TechTrends (2024) 68:174–185
https://doi.org/10.1007/s11528-023-00915-0

ORIGINAL PAPER

Game-Based Learning and Systems Thinking: an Innovative Instructional Approach for the 21st Century

Benjamin Emihovich[1]

Accepted: 20 October 2023 / Published online: 3 November 2023

Abstract
Serious games, board games, and well-designed commercial video games represent emerging technologies that have been utilized by instructors to help students develop systems thinking skills. In this paper, the author proposes an innovative pedagogical framework that can support educators using digital game-based learning in higher education. By following a series of steps and activities, university instructors can successfully integrate digital gameplay in their classrooms and align course content with gameplay objectives. Game-based environments for learning offer a glass box approach that can explain how and why these technologies can be suitable for teaching complex competencies like systems thinking skills in a variety of academic contexts. The glass box instructional approach can provide researchers with student data that can be used during gameplay to help students develop competencies and adapt instructional strategies that can tailor the game environment to improve student performance. Successfully implementing digital game-based learning in university classrooms requires a methodical instructional approach that can support both novice and expert technology using educators.

Keywords Emerging technologies · Game-based learning · Systems thinking · Pedagogy

Introduction

Novel approaches to teaching and learning through the advancement of innovative technologies in industry and education continue to play an important role in student growth and development (Lee & Hwang, 2022; Weisberg, 2011). Emerging technologies (ET) can include technological devices, modern innovations to pedagogy or research, as well as new ways of thinking that can advance knowledge (Veletsianos, 2010). However, ET may refer to innovative uses of previously existing technology tools that are repurposed or developed to support engagement, motivation, or cognition (Tiwari, 2022). One way to distinguish ET from *new technologies* is to identify several characteristics that explain how these technologies are used in research and practice to serve educational purposes. According to Veletsianos (2010) five central characteristics help define ET which includes the following: (1) these technologies are not always new, (2) they are continuously being refined and redeveloped, (3) they experience periods of heightened interest and skepticism, (4) they are not yet fully accepted or understood, and (5) while they are disruptive, their potential is often lost. For example, one type of ET that fits the aforementioned criteria includes serious games, board games, and commercial digital video games for learning. The goal of using serious games, video games or board games to help students learn systems thinking skills involves applying game design elements to non-game contexts, such as instruction, training, or design. Serious games are designed to support specific knowledge, skills, or abilities including social learning, prosocial behavior, and engagement through gameplay interactions (Bakhanova et al., 2020; Elsawah et al., 2017).

Player interactions in board games during gameplay are not mediated by a system which differentiates board games from serious games or digital games (Barbara, 2017). According to Rogerson and Gibbs (2016), the key difference between board games, online board games, serious games and digital games is the medium that facilitates gameplay. Board games (e.g., Settlers of Catan, Chess) are designed to be played in one setting on a tabletop surface and include all the physical pieces central to gameplay bundled in a paper box (Pierce et al., 2018). Board games are focused on the

✉ Benjamin Emihovich
bemihov@calstatela.edu

[1] California State University, 5151 State University Drive, Los Angeles, CA 90032, USA

materials themselves such as the dice, the board, the pieces, the rules for interacting, and the game context. Moreover, in board games or online board games, players represent the pieces or tokens with little emphasis on playing a role (Zagal et al., 2006). However, digital games such as the massive multiplayer online role-playing game (MMORPG) *World of Warcraft* (Activision Blizzard, 2023) emphasize the importance of an individual player's role, which can support the connections each player makes to the mechanics, rules, and concepts of the game as interconnected parts of a larger system during gameplay. Educational technologists have been investigating how interactive serious games, well-designed video games and board games can support learning extensively this past decade including numerous comprehensive literature reviews and studies exploring the effects of learning gains on students' performance through gameplay (e.g., Boyle et al., 2016; Byun & Joung, 2018; Clark et al., 2016; Connolly et al., 2012; Gatti Junior et al., 2020; Hainey et al., 2016; Hu et al., 2022; Ke, 2016; Pan et al., 2022). Games provide internal and external feedback on players' behaviors and choices. Borrowing from constructivist and situated learning perspectives, both digital video games and board games situate knowledge within a dynamic system, and provide learners with a meaningful context for systems thinking skills to develop (Castronova & Knowles, 2015; Corredor et al., 2014; Foster et al., 2010; Gatti Junior et al., 2020; Lave & Wenger, 1991). As an example, graduate students in a Master of Education course were shown to exhibit systems thinking skills while playing a board game, *Green Economy*, over the course of two days by learning how to manage resources to develop a prosperous economy as leaders of a fictional nation (Gatti Junior et al., 2020). Players can strengthen their understanding of causal relationships, anticipate system challenges through repeated gameplay, and experiment with various strategies to solve problems in board games and immersive video game environments (Castronova & Knowles, 2015; Shute & Emihovich, 2018; Shute et al., 2018).

