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Title: Self-directed learning in video games, affordances and pedagogical implications for teaching and learning

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Abstract

Self-directed learning is becoming increasingly important in the twenty-first century due to the rapid changes caused by technological advancement and automation, which necessitate a shift in the learning models adopted by students from a more teacher-directed to a more student-centred pedagogy. Video games can be leveraged to develop self-directed learning in students because digital play environments are engaging and possess features conducive for independent learning, such as safe spaces and authentic learning environments. Our aim in this paper is to first derive a set of self-directed learning strategies in video games that can be adopted for use in pedagogical contexts. Second, the coding scheme of self-directed learning strategies can be used to evaluate video games for their suitability for developing self-directed learning strategies in students. User experience approaches such as interviews and the think-aloud protocol were used to analyse the gameplay videos of the study's participants for deriving the coding scheme of the self-directed learning strategies. Based on player experience, we also derived a set of factors that promoted self-directed learning in video games. These factors can be integrated by educators and user experience designers to improve video game design to foster the development of self-directed learning strategies in students.

Keywords: Self-directed learning; game-based learning; player experience; think-aloud protocol; interviews

1. Introduction

Self-directed learning skills are important, especially in the twenty-first century, and have been found to be moderately correlated to lifelong learning tendencies (Tekkol & Demirel, 2018) and competencies such as creativity, communication, and collaboration in the workplace. There is a greater need for workers to learn how to develop metacognitive learning strategies without being passively taught by others. Self-directed learning is broadly defined as the process wherein individuals take the initiative, with or without others' support, to diagnose their learning needs, formulate their learning goals, identify human and material resources for learning, choose and implement appropriate learning strategies, and evaluate their learning outcomes (Knowles, 1975). Gibbons (2002) defines self-directed learning as any increase in knowledge, skill, accomplishment, or personal development that an individual realises through his or her own effort, using any method in any situation at any time. In pedagogical contexts, self-directed learning involves students gradually undertaking most of the traditional teaching operations in teacher-directed learning until they are designing and executing their own learning activities (Gibbons, 2002).

We contend that video games are well-suited for developing self-directed (incidental) learning in players and, by extension, students in an informal context because of their specific features, including a safe space for learners to experiment and fail without consequences and the autonomy that video games provide. This allows learners to learn at their own pace and receive immediate in-game feedback to develop their different skills and competences. Toh and Lim (2020) developed a metalanguage for digital play in the classroom to guide teachers on using video games for teaching and learning. One example of digital play involved *Minecraft*, which has three key features—the ability to customise context, live through stories, and assume roles in the virtual world—that can promote self-directed learning in students (Faas & Lin, 2017). Our aim is to develop a pedagogical framework for teaching and

promoting self-directed learning strategies derived from playing video games. The paper is structured around three research questions:

1. What self-directed learning strategies do players adopt in video games?
2. What factors promote self-directed learning in video games?
3. How can factors that promote self-directed learning in video games be used in pedagogical contexts for teaching and learning?

2. Theoretical Models of Self-Directed Learning

Synthesising the prior literature and psychological learning theories, Zap and Code (2009) reviewed self-regulated learning in video game environments and provided a detailed discussion of the regulatory mechanisms of self-regulated learning, including the learners' self-efficacy, self-determination, self-awareness, interest, intent, aptitude, motivation, goal and task orientation, metacognition, and emotional self-regulation. The design features of game environments that supported self-regulated learning were discussed, including an authentic learning environment's characteristics, which first included the simulation of a real-life context where students enacted decisions in a safe space without real-world consequences. Second, students engaged in authentic activities in a simulated environment where they learnt transferable skills. Third, they learnt by observation and modeling. Fourth, students occupied multiple roles to explore different ideas and learnt how to develop empathy. Finally, game environments provided a space for the collaborative construction of knowledge and scaffolded coaching through (simulated) companions. In contrast to their theoretical model, we adopted a grounded theory approach to derive the various self-directed learning strategies from video games. We also employed user experience research methods such as interviews and the think-aloud protocol to determine which game design features promoted self-directed learning in video game environments.

A sequential explanatory design was used to explore self-regulation of expert, moderately expert, and non-expert college-age video game players (Soylu & Bruning, 2016). Both quantitative and qualitative analyses comparing video game players in the three expertise groups demonstrated significant differences in self-regulation favouring expert players. Self-regulation processes were used considerably more by expert game players than moderately expert players, and moderately expert players self-regulated more than non-experts. The self-regulation processes included definition of task, goal setting and planning, enacting tactics, and adapting metacognition. Expert players reported being more aware of contextual factors of gameplay, such as specific game features and the physical environments in which they were playing, as well as the ways in which these influenced goal-setting, choosing tactics, and monitoring their progress. Expert and moderately expert players also reported setting more game specific goals than non-experts and expert players were found to deploy strategies for play quite purposefully. Additionally, expert players possessed a wider repertoire of tactics. Therefore, video game players can benefit by playing with and modelling more expert partners to reduce time and effort normally taken up by trial and error. In our proposed model, "trial and error" was conceptualised as the lowest order self-directed learning strategy of video game players, followed by "observation and modelling" as the second lowest self-directed learning strategy. Finally, expert players reported more adaptations in their play over time than the moderately expert players by rating items higher on average referring to formulating alternative ways to overcome a difficult game level and being receptive to ideas to improve their play. We conceptualised "reflect and improvise" as a higher order metacognition learning strategy in our proposed model where players were scaffolded by game mechanics to think of alternative ways to progress the game.

