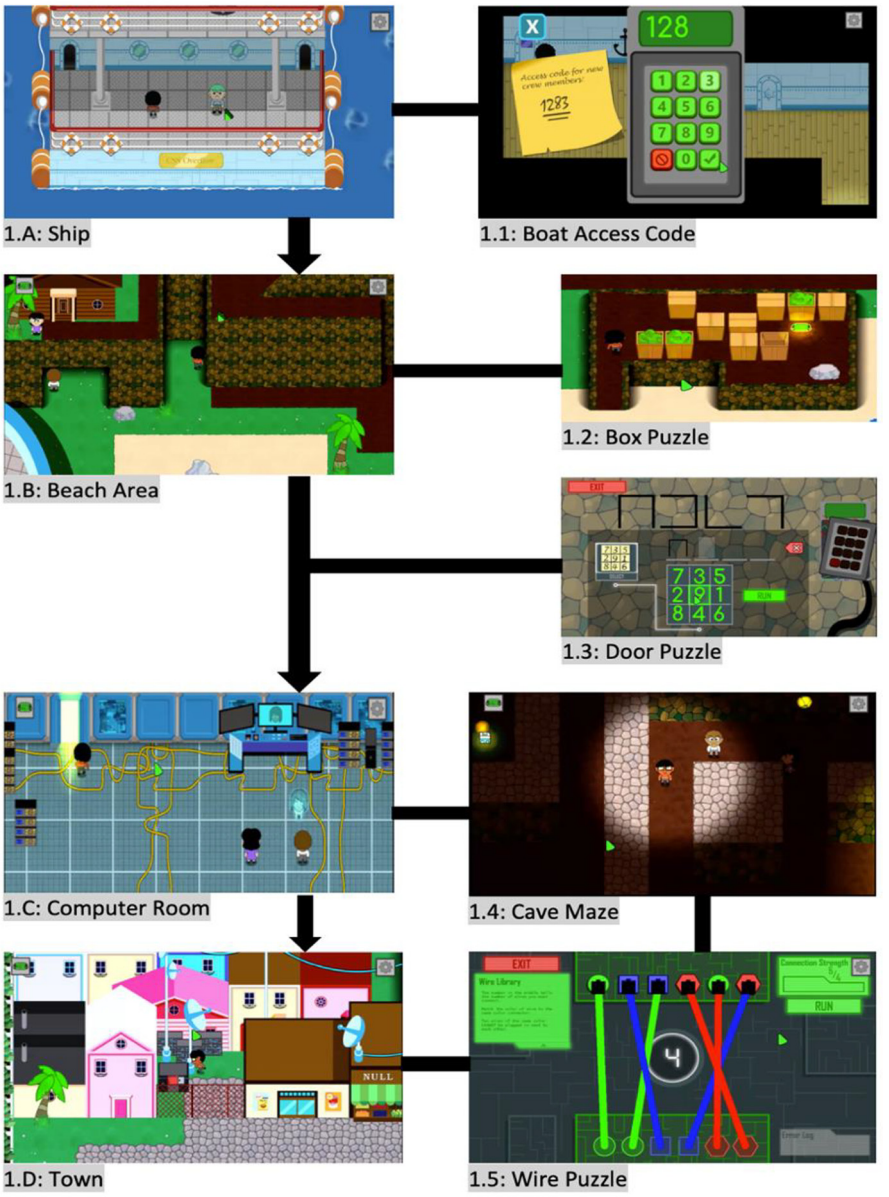

Figure 1.
A map of action through the game

Notes: Labels 1.A, 1.B, 1.C and 1.D represent locations that the player explores throughout the game, (The Ship, Beach, Computer Room, Cave Maze and Town). Labels 1.1, 1.2, 1.3, 1.4 and 1.5 represent puzzles that the player encounters in each location
Source: Figure by Authors

participant with their parent or guardian completing a short demographic survey. Participation in the study was incentivized by a $15 Amazon gift card. Also, to protect the identity of the participants, we have used pseudonyms names in this study.

Each of the data collection sessions was approximately an hour long including ~40 min of gameplay and ~20 min of the semistructured follow-up interview. The gameplay duration was measured based on when a player started and finished. The study employed the playing aloud methodology that invited participants to take on the role of a videogame streamer and talk through their gameplay experience to a pretend audience (Pellicone *et al.*, 2022). Gameplay sessions also included in-game testing prompts to get feedback about specific elements of the game from players. These in-game testing prompts appeared as questions on-screen at three different transition points within the game. The rationale behind having these in-game prompts was to get immediate feedback from the player just after they did something while not taking their attention away from the game itself to minimize the disruption to the on-going gameplay session. Participants responded to the prompts verbally before continuing their gameplay. During the gameplay session, participants were not interrupted by the researcher; however, they were encouraged to ask for help if they needed it. During the follow-up interview, participants were asked about their in-game experiences playing *HEX*. Interviews, included questions concerning the player's general impression of the game and its storyline, puzzles and frustrating and enjoyable incidences of playing the game.