Instruction with digital games refers to the use of commercial video games or video game-like elements in educational contexts to facilitate learning (Plass et al., 2015). Scholars agree that well-designed commercial video games support systems thinking skills when students are engaged with complex phenomena like gameplay or interactivity in immersive environments (Danish et al., 2017; Gee, 2004; Hmelo-Silver et al., 2015). Well-designed commercial video games are designed for entertainment purposes, but also provide players with sound design learning principles embedded within gameplay allowing players to solve complex problems which can be adapted to other academic disciplines (Lieberman et al., 2014). Systems thinking skills can be taught using serious games, board games or with well-designed commercial video games by asking students to critically think about how their behaviors in games impact the environment, other characters, and the consequences of acting or not acting in a given problem-solving scenario. The result is a feedback loop designed to help players master game mechanics while developing systems thinking skills through observing the consequences of their choices that impact the game environment (Gatti Junior et al., 2020; Kim et al., 2009; Kim & Pavlov, 2019). However, a methodical and organized pedagogical framework is needed to help students understand the connections between cognition, problem solving, gameplay, and system thinking skills (Alessi, 2000; Größler et al., 2000; Hmelo-Silver et al., 2015; Hmelo-Silver et al., 2017; Pavlov et al., 2015). In addition, teachers need support and guidance when selecting and integrating board games, serious games, or well-designed commercial video games that align with the goals of their curriculum (Clark et al., 2023; Gatti Junior et al., 2020; Tawafak et al., 2023). The purpose of this article is to develop an innovative instructional framework aimed at developing system thinking skills for students that are needed for investigating complex systems through interactive digital game-based learning (DGBL).

Interactive Digital Gameplay and Systems Thinking Skills

Interactive digital gameplay can support the development of systems thinking skills which can be defined as thinking about the relationships among various interrelated components of complex systems (Arnold & Wade, 2015). As an example, scholars investigating the effects of DGBL on hard-to-measure constructs like systems thinking skills posit that digital video gameplay supports the development of systems thinking skills when learners interact within immersive digital environments, which enhances their understanding of complex systems (Danish et al., 2017; Gee, 2003; Hmelo-Silver et al., 2015; Shute et al., 2018; Shute & Wang, 2016). Systems are comprised of different entities and their interrelationships, while systems thinking is a critical competency widely recognized as a fundamental lifelong learning skill that considers the components of a system as a whole, rather than focusing on individual parts alone (Groesser & Schaffernicht, 2012; National Research Council, 2012; Wasserman & Banks, 2017). Well-designed video games provide an engaging and interactive environment that promotes active participation and problem-solving skills (Gee, 2004). Video game environments challenge and motivate players to progress in the game through various rules, traps, puzzles, mechanics, feedback, quests, and goals that engender discovery learning, memory, and recall (Emihovich et al., 2020; Salen & Zimmerman, 2004). The iterative nature of gameplay encourages players to explore, refine their actions,

and adapt mental models of system components. Reflective activities after gameplay helps students to explain how their actions impact the game environment.

As a result, players are challenged by each other to adjust their strategies along with constructing and evaluating each player's decisions and consequences in the game environment (Nordby et al., 2016). During gameplay, players are motivated by experiencing a flow state where video game difficulty responds to the player's ability to solve puzzles or challenges, which is critical to understanding how exactly games can be used to assess cognitive and noncognitive competencies (Csikszentmihalyi, 1990; Shute & Rahimi, 2021). Open world digital game environments allow educators to collect data in real-time which allows for inferences to be made explaining how and why digital gameplay can support learning over time based on player interactions with the game mechanics, rules, goals, feedback, and interactivity with player characters (PCs) and non-players characters (NPCs) in the game environment (Shute & Rahimi, 2021). Traditional methods and instructional technologies are often criticized for failing to address hard-to-measure competencies including problem solving, systems thinking, critical thinking, collaboration, and creativity (Shute & Wang, 2016). Data scientists have been conducting studies measuring the effectiveness of a learning technologies compared to a traditional materials control condition, but this is problematic given that these interventions are often treated as "black boxes" that fail to explain why the intervention succeeded (Reeves & Lin, 2020; Reeves & Oh, 2017; Shute & Rahimi, 2021). Digital gameplay in technology-rich environments can allow educators to identify and analyze student behaviors as components of a larger ecosystem within education, which affords testing of how gameplay interactivity can support various knowledge, skills, or abilities (Kim & Pavlov, 2019; Shute et al., 2016). One of the underlying premises to support DGBL is that understanding complex systems can be facilitated through gameplay and linking their relationships to non-game contexts (Martinez-Garza & Clark, 2017).