A model formative assessment strategy has been proposed to complement existing university teaching to promote student-centred self-regulated learning/assessment with

minimal teacher input (Bose & Rengel, 2009). Compared to our framework, Bose and Rengel's (2009) model was developed from past research conducted on teaching and learning in institutional contexts and consisted of five levels with two dimensions: degree of student self-regulation and class size. In the first level, students' self-regulation was low in a large class. The second level, characterised by slightly higher student self-regulation and a smaller class size, consisted of a computer-assisted self-assessment with built-in feedback using learning analytics and the visualisation of learning patterns. This level has some similarities with our self-directed learning model in video games, where the player could be scaffolded by the games' data analytics to allow reflection on their actions. The third level, medium in terms of students' self-regulation and class size, consisted of peer assessment. The fourth level involved students' self-reflection/assessment as the heart of student self-regulation. In our model, players engaged in such self-directed learning strategies as reflection and enacting alternative actions when encountering game events that were unsolvable using normal actions. Finally, at the fifth level, characterised by the highest student self-regulation at the individual level, a teacher's assessment with future direction was proposed.

Watkins and Marsick (1992) proposed a theory of informal (self-directed) learning in organisations, wherein informal learning was characterised by several features. The first was its basis in experience, where people learnt from their everyday lives. Second, the context wherein one learns was a major determinant in organising a learning project. Self-directed learning occurred in natural, mundane settings, and the individual's perceptions of, and interactions with, that environment was what gave experience meaning. Third, self-directed learning occurred when people were surprised in nonroutine circumstances, engaged in critical reflection (often unaware of the underlying assumptions), and learnt to think like a professional. Fourth, self-directed learning occurred when people perceived a situation as nonroutine and were more likely to respond in a nonhabitual way. In our proposed framework,

nonroutine gameplay events were crucial for provoking players' critical reflection when adopting an alternative approach. Fifth, all knowledge and learning have a tacit dimension, which typically resided in the context outside a person's main focus. Sixth, both informal and incidental learning were delimited by one's intellectual capacity and highly influenced by how one framed a situation as a problem. Finally, the three conditions that enhanced learning effectiveness included proactivity or the readiness to take initiative; critical reflectivity or one's ability to identify and make explicit subconscious norms, values, and assumptions; and creativity, which helped learners think beyond their normal perspective and break preconceived patterns to reframe a situation. In our proposed model, player initiative was important for motivating and reinforcing players' learning, critical reflectivity was important for understanding the assumptions of game elements, and creativity was important for examining alternative solutions and establishing new learning patterns.

3. Method

3.1. Participant Recruitment

The data in this paper are from a study (Toh, 2018) on multimodality and the player experience. Participants were recruited through convenience and snowball sampling via advertisements on the university's website. Because gamers aged 18 or above represent 70% of the video game–playing population, and the average age of gamers is 34 years old (Entertainment Software Association, 2018), the required age range was 17–35, and the recruited participants' actual ages ranged from 19–24. A total of 37 participants signed up but only 11 finished the entire study, which included completing the whole video game and the first and final interview sessions. Of these 11, the data from 6 were used in this paper. We chose these 6 participants because they possessed at least 5 years of experience playing video games and were familiar with the games in the study. For instance, participants 1 and 2 had

previously watched YouTube videos of the games they chose to play. Participants were allowed to select their game(s) from a list curated by the researcher to maximise their enjoyment and self-directed learning.

3.2. Gameplay Sessions

Before the start of the first session, the participants completed a written survey to provide information about their demographics and gaming habits. During the first session, we observed the participants in the laboratory at a nearby computer, to which the gameplay was being streamed and recorded, playing the selected game(s) from the start for one to three hours. Video recordings of the participants' gameplay were made using Fraps (computer) and a PS3 recorder, providing us a reference when asking the participants to reflect on and verbalise (using the retrospective think-aloud protocol) what they learnt from the session. At the end of the first session, an interview lasting approximately one to two hours was conducted and recorded to understand the player experience. The participants were also debriefed by informing them about the aims and nature of the study.

During subsequent sessions, we instructed the participants to record their gameplay at home by incorporating their natural reactions with their think-aloud verbalisations (using concurrent think-aloud protocol). The numbers of subsequent sessions varied among the different participants who played their selected games as listed in Table 2 below. After they finished the game (approximately 14–30 hours), we arranged an interview session to review their gameplay recordings and discuss their game experience using the retrospective think-aloud protocol and stimulated recall. During the final interview session, the participants were again debriefed by informing them about the aims and nature of the study and relating the study's aims to their game experience. The number of hours of recordings, including think-aloud and interviews, are listed in Table 1 below. For detailed information about the

methodology, please refer to Toh (2018). This research was approved by our institution's Institutional Review Board. We obtained consent from the participants to share their video recordings, which included their voices, for research purposes. This paper adopted a grounded theory approach to induce a set of self-directed learning strategies from participants in their gameplay.

3.3. Data Coding

The data was hand-coded by using a mix of open, process, and conceptual coding in the first cycle of analysis (cf. Saldaña, 2016). Open coding is a process whereby the researcher reads multiple times through the data and assigns codes based on salience to the purpose of the study (e.g., codes related to self-directed learning). These codes were refined during each subsequent reading. Process coding refers to the identification of actions within data (Saldaña, 2016) where participants' actions in each study were reported from their recordings. Process codes comprise gerunds (i.e., "-ing" words) and were used for foregrounding elements of self-directed learning.