Data analysis

To analyze the data, we used a constructivist grounded theory approach (Charmaz, 2006). All video data were transcribed in accordance with observation notes to include both the gesture and the actions of players in gameplay sessions. The analysis process took an iterative approach (Charmaz, 2006; Strauss and Corbin, 1990).

We began the analysis process with the aim to understand the differences in players' experiences and their ways of approaching challenges in the game. We were particularly interested in understanding what challenges players faced and how they dealt with the in-game challenges? To identify and name each interaction in the game, one participant's video data was co-watched by two researchers in increments of one minute, with each one-minute section discussed by the two researchers. This process of open consensus coding was conducted to develop the initial set of codes and develop a shared understanding of their meaning to ensure reliability (Cascio *et al.*, 2019). Then, three rounds of independent coding were applied to the data including open coding, focused coding and axial coding (Saldaña, 2021).

First, through open coding, we identified consistent patterns of where and how players were challenged with different elements of the game and how they overcame those challenges. During open coding, we found players had different experiences; some expressed liking the openness during exploration, while others showed preferences toward direct instruction and feedback. To better understand these differences, a focused codebook was developed based on this emerging theme and informed by background knowledge about GBL [See Appendix]. These focused codes were interconnected; for example, the excerpt coded for "perplexity" was further coded for "location of perplexity" and the "reflective thinking cycle phases".

Second, we applied the identified codes to label the recurrent categories of data. After identifying different forms of perplexity that take place for youth in a videogame-based learning context and to further investigate how players dealt with perplexity, we applied another round of coding, using codes from an adapted version of Dewey's reflective thinking

phases (Shokeen *et al.*, 2022) to understand their approaches to overcome these perplexing scenarios in gameplay.

Finally, we conducted a round of axial coding to bridge themes and get a broader sense of the structure of the data in reference to our research questions. The flexible structure of the grounded constructivist method was useful to answer our research questions about players' experiences with perplexity and reflective thinking in gameplay.

Findings

First, we present what perplexity looks like in gameplay and provide two forms of perplexity – exploration-based and puzzle-based. Second, we present two vignettes showing how players overcome perplexing scenarios using reflective thinking in gameplay.

Perplexity in gameplay

In answer to the first research question – *What forms does perplexity take for youth in a videogame-based context?* We found that players experienced perplexity in a form of temporary uncertainty about how to proceed during gameplay. In total, we identified 39 instances of perplexity in our data. These instances then served to provide players with opportunities to think critically about their current situation and how to proceed. Our analysis identified two in-game forms of in-game perplexity – *exploration perplexity* (21 occurrences) and *puzzle perplexity* (18 occurrences). Additionally, we found that players with less prior gameplay experience (seldom or occasional) were more likely to be perplexed while exploring the game-world than their peers with greater prior gaming experience. These perplexity experiences during gameplay provided opportunities for players to reflect on their current in-game situation and think critically about how to proceed in the game. In the following sections, we further explore these two forms of perplexity and how players respond to them.

Exploration perplexity. Exploration perplexity describes an experience when players encounter uncertainty related to where to go next in the game. This perplexity is a feature of nonlinearity in the game narrative where players must explore the game world to figure out how to advance. In *HEX*, the ship and the beach (Figure 1) both present the player with a situation where they must explore the game world, and thus the player may experience perplexity in exploration. For instance, Daniel encountered perplexity when he landed on the beach from the ship and talked to the two friendly non-player characters (NPCs) who directed him to go to explore. Daniel was observed to be confused at this stage; while considering his options he commented:

> Well now we have to go up to the other place um, we have to find a house, where is this house? Oh, never mind we can't go that way. This way does not seem like the right way. Where in this world do I need to go? Well, I guess [the level is] less straightforward now. So that's nice.

His in-game commentary shows that the "right" next step in the game was ambiguous, which lead to uncertainty, but that he appreciated the level's design which was less straightforward than the previous segment on the ship. In another example, when Arya was observed becoming perplexed during her gameplay, she commented, "*They* [NPCs] *asked me to look for the notes. I do not know where I'm supposed to go.*" After exploring for a few minutes in the room, she figured out the exit from the room she was in, and commented, "*There's an entire other room! I honestly did not see that until now. Okay.*" During the prompt "what just happened on the ship?" she responded, "*I was stuck in the one room, and I didn't realize that I could leave so I was there for like five minutes. And then there [. . .] was like a storyline.*" Her responses emphasize that she was able to follow the storyline and interact

with NPCs to understand what to do, but the exploration mechanism in the game made her feel perplexed while exploring the game-world of *HEX*.