Integrating Digital Gameplay with Systems Thinking Skills in Higher Education

Systems thinking skills and interactive digital gameplay are interconnected and can be successfully integrated into higher education classroom contexts. Research scientists continue to develop significant contributions to the field of DGBL and systems thinking with valuable insights into the design, implementation, and effectiveness of instructional approaches that connect these two areas of study (González-Pérez & Ramírez-Montoya, 2022; Sajjadi et al., 2022). The innovative development of accessibility devices (i.e., Microsoft Xbox adaptive controller) to provide a more inclusive space for all players to enjoy games and further reduces mobility barriers to gaming for teaching and learning contexts. The design and application of inclusive devices with commercial video games represents how technologies and innovation are connected through a continuous cycle of development and refinement for research, teaching, practice and use in society (Veletsianos, 2010). Literature reviews conducted by researchers on digital gameplay and learning indicate that digital games are beneficial to learning for a variety of disciplines including science, technology, engineering, and math (Boyle et al., 2014; Ke, 2016; Klopfer & Thompson, 2020; Pan et al., 2022). Instructors need to align the curriculum with the digital gameplay elements so that students can build connections between their actions during gameplay and academic contexts (Clark et al., 2016).

Integrating digital gameplay to support learning requires a clear understanding of what knowledge, skills, or abilities games can support and structure lesson activities to foster meaningful learning (Squire, 2011). Instructor experience and practice with games for learning is critical to helping students achieve success in classroom contexts (Hmelo-Silver et al., 2015, 2017). Some of the challenges associated with integrating digital gameplay in classroom contexts (Baek, 2008; Hmelo-Silver et al., 2015; Takeuchi & Vaala, 2014) include lack of flexibility in the curriculum, negative associations with video games for learning, lack of student interest or preparedness, insufficient materials, resources, or space. Further investigation is needed to illuminate teachers' pedagogical decisions and activities with a game-based curriculum (Foster & Shah, 2015). Designing instruction for gameplay must be relevant for a classroom context while meeting specific curricular needs. Striking a balance between the needs of the curriculum with the flow of gameplay is critical to achieving targeted outcomes of any game-based instructional approach (Shute & Rahimi, 2021). Therefore, any instructional approach aimed at fostering systems thinking skills that are needed for analyzing complex systems requires critical thinking, communication, data collection, as well as hypotheses formation and testing (Hmelo-Silver & Azevedo, 2006; Hmelo-Silver et al., 2015; Jacobson & Wilensky, 2006; Yoon et al., 2016). Several curriculum design frameworks exist that can guide instructors on implementing DGBL lesson plans and activities which have been adapted to create a more generalized procedure when using video games for instruction (Coleman & Money, 2020; Kim & Pavlov, 2019).

Well-designed commercial video games provide interactive and collaborative environments that can support the development of systems thinking skills for students in the twenty-first century (Kim & Pavlov, 2019; Martinez et al., 2022; Shah & Foster, 2014). Some of the benefits of playing digital video games includes improved outcomes such as knowledge acquisition, affect, and cognition through

problem solving actions taken by players during gameplay (Shute & Emihovich, 2018). For example, when students play an MMORPG like *World of Warcraft* they are interacting and collaborating with one another, the environment, different skills, and abilities, a digital economy, and negotiating the interrelationships between each of these gameplay elements. Students learn how each of these gameplay elements exist as small parts of a much larger integrated complex ecosystem that includes a digital economy, multiplayer interactivity, and questing. As students are confronted with various well-defined problems in their gameplay environments, quests often drive the gameplay forward which offers students a chance to understand goals, develop strategies to achieve goals, test various strategies, and discover a solution pathway that can be used to solve similar problems as gameplay becomes more difficult.

The ensuing sections provide a review of the situated learning matrix for gameplay in *World of Warcraft* and a series of steps for instructors to guide lessons and activities using the game to foster systems thinking skills in higher education. The rationale for this innovative instructional framework is to show how well-designed commercial video games can support systems thinking skills in higher education. According to the Entertainment Software Association's (2023) report, 65% of Americans (212.6 million) play video games for at least one hour per week including 62% of adults aged 18 and over. The report also reveals that video games are played by 53% of males and 46% of females. In 2022, US consumers spent $56.6 billion on various types of digital video games (e.g., mobile, console, pc, tablet, VR). Moreover, playing digital video games is prevalent across gender, age, and ethnicity (Entertainment Software Association, 2023). The popularity of digital games has increased interest in examining the effectiveness of these games on supporting the development of various competencies for learning and assessment (Shute et al., 2020). Digital video games foster continuous feedback, interactivity, and active participation (Gee, 2003; Ifenthaler et al., 2012). The example provided in this paper includes the MMORPG *World of Warcraft* to help students learn systems thinking skills.