Finally, conceptual coding refers to the use of concepts and ideas from the framing theoretical terrain (i.e., educational theories) to identify salient elements within the data. To minimise the incidences of over-interpretation of the data, the codes were rechecked regularly. A second coder checked the coding and a consensus was reached in relation to any disagreements in the coding. During the second cycle of analysis, the codes were reviewed and then grouped into larger thematic patterns that were useful and explanatory (cf. Saldaña, 2016).

Participant	**Selected Game**	**Think-aloud video recordings (Hours**	**Interviews (Hours analysed)**

		analysed)	
1	*The Last of Us*	23.7	7
1	*Mass Effect*	24.4	5.5
2	*The Walking Dead: Season 1 Eps. 1–3*	7.2	1.37
2	*Bioshock*	19.5	2.84
3	*Mass Effect*	29.6	6.7
4	*Bioshock*	8.4	1
5	*The Walking Dead: Season 1 Eps. 1–5*	15	6.7
6	*Bioshock*	16	5

Table 1 No. of hours of recordings analysed

3.4. Description of the Participants

The participants' profiles whose data are used in this paper are listed in Table 2 below. The participants were full-time undergraduate students studying in the university. In terms of their video gaming habits, they played video games a few times per week and they played mostly computer and some PlayStation games. The participants played a variety of game types including first-person shooters, action, adventure, and sports games. They also mentioned that they played games for both story and gameplay.

Participant	**Age**	**Gender**	**Game Experience**	**Game(s) Played**	**Gaming Platform**	**No. of Subsequent Sessions**
1	24	M	11–15 years	*The Last of Us*	PS3 &	8 and 14

				and *Mass Effect*	Computer	
2	19	F	6–10 years	*The Walking Dead: Season 1 Eps. 1–3* and *Bioshock*	Computer	9 and 26
3	24	M	8 years	*Mass Effect*	Computer	25
4	22	M	11–15 years	*Bioshock*	Computer	9
5	22	M	11–15 years	*The Walking Dead: Season 1 Eps. 1–5*	Computer	21
6	23	M	11–15 years	*Bioshock*	Computer	20

Table 2 Profiles of the study's participants

3.5. Description and Rationale of the Game Choices

The Last of Us (TLOU), a narrative PlayStation game, is set in a postapocalyptic world where a mutated fungal strain has transformed humans into zombies. The player primarily controls Joel, the main character. *The Walking Dead (TWD)*, a multiplatform game, is set in a fictional world overrun by a zombie apocalypse. To explore the story world, the player controls the main character, Lee Everett, and is accompanied by several survivors, including a young girl called Clementine. A multiplatform game, *Mass Effect (ME)* is a third-person shooter with role-playing elements set in a distant future where humankind is the youngest spacefaring civilization. The player controls a human hero, Commander Shepard, who must save the galaxy by defeating the main antagonists. *Bioshock* is a role-playing first-person shooter set in the underwater city of Rapture in 1960. The player controls Jack, a

character forcibly compelled to defeat the city's founder and liberate the inhabitants from servitude to the city.

Our game selection is based on the condition that the games must allow participants to adopt self-directed learning strategies on their own initiative during gameplay. The second condition is that the games must have specific features facilitating the development of self-directed learning, including defamiliarisation mechanics (Toh, 2018; Mitchell, 2018), learning analytics, or in-game companions. The third condition is that the games, or the genres they represent, must be familiar to the participants to allow them to demonstrate multiliteracies such as critical thinking (reflection), creativity, and digital fluency in supporting their development of self-directed learning strategies. The following sections will discuss the various subcategories of the self-directed learning strategies induced from the players' experience in video games.

4. Results

This section explains how the self-directed learning model is developed from player experience. It is structured in terms of "meta-behaviour"," metacognition", and "meta-emotion". Meta-behaviour is thinking about doing and includes the subcategory of "trial and error", "observation and modeling", and "reinforcement learning". Metacognition is thinking about thinking and includes the subcategories of "connected learning", "reflect and improvise", "logical and analytical reasoning", "inquiry-based learning", and "synthesis". Meta-emotion is thinking about feelings and includes the subcategories of "dissatisfaction and anger" and "curiosity and satisfaction".

4.1. Meta-Behaviour or Self-Regulated Behaviour Strategies

Meta-behaviour was originally conceptualised in psychological studies to understand adolescents' acquisition of social skills by combining traditional metacognitive explanations with situationally specific environment variables (Svec & Bechard, 1988). In this paper, we adapted the psychological concept to refer to the players' thinking about their actions during gameplay, enabling us to understand how players learnt to make sense of the game elements to progress the game. Doing so can help us draw insights on how educational games can be designed to enable students to reflect on their behaviour during pedagogical activities to self-regulate their actions for self-directed learning.