We also found some players appreciated the scenarios where they got confused and did not have a clear sense of where to go or what to do next in the gameplay. For example, in the interview when asked about what he liked and disliked in the game, Thomas responded, "*Alright, so I like the fact how* [*HEX*] *is a mystery game. I like mystery games because* [they] *make you think*." Thomas also briefly described a similar "mystery" game he was currently playing on another system. Thomas's response highlights that he likes the elements of the game that he identifies as being similar to other games he's played in the past – a genre he identifies as "mystery games". On the other hand, we found Arya expressing doubt about her abilities while exploring the game world. She was observed commenting, "*I might just not have like common sense, but I have not been able to figure out the first few things*". Throughout her gameplay, she found perplexed multiple times and asked the researcher to help her get out of those perplexing scenarios. Thomas reported himself to be an experienced player, whereas Arya shared that her prior experience with gameplay was limited to just one game. These findings suggest that previous gameplay experience modulates players' responses to perplexity, where players with more experience may enjoy perplexity and those with lack of prior gaming experience may perceive it as negative feedback on their abilities.

Perplexity in puzzles. Puzzles are the other primary source of perplexity, as our analysis revealed. Players experienced perplexity when they were confused about how to solve a particular puzzle. For example, we found Adam getting perplexed while solving the door puzzle [Refer to (Figure 1.3)]. During gameplay, he was observed making multiple clicks on the cipher keypad and commented, "*It's a puzzle with some twists*". Similarly, Arya was also found to be perplexed while solving the door puzzle, as during gameplay we observed her commenting "*Okay, I'm confused. There are four numbers, but there's this keypad that matches up*." After a while, she realized, "*Oh! Okay. This* [the shape that corresponds with number in cipher] *matches up with that* [the shape code given on the top]." After solving the puzzle, she commented, "*I just realized that what this code meant. I definitely didn't understand it before*." Her response suggests that the door puzzle was perplexing for her at first, however after thinking through it she was able to make sense of how to solve it. Additionally, Ben was found getting perplexed while solving the door puzzle [Refer (Figure 1.3)]. He shared in his interview that the door puzzle was confusing for him at first, and it took him a while to figure it out. He said, "*my favorite was the one where you had to figure out the number pad* [the door puzzle] *to get into the computer room because I couldn't figure it out for a little bit. I was like, how am I supposed to do this, and then it just clicked, and I was able to get it*." We found Adam, Arya and Ben perplexed while solving the door puzzle, and their response elaborated on the temporary confusion that they experienced while solving the door puzzle.

We found that players' experiences with perplexity while solving puzzles differed. For instance, we observed Sahil felt perplexed while solving the wire puzzle, but Ben solved the wire puzzle on his first attempt. In reference to solving the wire puzzle, Sahil said in his interview that "*The* [wire puzzles] *weren't hard because I mean, the task itself is easy, but, like, how to do them* [solving the puzzle] *is hard. So, it was like, good. Like, connecting wires are easy, like just dragging them on* [the port]. *But like remembering the rules for each one wasn't* [easy]." In this example, Sahil emphasized that the task of connecting wires by dragging them from one port to another was not confusing, but remembering the given set of rules while making the connection of wires made it perplexing for him. Some other players were perplexed when they were solving the box puzzle. For example, we observed

Sahil getting perplexed as he was trying to move the boxes, he commented, "*Looks like there is not much. I am stuck here*". After a while, he figured out that he could push the boxes to reach the device hidden beyond those boxes. In his initial exploration, he was found temporarily perplexed, but later he figured out how to get out of that area. To further investigate differences in players' approaches to dealing with perplexity, we analyzed players' interactions in-game using reflective thinking phases (Shokeen *et al.*, 2022), which we present in the next section.

Encountering perplexity

In response to the second research question – *What does it look like for learners to employ reflective thinking to resolve in-game perplexity?* We found participants engaging in reflective thinking while figuring out their solutions to overcome perplexity. For instance, during the interview when asked about Arya's approach to solving the door puzzle [Refer Figure 1.3], she responded that, "[. . .] *I was like, guessing and checking all* [digits], *I figured out each of the symbols wasn't the number. But like, I didn't realize [. . .] the boxes corresponded with the sheet they gave us [. . .] until the last number*." Her response reveals her initial strategy for resolving her perplexity (guess and check), but then she was reflecting on her actions to figure out the puzzle mechanism as she kept working. However, we found that the process of reflective thinking to overcome perplexity was not consistent across players. We found 14 occurrences where participants asked for external help.

To further investigate the differences between participants' ways of reflective thinking, and why certain participants needed external help, we applied Shokeen (2022) modified version of Dewey's reflective thinking phases as an analytic lens. Based on that, we found some players went through all six phases of reflective thinking, whereas others' reflective cycles were interrupted before overcoming perplexity. We also found those who did not complete the cycle of six phases of reflective thinking were found making unproductive inferences and failed to identify the problem on their own at which point they felt stuck and needed external help from the researcher to advance in the game. Below, we present two vignettes from the same location in the game to demonstrate differences in players' approaches while they experienced Exploration Perplexity. These vignettes have been chosen as representative samples to highlight the differences in players' reflective thinking approaches while navigating the same perplexing location in the game – Vignette 1 represents an example where a player goes through all six phases of the reflective thinking cycle, whereas Vignette 2 represents an example where a player's reflective thinking cycle is interrupted, and external help is requested by the player to overcome the perplexity.

Vignette 1: Encountering perplexity with reflective thinking. This vignette describes how Thomas encountered Exploration Perplexity while going from the Computer Room to the cave maze using reflective thinking phases. As he entered the Computer Room, he started his exploration by interacting with different objects. Then, he moved to the cave maze, where he explored and interacted with the inventory [where modules appeared once the player collected it and allowed the player to read them again] which gave him the information that he needed to find more wire modules. He searched for wire modules and solved the wire puzzle using information from them. Below, we show how Thomas went through the different phases of reflective thinking while resolving his perplexity during exploration.

- In Phase 1: Initial Interaction: Thomas entered the Computer Room, and he started exploring by interacting with the NPC faith.

- In Phase 2: Spontaneous interpretation: He made an interpretation, "So, this is like the mothership of the bunker – I guess". Thomas then moved to the next area of the game, a simple maze within a cave.
- In Phase 3: Identifying the problem(s): Thomas continued wandering around exploring to find more clues to make sense of what's going on in the cave. In the cave, Thomas found a malfunctioning device used to lower a ladder to town which needed to be fixed by the player. He interacted with the device (the first wire puzzle) which notified him about the error, which reads, ERROR: PROPER WIRE MODULE NOT FOUND. PLEASE INSTALL THE REQUIRED MODULE AND TRY AGAIN. After reading these messages, he identified the problem: finding more wire modules, so continued his search for more wire modules in the cave.
- In Phase 4: Generating possible explanations: During his search in the cave, he referred to the inventory to generate a possible explanation behind his search. Referring to the information in the inventory, he explains to himself, "These are wires that I'm looking for."
- In Phase 5: Hypothesis: He found the wire module and commented, "Thank you I will be taking this", and after collecting it, he went back to the ladder suggesting he had hypothesized that this was the missing module, and he would now be able to attempt the wire puzzle.
- In Phase 6: Testing: When Thomas tested his hypothesis and went back to interact with the malfunctioning wire puzzle, he was able to interact with the puzzle which then led to him being introduced to the next area of the game.

Here we found how designed features of the game narrative and environmental clues both led Thomas to a state of Exploration Perplexity but then also provided scaffolds to help him out of it as he progressed through the six phases of the reflection cycle.

Vignette 2: Encountering perplexity with external help. This vignette presents Sahil's approach to exploring the same sequence of the Computer Room and cave maze that Thomas explored in the previous vignette. When he reached the *malfunctioning device,* it gave him the same error that Thomas received about needing another wire module. Then he moved until he saw a wall and he interpreted this to mean that he had reached the end of the cave. This led him to ask a researcher to help him. Unlike Thomas, Sahil did not refer to the inventory to find clues but instead asked the researcher to guide him about what to do next. The researcher suggested he continue his search in the cave to find more wire modules. Here, Sahil was not able to identify on his own what he needed to do, so his reflection was interrupted when he asked the researcher for help. Interpreting these actions through the phases of the reflective thinking model, we can see where and how his reflective thinking process was interrupted.

- In Phase 1: Initial Interaction: Sahil's Exploration Perplexity started from the computer room where he interacted with Faith and moved to the cave area.
- In Phase 2: Spontaneous interpretation: In computer room, he didn't share anything aloud suggesting he had not made any interpretation there. He continued his exploration of the cave, he reached the malfunctioning device, and it gave him the same error as Thomas: ERROR: PROPER WIRE MODULE NOT FOUND. PLEASE INSTALL THE REQUIRED MODULE AND TRY AGAIN. He continued his exploration. After a while, he returned to the HEX device and interacted with it and received the same error as last time. Then he made an interpretation and shared, "That's the end of the tunnel I guess". His interpretation stopped him from exploring more, and he approached the researcher to help.

Here, Sahil's reflective thinking cycle was stopped due to his interpretation that he reached the end in the cave which led him truncating his exploration.

Comparing moments of perplexity based on information seeking behavior. We found that players' information seeking behaviors in the game play a critical role in shaping how they try to resolve encountered perplexity within the game. As demonstrated in the vignettes above, the same moment of perplexity was approached differently by different players. The main difference between their reflective thinking approach is their information seeking behavior, Thomas figured out that he needed to keep looking for information (via the inventory), whereas Sahil thought he hit a dead end and stopped exploring. Even though both are occasional players, Thomas leveraged the inventory's information to find the clue, whereas Sahil's reflective thinking process was interrupted as he stopped seeking information in the game and asked for help from the researcher.