4.1.1. Trial and Error

Trial and error involves an unsystematic self-directed learning process occurring when the participant possesses insufficient information to actualise the cognitive learning process. This process, considered a low-order self-directed learning strategy, closely parallels informal learning, which is nonroutine because it occurs in an indeterminate, unsystematic, and uncontrolled context (Watkins & Marsick, 1992). This could happen when the game only provides a brief description about a new concept, objective, system, or ability, resulting in the player becoming confused and having to experiment with the different options to understand their specific functions and/or how to progress the game. For instance, in *ME*, participant 1 mentioned that specific character class abilities were not well structured in the gameplay because the game assumes that the player controls a default character and does not provide a tutorial for each specific character class. Thus, participant 1 had to use trial and error to learn those class abilities:

> There are different types of classes so then, like, even though they give you a brief description, you don't really know what you are getting into…. So, in that sense, for those specific class abilities, I don't think it was really structured well in the

gameplay… Might be a bit complicated, but ya in the sense the class system or at least the class abilities are just had to trial and error, then after a while, ok, you realise you can use this and this and all that.

4.1.2. Observation and Modeling

From a social learning perspective (Zimmerman, 2001), one's real-life experiences and exposures directly or indirectly shape behaviour (O'Connor et al., 2013). The processes by which this learning occurs can be diverse, and include imitation. Modeling occurs when learners observe and imitate others' actions without obtaining a deep understanding of them. In social learning, four conditions are required for one to successfully model another's behaviour: attention, retention, reproduction, and motivation. The most basic or low-order self-directed learning strategy that players engage in during video gameplay consists of watching, listening to, and modeling nonplayer characters (NPCs) performing actions in single-player games. For instance, in *TLOU,* when participant 1 observed NPCs shooting enemies or performing stealth kills, he learnt how to interact with the enemies in the game world. In *Bioshock*, participants 2, 4, and 6 learnt how to combine attacks by listening to the NPC's instructions to perform the "one-two punch". Outside the game world, players can learn game controls by observing other players interacting with the game. Participants 1 and 2 also mentioned during the interviews that they watched paratexts such as YouTube videos to learn about the game structure and game strategies prior to playing the games and developed anticipatory socialisation (Kirschner, 2014) as a result.

4.1.3. Reinforcement Learning

Reinforcement learning (Sawyer, Rowe, & Lester, 2017) is guided by the assumption that human beings learn by forging links between actions and results. Like modeling, reinforcement learning is also grounded in social learning theory, where one's prior

experiences affect behaviour. Specifically, positive outcomes strengthen the stimulus–response connection, whereas negative outcomes weaken it. Thus, players' actions and desire to learn (new skills or backstory) are guided by the rewards (e.g., new gameplay abilities, skill points, upgrades, aesthetic enhancements to their character, visual aesthetics of the environment, and deeper story understanding) they anticipate obtaining by performing specific actions or making relevant choices during gameplay. As such, reinforcement learning is related to extrinsic motivation (Deci & Ryan, 1985). For instance, in *Bioshock*, participant 2 mentioned that:

> Because most of the times, they will hide the "not as necessary" things like the audio tapes in those secret areas. So, if I don't actually explore them, then I'll miss out on audio tapes, and part of the storyline. I realise most of the so-called "hidden areas" are for collecting resources…. There is a sense of accomplishment when you find it…. If I don't explore, I would have missed out.

4.2. Metacognition or Self-Regulated Cognitive Strategies

Metacognition, meaning "thinking about thinking", involves knowledge and self-regulation (Kills & Yıldırımb, 2018). Metacognitive knowledge includes the learner's knowledge about herself as a learner and the different factors that might affect performance, and the knowledge of learning strategies and of when and why to use them. Metacognitive regulation involves the learner's monitoring of her cognition. It includes planning activities, an awareness of comprehension and task performance, and evaluating the effectiveness of monitoring processes and strategies (Lai, 2011). Meta-learning occurs when the learner can match the learning strategy with the motive and task to produce a desired outcome (Biggs, 1988). Adapting Biggs' (1988) surface to deep learning approaches, we conceptualised the

players' metacognition as progressing from the lowest order of "connected learning" to the highest order of "synthesis".

4.2.1. Connected Learning

The learning theory of constructivism assumes that learning is an active and constructive process where the learner creates their own subjective representations of objective reality by linking new information to prior knowledge (Wu et al., 2011). Designing game features (e.g., the dialogue system in role-playing games) that allow players to connect to their prior game-playing knowledge or interest-driven digital practices (Deng, Connelly, & Lau, 2016) is important in promoting self-directed learning in video games. Participant 3 (*ME*) mentioned that he used his prior experience of playing *Dragon Age,* another role-playing game made by the same company, to scaffold his experience of playing *Mass Effect*. He reported learning from his experience that the more he interacted with the NPCs, the greater the possibility that they might open up new quests or give him extra rewards.

Participant 4, who played the minigame in *Bioshock*, connected it with his previous experience of playing the puzzle game *Pipe Dream*. In both games, players manipulate pipes to make water flow. This connection supported his learning of how to interact with *Bioshock's* minigame, as he linked it with *Bioshock's* story:

> This is a game where I basically have to unlock, it's basically like *Pipe Dream*, where it's their way of trying to unlock stuff from hacking. I find it strange that they actually chose to use *Pipe Dream* as their minigame? This really tie[s] into the main theme.