We also found some connections between players' prior gaming experiences and ways of reflective thinking. We found external help was sought often by players who played games seldomly and sometimes by occasional players; however, no player with frequent gaming experience was found to be asking the researcher to help them overcome perplexity. Even though our players were novices at playing *HEX*, the differences in their prior gaming experience influenced their approaches to perplexity in the game. For example, frequent players (e.g. Daniel) were observed to be more confident in their ability to get out of perplexing situations on their own and never asked for help, whereas seldom players (e.g. Arya) were found doubting their ability to get out of perplexing situations on their own and asked for help from the researcher. Additionally, we found that the design of information being direct or indirect influenced players' experiences of overcoming perplexity as there were 14 incidents found where players sought external help during exploration, whereas there were none who asked external help to overcome puzzle perplexing scenarios.

Discussion

Our findings show that while playing *HEX,* players experienced two forms of perplexity – 1) *Exploration Perplexity* – while exploring the game world and 2) *Puzzle Perplexity* – while solving an in-game puzzle. These forms of perplexity were resolved by players using reflective thinking. The use of the six phases of reflective thinking as an analytic lens helped to highlight differences in players' reflective thinking approaches to overcome perplexity encountered during gameplay. Also, we found all players experienced moments of perplexity in the game. This implies that perplexity is not a rare phenomenon as it occurs both in players with limited prior gaming experiences and more experienced players. Our findings extend prior GBL work on reflection by providing micro-level descriptions of young players' reflective thinking processes when they encounter a perplexing scenario within a game (Khaled, 2018; Mekler *et al.*, 2018; Shokeen *et al.*, 2022). These findings show how perplexing scenarios in gameplay can generate productive frustration through the challenges presented to players. These challenges encouraged players to reflect, providing the potential for sustainable engagement and productive learning opportunities for players. Our study extends prior claims on the use of games as tools to promote and support players to think reflectively (Khaled, 2018; Marsh and Costello, 2013).

Additionally, our analysis shows how players engage in reflective thinking on their in-game actions using in-game information (such as clues and feedback) to get out of perplexing experiences. Players make meaning of their actions through reflection on the information they received from the game. Our findings indicate that puzzle perplexity is easier for players to overcome based on direct feedback on a failed attempt. However, exploration perplexity is difficult for some players, especially those players with seldom

experience who are unfamiliar with the multiple ways of accessing in-moment information in the game. This leads to the finding that players' actions in the game impacted their access to information in game elements (such as the inventory). These findings illuminate another facet of Squire's (2006) claim of games as an emergent experience: our findings suggest that perplexity in gameplay is also an emergent experience between the player and the game's design as players' information seeking behaviors influence their emerging experiences in the game. Moreover, the identification and classification of perplexing moments in the game provide clarity on what Gee (2003) refers to as pleasantly frustrating experiences.

Based on our findings, we suggest that in-game perplexing situations engage players to think and reflect on their actions in-game action. These in-game thinking and reflection opportunities engage players in an active learning process. Perplexity in the game encouraged players to actively pursue the goal of the game by engaging with in-game information (e.g. the staff board, and interaction with NPCs). This finding suggests potential design strategies for holding players' attention (Shute and Wang, 2015; Squire, 2006) and providing them with continuous information about the game (Juul, 2013; Williams-Pierce, 2019). This implies that game mechanics that induce perplexity can be useful to engage players with domain specific concepts (Green and Bavelier, 2012; Ventura *et al.*, 2013; Wang and Chen, 2010). Thus, our study further strengthens the claim on the use of games for an active learning environment for players (Green and Bavelier, 2012; Ventura *et al.*, 2013; Wang and Chen, 2010).

Our study presents a novel theoretical contribution to GBL on ways to understand players' experiences of in-game challenges. We suggest deliberately designing a variety of in-game challenges to provoke moments of perplexity which will encourage players to engage in reflective thinking. Below, we discuss the implications of these findings for researchers, designers, and educators.

Implications for researchers

This research provides an operationalization of perplexity within gameplay, describing when and how a player may experience perplexity. This construct can be a useful analytical lens for researchers to understand players' in-game experiences. It can provide insights as to why players get stuck and how we can support them in overcoming their in-game perplexity. Further, this work shows how the constructs of perplexity and reflective thinking are interrelated, and to understand players' reflection in games we need to begin by identifying moments of perplexity which is the starting point of reflection. Therefore, we suggest researchers should consider attending to in-game perplexity and reflective thinking in GBL. This study extends prior work investigating players' in-game interactions by grounding their engagement with challenges in a theory of perplexity and reflective thinking. This lens may open new avenues for researchers to further develop these constructs in relation to players' learning experiences and deepen our understanding of the learner experience in GBL environments.

Implications for designers

Our study shows that the design of game elements and mechanics can directly spur moments of perplexity and reflection. For instance, the two forms of perplexity – puzzles and exploration – are directly related to the *HEX* mechanics, which our analysis found to be productive for inducing moments of perplexity and reflection for players. Therefore, we suggest designers consider deliberately designing a variety of in-game challenges to spur such moments of perplexity which may, in turn, lead to players engaging in reflective thinking.

Our findings also show that players encounter both Puzzle Perplexity and Exploration Perplexity irrespective of differences in the design of supporting information in these elements. It is important for designers to distinguish between players getting perplexed due to poor design rather than a design that encourages players to have critical engagement. A design that produces productive perplexity encourages players to engage in reflective thinking while a poor design can cause players to experience unproductive perplexity and ultimately drop the game. Therefore, we suggest designers use the distinct phases of reflective thinking while playtesting the game design as it can provide insight into the ways in which information design shapes players' experiences in the game.

Players' perplexing experiences might change due to differences in their individual information seeking behavior during gameplay. This work suggests that a player's prior gaming experiences shape their response to perplexity. Players with more experience may have more tolerance for perplexity, while those who are new to the experience may perceive it as negative feedback from the game about their gameplay abilities. To avoid this, designers should consider ways to introduce perplexing situations that will not cause players to doubt their own abilities by adding information in the game in form of positive feedback and structured scaffolds.

Understanding perplexity and the reflective cycle the targeted audience use to deal with perplexing scenarios in the game can help game designers to examine whether built-in support features in the game provide relevant information at the right time to players to prevent them from ending the reflection cycle prematurely. Thus, testing in-game support with target audiences helps a designer understand how to best support cycles of reflective thinking.

Implications for educators

The understanding of perplexity and the reflective thinking cycle is useful for educators to support students' learning. It can help educators identify which games are appropriate for their students as well as highlight potential features of a game to highlight and discuss with players. We suggest educators identify the moments of perplexity in the game before using it with students, as they can indicate whether a game has appropriate challenges to engage students in reflective thinking.

Our study shows reflective thinking is a productive approach to getting out of in-game perplexity situations. Applying the six phases of the reflective thinking cycle can provide educators with a deeper understanding of how perplexity is encountered by their students in a game. It can help educators identify where their students might feel stuck and need additional support to continue their gameplay. Also, promoting in-game reflection encourages students to find meaning in the scenarios where they feel perplexed in the game. Therefore, we suggest educators support students in developing their reflective thinking by encouraging them to respond to various in-game challenges.

Limitations

In this study, we sought to maximize the validity by triangulating data from gameplay observations, players' responses to in-game prompts, and post-gameplay interviews. Still, this study is not without its limitations. First, the perplexing experiences identified in this study are situated in the designed elements of *HEX*. Different videogame genres may provide different types of perplexity and alternative resources to support player reflection. Future research should be conducted to better understand the nature of perplexity across various game genres. Second, there are additional game design steps that we could have taken to reduce player perplexity, like including a game map that could have impacted how

players resolved perplexity in exploration. These types of specific game elements shape the results and narrow the design recommendations that can be made based on this work. Third, this study is limited due to the virtual implementation with one participant per session. Further research could be conducted to examine the role of peer interaction during moments of perplexity and reflective thinking in gameplay. While the findings presented in this work do not involve peer interaction opportunities during gameplay, they do show the benefits of playtesting, along with collecting multiple data streams, to reveal useful and potentially counterproductive instances of perplexity and reflective thinking in gameplay. In our next steps, we are addressing how this theoretical understanding of perplexity and reflective thinking in GBL can be applied to measure students' learning and in-game performance.

Conclusion

This study provides a theoretical understanding of how players experience in-game challenges via the lens of perplexity and reflective thinking. This study provides a novel analytical lens to understand players' interaction with in-game challenges and their approaches to resolving it. We found in-game moments of perplexity encourage players to reflect on their in-game actions which can lead to opportunities for learning. Our work shows that there is a potential value in inducing perplexity mechanics in games to encourage players to interact with the information provided in the game. We hope this work inspires game-based educators to employ the lens of perplexity and reflective thinking to examine game elements and students' emergent learning experiences within gameplay.

References

Adachi, P.J. and Willoughby, T. (2013), "More than just fun and games: the longitudinal relationships between strategic video games, self-reported problem solving skills, and academic grades", *Journal of Youth and Adolescence*, Vol. 42 No. 7, pp. 1041-1052.

Adachi, P.J. and Willoughby, T. (2017), "The link between playing video games and positive youth outcomes", *Child Development Perspectives*, Vol. 11 No. 3, pp. 202-206.