4.2.2. Reflect and Improvise

Reflection is a representation of human consciousness, a process in which the human mind has knowledge of itself and its thinking. The thinking process is deeply embedded in

the continuous relationship between action and reflection and it is activated when one's thoughts are fixated on some subject, in order to learn (Higgins, 2011). Reflection and improvisation occur when players are faced with an unfamiliar or nonroutine game event as compared to the rest of the game that serves as a distancing device to promote critical thinking about the situation. An instance of a nonroutine situation is when participants 2 and 5's completion of specific gameplay mechanics did not allow game progression, requiring them to find alternative ways to progress the game. In *TWD Season 1 Episode 2*, participant 2 was observed facing difficulties when fighting enemies during a quick time event, a context-sensitive gameplay mechanic that requires the player to perform specific actions by pressing the controller or keyboard buttons when an on-screen prompt appears. She reflected on her actions and said it was strange that she could not progress even when following the game's prompts to press *Q*. Eventually, she decided to pursue an alternative action by pressing down and then gradually releasing the button. This shows that when participant 2 could not progress using the usual method, she resorted to formulating an alternative solution and performing a counterintuitive motion by reflecting on her actions:

> I'm Q-ing so hard right now…. Come on, come on! Are you kidding me? Come on, how long is this going to take? Am I doing something wrong? Why is it not proceeding? This is weird. Did I break the game? What's supposed to happen? Am I supposed to punch him? No, it's not. Nothing's working. Oh, I was supposed to let go.

4.2.3. Logical and Analytical Reasoning

Logical and analytical reasoning is an evidence-based self-directed learning strategy that is grounded in a complete understanding of the context, including relevant ideas and facts where one learns how to reason and argue by deductive, abductive, inductive, and/or inferential logic (Ormerod, 2010). One of the characteristics of logical and analytical

reasoning involves the consideration of both sides of an issue before evidence is used to support one's decision. Participant 2 uses logical and analytical reasoning to learn how to make decisions within the game. Toward the end of *TWD Season 1 Episode 2*, her explanation tells us how she learnt to use this reasoning within the game's context to justify her decision to take the Stranger's supplies to ensure survival:

> I could have easily made the ethically correct decisions of leaving the stuff here because you know someone [The Stranger] might need it. But if you put yourself in their [Lee's group] shoes, they need to survive, and they haven't been eating ever since the Motor Inn. If they [The Stranger] are still alive, they were the ones at fault for leaving their cars unattended with all the supplies inside. And if they [The Stranger] are dead, then some other group may appear and scavenge it anyway, and we might die without the food. So, I'm just putting myself in their shoes.

4.2.4. Inquiry-Based Learning

The ability to direct one's own learning is crucial for lifelong and independent learning. Inquiry-based learning, an educational strategy derived from scientific methods and practices, follows the steps professional scientists take to construct knowledge, focusing on the active participation of the learner, who adopts various problem-solving skills (Suárez et al., 2018) to solve problems and discover new knowledge. Toh (submitted for publication) described how in *TWD Season 1 Episode 1*, participant 5 used the four steps in inquiry-based learning to understand (orientate), plan (conceptualise), act (apply), and reflect to learn how to remove obstacles (e.g., zombies) to reach game objectives (e.g., the woman trapped in the motel). In the first step, the game shows participant 5 an overview of the scene, enabling him to understand the basic situation, such as the number of zombies to remove. He commented:

> Oh, that's one, two, three, four, five zombies. Yup, five…. Now we have to rescue this survivor upstairs over here. So, we have to kill all the zombies to rescue her. So, let's find some way to kill them quietly.

After obtaining a basic understanding of the situation, participant 5 engaged in the second step of planning to execute his actions.

> Let's see. I have to kill this guy, probably with the screwdriver, before making use of the car to kill something else. So, let's head back to brick wall and see if we can find anything. There's a pillow here. Oh, I can use the pillow to stuff the, probably lessen the noise, I guess, so let's just take it.

In the third step, he took the pillow back to the truck. He selected the pillow option to try to open the car's door but failed. Finally, in the fourth step, he reflected on his failure by commenting that he must use the pillow for another purpose. The four-step sequence in the inquiry-based learning process is used in an iterative manner by participant 5 to subsequently reach the trapped woman located on the motel's second floor.

4.2.5. Synthesis and the Emerging Mental Model

We propose that synthesis is the highest-level self-directed learning skill that includes lower-level self-directed learning skills such as selecting information, evaluating or reflecting on the selected information, and integrating the information from multiple sources such as websites, books, and the multimodal information from visual and verbal modes into a coherent whole in the mental model (Toh, 2018). This self-directed learning strategy is related to connected learning because both strategies can involve similar meaning-making processes involving drawing on prior experiences with paratexts. However, the difference in the data reported here is that in connected learning, prior experience is drawn from a different

fictional universe of the same medium. In contrast, synthesis integrates information in the same fictional universe across different media. The synthesis and emerging mental model of the players' conception of the game's story and gameplay developed as they interacted with the game. For instance, participant 4 (*Bioshock*) commented that:

> I think I have come to a point where I am actually devaluing the lives of these Splicers, and I just see them as something that I need to eliminate. I no longer feel sorry for them. I actually feel that they are nothing more than a means to an end.

The player's emerging model of the game depended on the amount of game content uncovered and the paratexts they read, which added to their understanding of the game world. Participant 2, who read the *Bioshock* novel, had a specific narrative model of the game, which she reflected on:

> Actually, to be honest, I was very confused about the weaponry. It's like why was there this arsenal? Why did they give us these weapons? But after reading the novel, it's like supplementing; I realised that plasmids were created by Fontaine. And the weapons were created by Andrew Ryan, if I am not wrong. So, I guess it was like Jack was a union in a sense between Andrew Ryan because he was his baby and Fontaine's creation. So, I guess that was what the game was trying to go for like a mixture of the plasmids and the weapons.

4.3. Meta-Emotion or Self-Regulated Emotion Strategies

Meta-emotions, defined as second-order emotions about one's emotions (Bailen, Wu, & Thompson, 2019; Miceli & Castelfranchi, 2019), can be produced by emotion goals and evaluations about emotions. The elicitation of meta-emotions is important in fostering emotional regulation for self-directed learning by aligning it with values or goals. In video

games, meta-emotions can be elicited by the first-order emotion's importance, the emotion's perceived unexpectedness, the actual or imagined presence of an evaluative audience, and the emotion's impact on the self-image (Miceli & Castelfranchi, 2019).

4.3.1. Meta-Emotions of Dissatisfaction and Anger

This meta-emotional experience can be categorised as negative-negative (Bailen et al., 2019). The negative-negative meta-emotional experience is important because it promotes emotional learning and teaches one to take a broader perspective and look at more long-term costs and benefits, rather than at the immediate valence, of one's emotions (Miceli & Castelfranchi, 2019). An important factor contributing to self-directed learning involves the dissatisfaction derived from an unexpected or random event, as when participant 2 overcame a challenging fight, and her anger motivated her to learn to be better prepared when fighting. In *Bioshock*, participant 2 was fighting the Big Daddy when her powers shifted randomly during the fight and disrupted her use of a weapon at a crucial moment. In the video recording, she exclaimed, "You see what I mean? The plasmid freaking changed at a terrible moment, and I almost got killed. I would have raged so badly at that."

The meta-emotions of dissatisfaction and anger motivated participant 2 to subsequently learn to plan her attacks. She was more careful when fighting the Big Daddy and quickly proceeded to find the antidote to resolve the problem of her randomly shifting powers.

4.3.2. Meta-Emotions of Curiosity and Satisfaction

This meta-emotional experience can be categorised as positive-positive (Bailen et al., 2019). The positive-positive meta-emotional experience is important as it serves to uphold and maintain the situations that one thinks can bring about these emotions (Jäger &

Bänninger-Huber, 2015). One can enjoy strong affective self-endorsement when positive meta-emotions are experienced in relation to the first-order emotions (Jäger & Bänninger-Huber, 2015), thereby motivating actions that promote self-directed learning. Curiosity combined with the satisfaction derived from discovering new concepts or solving puzzles to unlock a hidden area within the game world are key to engaging the players in self-directed learning. The positive-positive meta-emotional sequence is closely related to intrinsic motivation (Deci & Ryan, 1985) and is contrasted to participant 2's behavioural response discussed in reinforcement learning where she was extrinsically motivated by the rewards from exploring. Participant 5 (*TWD Season 1 Episode 2*) was motivated by curiosity to discover the correct action to uncover the door to a hidden room. Upon solving the puzzle and discovering the hidden room used by the Saint John brothers to hide the NPC Mark, participant 5 felt a sense of satisfaction:

> Oh, there's light; oh there's a room back here. Can I get through? Can I pass through this wall? Oh, I know, this is the hidden room. Let's push this shelf. Ah-ha there. I'm a genius. Why are they hiding this room? What is going on?

Following the discussion in this section, Table 3 summarises the self-directed learning strategies induced from the player experience according to the meta-behaviour, metacognition, and meta-emotion subcategories.

Meta-Behaviour	**Definition**	**Example**
Trial and Error	A low-order learning strategy involving an unsystematic self-directed learning process.	Participant 1 learnt how to use the character class abilities in *ME* in repeated, varied attempts until success, or until he gave up.

Observation and Modeling	Modeling occurred when the participant learnt through observing and imitating others' actions without deep understanding.	Participants 1–6 observed how NPCs acted within the game world to understand how to interact within it. This can also refer to how the player watched another player interacting with the game to learn game controls.
Reinforcement Learning	Learning occurred when the participant reflected on behaviour that was extrinsically motivated (Deci & Ryan, 1985) by a reward.	Participants 1–6 were motivated to explore the game world by the resources they could collect.
Metacognition	**Definition**	**Example**
Connected Learning	Learning occurred when the participant could connect game features with their interests (Deng, Connelly, & Lau, 2016) or prior or existing knowledge.	Participant 4 learnt how to play *Bioshock*'s minigame by drawing on his prior knowledge of playing *Pipe Dream*.
Reflect and Improvise	Learning occurred when the participant was faced with an unfamiliar or nonroutine game event as compared to the rest of the game.	When they were stuck, participants 2 and 5 learnt how to progress by pausing to reflect and enact an alternate or counterintuitive action.

Logical and Analytical Reasoning	Learning occurred when the participant constructed or inferred a hypothetical situation to reason about potential and enacted in-game actions.	Participants 2 and 5 used logical reasoning to justify their choices or actions in the context of the game.
Inquiry-Based Learning	Learning occurred when the participant actively adopted various problem-solving skills to solve problems or discover new knowledge.	Participant 5 used a four-step approach to orientate, plan, act, and reflect on how to overcome game challenges.
Synthesis	The highest-order learning strategy that involved selecting, evaluating, reflecting, and integrating information into a coherent whole.	Participants 1–6 gradually updated their narrative model of the game as they played the game (and read its novel).
Meta-Emotion	**Definition**	**Example**
Dissatisfaction and Anger	The learner felt dissatisfied when an unexpected event occurred during a fight, and a second-order emotion of anger was aroused.	In *Bioshock*, participant 2 felt dissatisfied when her powers randomly shifted while fighting the Big Daddy. A second-order emotion of anger was aroused.
Curiosity and Satisfaction	The learner was intrinsically motivated (Deci & Ryan, 1985) to learn by curiosity, and felt	In *TWD*, participant 5 was motivated by curiosity to solve the puzzle to find the

	satisfaction when obtaining new knowledge.	hidden room with Mark. A second-order emotion of satisfaction was aroused at solving the puzzle.