Berlyne, D.E. (1960). "Conflict, arousal, and curiosity", Reprint by Martino Publishing, USA, ISBN 978-1-61427-752-1.

Cascio, M.A., Lee, E., Vaudrin, N. and Freedman, D.A. (2019), "A team-based approach to open coding: considerations for creating intercoder consensus", *Field Methods*, Vol. 31 No. 2, pp. 116-130.

Charmaz, K. (2006), *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*, SAGE.

Choontanom, T. and Nardi, B. (2012), "13 Theorycrafting: the art and science of using numbers to interpret the world", *Games, Learning, and Society: Learning and Meaning in the Digital Age*, Vol. 185.

Cox, A., Cairns, P., Shah, P. and Carroll, M. (2012), "Not doing but thinking: the role of challenge in the gaming experience", *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, *New York, NY*, pp. 79-88.

Crookall, D. (2010), "Serious games, debriefing, and simulation/gaming as a discipline", *Simulation and Gaming*, Vol. 41 No. 6, pp. 898-920.

de Freitas, S. (2018), "Are games effective learning tools? A review of educational games", *Journal of Educational Technology and Society*, Vol. 21 No. 2, pp. 74-84.

Dewey, J. (1933), *How we Think*, Prometheus Books, Buffalo, New York, NY.

Ellis, G. (2014), "Young learners': clarifying our terms", *ELT Journal*, Vol. 68 No. 1, pp. 75-78.

Gee, J.P. (2003), "What video games have to teach us about learning and literacy", *Computers in Entertainment*, Vol. 1 No. 1, p. 20, doi: 10.1145/950566.950595.

Gee, J.P. (2007), *Good Video Games+ Good Learning: Collected Essays on Video Games, Learning, and Literacy*, Peter Lang, Bern.

Gibson, E., Griffiths, M., Calado, F. and Harris, A. (2022), "The relationship between videogame micro-transactions and problem gaming and gambling: a systematic review", *Computers in Human Behavior*, Vol. 131, p. 107219.

Green, C.S. and Bavelier, D. (2012), "Learning, attentional control, and action video games", *Current Biology*, Vol. 22 No. 6, pp. 197-206.

Hamlen, K.R. (2018), "General problem-solving styles and problem-solving approaches in video games", *Journal of Educational Computing Research*, Vol. 56 No. 4, pp. 467-484.

Hazar, Z. and Hazar, M. (2018), "Effect of games including physical activity on digital game addiction of 11-14 age group middle-school students", *Journal of Education and Training Studies*, Vol. 6 No. 11, pp. 243-253.

Iacovides, I. and Cox, A.L. (2015), "Moving beyond fun: evaluating serious experience in digital games", *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, Association for Computing Machinery, pp. 2245-2254.

Juul, J. (2013), *The Art of Failure: An Essay on the Pain of Playing Video Games*, MIT Press, Cambridge.

Khaled, R. (2018), "Questions over answers: reflective game design", in Cermak-Sassenrath, D. (Ed.), *Playful Disruption of Digital Media*, Springer, Berlin, pp. 3-27.

Koster, R. (2013), *Theory of Fun for Game Design*, O'Reilly Media, Sebastopol.

Marsh, T. and Costello, B. (2013), "Lingering serious experience as trigger to raise awareness, encourage reflection and change behavior", *Persuasive Technology*, Springer, Berlin, Heidelberg, pp. 116.-124.

Mekler, E.D., Iacovides, I. and Bopp, J.A. (2018), "A game that makes you question. . .': exploring the role of reflection for the player experience", *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play, New York, NY*, pp. 315-327.

Nordin, A.I., Denisova, A. and Cairns, P. (2014), "Too many questionnaires: measuring player experience whilst playing digital games", York, UK.

Odgers, C.L., Schueller, S.M. and Ito, M. (2020), "Screen time, social media use, and adolescent development", *Annual Review of Developmental Psychology*, Vol. 2 No. 1, pp. 485-502.

Ortiz, P. and Harrell, D.F. (2018), "Enabling critical self-reflection through roleplay with chimeria: grayscale", *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*, pp. 353-364.

Pellicone, A., Weintrop, D., Ketelhut, D.J., Shokeen, E., Cukier, M., Plane, J.D. and Rahimian, F. (2022), "Playing aloud: leveraging game commentary culture for playtesting", *International Journal of Gaming and Computer-Mediated Simulations (IJGCMS)*, Vol. 14 No. 1, pp. 1-16, available at: www.igi-global.com/article/playing-aloud/296705

Rodgers, C. (2002), "Defining reflection: another look at John Dewey and reflective thinking", *Teachers College Record: The Voice of Scholarship in Education*, Vol. 104 No. 4, pp. 842-866.

Saldaña, J. (2021), "The coding manual for qualitative researchers", *The Coding Manual for Qualitative Researchers*, Sage, London, pp. 1-440.