Table 3 Self-directed learning strategies

5. Discussion

Based on the study of the player experience (Toh, 2018), this section suggests some relevant factors that game designers and educators can consider when creating games to promote self-directed learning in video games in pedagogical contexts. These factors include providing "learning analytics as a metacognitive tool", "gradual release of new information over time", "a safe space", "defamiliarisation mechanics", and "scaffolded learning".

5.1. Learning Analytics as a Metacognitive Tool

After each episode of *TWD Season 1* game, players were provided with visualisation patterns of their important gameplay choices in comparison with a baseline from other players. Participants 2 and 5 used the data analytics to revisit and reflect on their in-game actions and choices, for instance, why participant 5 opted for Clementine to kill Lee Everett. He demonstrated how he developed empathy skills by putting himself in both Lee's and Clementine's perspectives to guide Clementine's actions. He explained that his choice would make Clementine stronger and more independent:

> I asked Clementine to shoot me because if I were Lee, I wouldn't want to come back as a zombie and start killing people…. I know it may be a hard decision for Clementine…. She has seen her parents die, and Lee is going to die. But if she shoots me, which is the

closest thing next to a family member, I contend she will feel sad and pain initially. But after that, she will turn out stronger.

Learning analytics can provide computational support for self-directed learning and twenty-first century education by allowing learners to track their behaviour, choices, and learning progress through visualising patterns and providing rapid feedback using a computerised or mobile platform (Aldowah, Al-Samarraie, & Fauzy, 2019). Integrating learning analytics and data visualisation features into games or the classroom context can enable learners to reflect on their gameplay actions or the learning process and allows students to assess their performance and learnings compared with a baseline from other students.

5.2. Gradual Release of New Information Over Time

To promote self-directed learning, new information, such as the learning of specific skills or concepts, can be designed in educational games and given gradually and "just-in-time" (Gee, 2005) as the learner progresses the game or lessons. For instance, in *TLOU's* prologue, participant 1 was only provided with a tutorial on basic movement and environment interaction. More advanced information, such as killing an enemy using multiple approaches (stealth options or direct combat), was only given after the prologue. Similarly, Participant 2 commented that *Bioshock* allowed her to learn controls gradually:

> They unlock the abilities and everything slowly rather than throw everything at once on you right at the tutorial…. The controls are much easier to, let's say, select it according to let you choose. The combat is a lot more easier as well; you don't have so many options. Providing all the options simultaneously is too much for me, and I won't instinctively use them, so you can see in the gameplay that I hardly use such things.

5.3. A Safe Space to Try Multiple Approaches and Learn from Failures

In *TWD Season 1 Episode 4,* participant 5 was observed attempting to find a sewer tunnel exit. During his first attempt, he opted to shoot the zombie blocking the exit, but the noise alerted nearby zombies, limiting the time to solve the puzzle to escape. He could not solve the puzzle in time and, hence, failed during the first attempt. However, the game gave participant 5 a second chance during which he explained that, "I only want[ed] to kill the zombie. I panicked and chose the option to shoot instead of choosing the option to use the crowbar to kill the zombie."

By choosing melee attacks to kill the zombie in the second attempt, participant 5 was provided with unlimited time to explore without fear of being attacked. Thus, he managed to complete this section of the game during the second attempt. We argue that the classroom curriculum or assessment structure can provide learners a safe space for determining alternative ways to solve a problem or understand a concept without penalty, as this encourages risk taking, which is important in the real world. This could include low-stakes assessments that have little impact on a student's course grade, specifications grading, or integrating assessment for learning (Heritage, 2018) to conduct formative assessment of the process of students' learning in the classroom. Educators can also use the data analytics afforded by educational video games to track student progress and conduct formative assessment.

5.4. Defamiliarisation Mechanics

Self-directed learning strategies such as reflection and improvisation can be promoted when learners perceive a situation as nonroutine and are therefore more likely to respond in a new or alternative way (Watkins & Marsick, 1992). Defamiliarisation mechanics can be designed and integrated into video games to force players to reflect upon their game

experience or issues beyond the immediate game experience (Mitchell, 2018) for pedagogical purposes by making specific game mechanics nonroutine compared to those used earlier in the game. In *TWD Season 1 Episode 2*, participants 2 and 5 had previously learnt to finish the quick time event to progress the game (Toh, 2018); they were confused when they followed the game prompts, but the game did not progress. Through think-aloud verbalisations, the participants were observed to briefly pause the game to reassess their actions and think of an alternative solution, which involved gradually releasing the controls.

Defamiliarisation mechanics can therefore be used to foster metacognitive strategies of learning how to unlearn and relearn to foster the development of cognitive flexibility in learners. In pedagogical contexts, we propose that teachers can adopt various ways to defamiliarise learners (e.g., having learners problem solve in diverse contexts) to promote their learning rather than teach them model answers that have little use in the long run. Educational games could also be designed by guiding players through a debriefing of their play, to provide explicit prompts for learners to reflect on their learning, to adapt the game and learning activities to the learner's zone of proximal development during gameplay (Verma et al., 2019), and to use stealth assessment (Shute, Rahimi, & Lu, 2019) to evaluate self-directed learning.

5.5. Scaffolded Learning: An In-Game Companion

Scaffolded learning is important in guiding learners' development and acquisition of new concepts. Scaffolding is a way to operationalise Vygotsky's (1987) concept of working in the zone of proximal development (Wells, 1999) by building on the learners' knowledge. Educational scaffolding relies on three important assumptions. First, there is an essential need for the dialogic co-construction of knowledge in discourse processing. Second, the kind of

activity wherein knowledge (creation) is embedded is significant. Third, artifacts play an important role in mediating knowing (or knowledge creation) (Wells, 1999).

Based on the above assumptions and prior research demonstrating the importance of a learning companion in building social relations with learners and motivating learning (Michaelis & Mutlu, 2018), educational game designers could consider designing and integrating a mediator or in-game anthropomorphic character to promote the learner's (scaffolded) self-directed learning in virtual, computer-mediated, or game-based learning environments. For instance, our findings indicated that early in *Bioshock*, participants 2, 4, and 6 were guided by the NPC Atlas in learning how to use basic attacks and combine them with melee weapons to enact special moves. An in-game companion could also support the player in learning how to make difficult moral decisions. For instance, participant 5 explained that at the end of *TWD Season 1 Episode 2,* he chose not to kill the Saint John brothers and hesitated at stealing food from the Stranger's vehicle, as Clementine functioned as a moral anchor/compass (Stang, 2019):

> The most important reason was that I didn't want Clementine to see me as a killer…. Why I hesitated from stealing food was because Clementine asked me not to…. I mean what she says make sense that it's not our food, and we shouldn't steal it.... If we don't steal the food, then I think our chance of survival won't be as good. So, I chose to steal the food, although…. I think Clementine was a bit angry at me.

Table 4 summarises the factors that promote self-directed learning.

No.	**Factors Promoting Self-Directed Learning**
1	Learning Analytics and Data Visualisations
2	Gradual Release of New Information Over Time

3	A Safe Space to try Multiple Approaches and Learn from Failures
4	Defamiliarisation Mechanics
5	Scaffolded Learning: An In-Game Companion

Table 4 Factors that promote self-directed learning

6. Limitations and Future Research

The goal of this study was to describe the types of self-directed learning strategies that players can adopt in video games, discuss the factors that can promote self-directed learning in video games, and provide some suggestions on how these factors can be used in pedagogical contexts for teaching and learning. The study has some limitations that present future research opportunities. First, the study was qualitative by design in order to understand player experiences and quantitative data was not collected to support the findings. Future studies could be supplemented with behavioural data for further exploration. Second, the method of think-aloud protocol can be considered as self-reports of thinking and there may be concerns over its validity (Eccles & Arsal, 2017). Future research could adopt more objective measures to examine self-directed learning in video games to triangulate the findings. For instance, objective assessment methods using non-invasive physiological responses such as heart rate variability, eye tracking, functional near-infrared spectroscopy, and galvanic skin conductance could be used to track the players' engagement during video gameplay and measure their brain activity to understand their self-directed learning in video games. Third, this research was conducted on predominantly male university students and there is a gender bias due to the snowball and convenience sampling method used. To establish validity (Makel & Plucker, 2014) and generalisability of the research findings, a follow-up study can be done to validate and refine the types of self-directed learning strategies in video games using a different and more balanced sample. Lastly, the chosen games in this study were

action and adventure games. Future research could be conducted on other game genres, such as real-time strategy games, to understand similarities and differences in self-directed learning strategies by genre, and to measure the extent to which self-directed learning may be more easily developed in certain genres.

7. Conclusion

This self-directed learning framework can be used by game designers or educators to evaluate games' pedagogical value or potential to foster learners' self-directed learning strategies. Using the proposed framework's self-directed learning strategies as a coding scheme in user experience studies to analyse the quantity and quality of the self-directed learning strategies players adopt when interacting with the game, educators and researchers can gain an empirical basis for understanding which games can be used in formal or informal contexts to train specific self-directed learning strategies. Additionally, educators and researchers can explore the player experience using the coding scheme to understand how the lower order self-directed learning strategies can be used to support the development of the higher order self-directed learning strategies for independent and lifelong learning.

The principles from self-directed learning derived from video games can be adapted in pedagogical contexts to engage with students' interests (Deng, Connelly, & Lau, 2016), motivations (Bawa, Watson, & Watson, 2018), and the player type (Lopez & Tucker, 2019) to promote their self-directed learning of metacognitive skills (i.e., learning how to learn) and the integration of new concepts and curricular content. Finally, using this proposed framework and coding scheme to analyse learners will enable user experience designers to understand which game aspects promote (e.g., learning analytics, defamiliarisation mechanics, in-game companion, and so on) self-directed learning and to incorporate this information into the design of future games to promote their pedagogical utility. Future research can continue

to build on this framework by using more games to analyse the player experience and refine the self-directed learning strategies in the coding scheme.

CRediT authorship contribution statement

Weimin Toh: Conceptualization, Methodology, Investigation, Resources, Funding acquisition, Writing - original draft. **David Kirschner:** Writing - review & editing.

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