Scozzi, M.V., Iacovides, I. and Linehan, C. (2017), "A mixed method approach for evaluating and improving the design of learning in puzzle games", *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, pp. 217-228.

Shokeen, E., Pellicone, A., Weintrop, D., Jass Ketelhut, D., Williams-Pierce, C., Plane, J.D. and Cukier, M. (2020), "Designing failure and feedback within puzzles", *Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play*, pp. 370-374.

Shokeen, E., Pellicone, A., Weintrop, D., Ketelhut, D.J., Pellicone, A., Weintrop, D., Pierce, C.W., Plane, J., Cukier, M. and Rahimian, F. (2021), "An iterative design cycle: using productive and unproductive frustration to guide re-design", *Proceedings of the 15th International Conference of the Learning Sciences-ICLS 2021*, *International Society of the Learning Sciences*, pp. 957-958, doi: 10.22318/icls2021.957.

Shokeen, E., Williams-Pierce, C. and Katirci, N. (2022), "Reflective thinking: a learning process within gameplay", *Presented at the 2022 American Educational Research Association Annual Meeting and Exhibition (AERA)*.

Shute, V.J. and Wang, L. (2015), *Measuring Problem Solving Skills in Portal 2. E-Learning Systems, Environments and Approaches*, Springer, Berlin, pp. 11-24.

Shute, V.J., Wang, L., Greiff, S., Zhao, W. and Moore, G. (2016), "Measuring problem solving skills via stealth assessment in an engaging video game", *Computers in Human Behavior*, Vol. 63, pp. 106-117.

Slovák, P., Frauenberger, C. and Fitzpatrick, G. (2017), "Reflective practicum: a framework of sensitising concepts to design for transformative reflection", *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pp. 2696-2707.

Squire, K. (2006), "From content to context: videogames as designed experience", *Educational Researcher*, Vol. 35 No. 8, pp. 19-29.

Strauss, A. and Corbin, J. (1990), *Basics of Qualitative Research*, Sage publications, London.

Ventura, M., Shute, V. and Zhao, W. (2013), "The relationship between video game use and a performance-based measure of persistence", *Computers and Education*, Vol. 60 No. 1, pp. 52-58.

Wang, L.-C. and Chen, M.-P. (2010), "The effects of game strategy and preference-matching on flow experience and programming performance in game-based learning", *Innovations in Education and Teaching International*, Vol. 47, No. 1, pp. 39-52.

Williams-Pierce, C. (2019), "Designing for mathematical play: failure and feedback", *Information and Learning Sciences*, Vol. 120 Nos 9/10, pp. 589-610, doi: 10.1108/ILS-03-2019-0027.

Zhao, W. and Shute, V.J. (2019), "Can playing a video game foster computational thinking skills?", Computers and Education.

Appendix

Table A1.
The priori used for focused coding during data-analysis process

Focused codes	Description
Perplexity incidences	The incidences where players were observed, or they expressed having experienced a temporary form of uncertainty of how to proceed during gameplay
Reaction to perplexity	Players observed or expressed likeness or dislike to temporary uncertainty they were experiences in the game
Location of perplexity [Puzzle, Exploration]	Weather player was exploring game world, or they were solving puzzle when they encountered uncertainty
Use of in-game affordances	Players making use of in-game affordances such as inventory, talking to non-playing characters in the game etc. to figure out how deal with uncertainty to move-on in the game
Reflection thinking cycle	Which phases of reflective cycle – *Initial Interaction, Spontaneous Interpretation, Identifying the problem(s), Generating possible explanations, Hypothesis, Testing* – did the player applied to get out of the uncertainty in the game
External help	Whether players seek help from the researcher to get out of the uncertainty that were experiencing in the game

Source: Appendix by authors

Author affiliations

Ekta Shokeen, College of Information Studies, University of Maryland, College Park, Maryland, USA

David Weintrop, College of Education, College of Information Studies, University of Maryland, College Park, Maryland, USA

Anthony James Pellicone, University of Maryland Institute for Advanced Computer Studies, University of Maryland, College Park, Maryland, USA

Peter Francis Moon, College of Education, University of Maryland, College Park, Maryland, USA

Diane Ketelhut, Department of Teaching and Learning, Policy and Leadership, University of Maryland, College Park, Maryland, USA

Michel Cukier, University of Maryland Institute for Advanced Computer Studies, University of Maryland, College Park, Maryland, USA, and

Jandelyn Dawn Plane, Department of Computer Science, University of Maryland, College Park, Maryland, USA

Corresponding author

Ekta Shokeen can be contacted at: eshokeen@umd.edu

For instructions on how to order reprints of this article, please visit our website:
www.emeraldgrouppublishing.com/licensing/reprints.htm
Or contact us for further details: **permissions@emeraldinsight.com**