Situated Learning Matrix Framework for Digital Gameplay and Systems Thinking Skills

Video games help facilitate the acquisition of knowledge and skills differently than traditional learning by chunking content through a series of goals that are subordinate to other similar goals referred to as the situated learning matrix experience (Gee, 2008). The matrix presented below (see Table 1) is adapted from the work of Emihovich (2017) and combines several conditions of gameplay experiences in

Table 1 Situated learning matrix for developing systems thinking skills with World of Warcraft

	Player vs. Environment	Player vs. Player	Trading & Economy
Identity Formation	Choose faction, class, and race; Determine role in the world (damage dealer, healer, defender)	Select a combat style that defines character identity; Utilize suitable spells and talents for the class specialty	Identify professions that support class and specific talents; Learn two professions that can earn rewards (i.e., mining, blacksmithing)
Goals, Behaviors, & Norms	Explore locations and use the map tool; Interact with the environment, complete quests, speak with NPCs, and discover new quests	Scout the enemy; Battle enemies to learn strengths and weaknesses of each class, adjust tactics	Improve profession skills by completing recipes earned from quests and combat; Sell goods on the market for profit
Learning Context/Using Skills & Abilities	Dungeons, cities, and raid environments; Roleplaying, collaborate with players to make friends, test spells and talents	Battlegrounds, invasions, and gladiator arenas; Organize spells and combat talents to defeat enemies	Connect professions with the in-game economy; Discern which items are valuable for selling, and which items can be traded
Feedback, Analysis, & Interactivity	Adjust combat tactics based on the opponent's skills, reflect on which skills and abilities apply to various combat scenarios and bosses	Organize, code, and apply combat abilities with keyboard shortcuts; Alter spells and talents based on different player class/specialty	Analyze pros and cons of new items and weapons, craft more powerful items to enhance player performance

World of Warcraft suitable for the development of systems thinking skills through problem-solving scenarios that players encounter in the game environment: identity formation, establishing goals, behaviors, and norms, efficient use of skills and abilities, learning context through repeated but varied problems depending on the environment, and feedback, analysis, and interactivity from gameplay interactions. Roleplaying video games like *World of Warcraft* are unique in that instead of players being designated one specific character, they have the option to create their own character and class combination (i.e., shaman, mage, priest, warrior). Players have full customization over their character's appearance, faction (horde or alliance), class, race (i.e., human, troll, gnome), physical makeup, name, and skills (see shaman class talent tree in Fig. 1). The limitless customization features in the game help players maintain their interest which can affect how players understand the interrelationships of various skills and abilities as components of a system in the game environment. Commercial video games like *World of Warcraft* are suitable for the development of system thinking skills because they present players with distinct but similar problems that teach players how to connect interrelated parts of the game like combat abilities, rules, sequencing, and strategy to fine tune in-game performance (Emihovich et al., 2020). Open world game environments that promote collaboration and interactivity are useful to help players develop systems thinking skills by solving similar but varied problems in the game environment (Clark & Sheridan, 2010; Kiili, 2007; Zimmerman, 2007). As gameplay begins, players first create a character and assume an identity that comes to define their place in the world—including interactions with friends, adversaries, and NPCs that offer quests, while establishing in-game behaviors and norms that form a value system. These behavioral norms during gameplay include how to explore certain parts of the world, locate where help is needed, establish which enemies must be vanquished to advance gameplay, and learn how multiple skill professions can be used to sell goods and services on the auction house (AH) market economy. Norms are critical in helping players learn which behaviors are needed to accomplish various goals.

Figure 1 above provides an example of the skills and abilities of the shaman class talent tree that players can edit and change to create optimal performance. As an illustration, players can adjust their talents and combat abilities based on specific quest objectives, or enemy skills that may nullify certain player abilities. The overall goal during gameplay is to defeat opponents, gain more powerful items, gather new goods and services which can provide wealth on the market, and connect how interrelated goals must be completed to improve overall character performance. Players can complete goals within the game environment using

Fig. 1 Shaman class talent tree skills and abilities in *World of Warcraft*

available tools and resources to master game content—the rules, facts, principles, and procedures within the game. In *World of Warcraft*, tools typically refer to the spells and abilities that players learn as they increase their experience level over time, whereas resources are often weapons, armor, trade goods, crafting reagents, maps, and enchantments that produce in-game rewards. Players learn to develop systems thinking skills by critically reflecting on the relationships of these gameplay elements through frequent active problem-solving contexts such as combat, resource gathering, profession training, exploration, and questing. The tools and resources players repeatedly use to solve problems solidifies the connections between gameplay elements and understanding how the various game elements support the development of systems thinking skills.

The situated learning matrix for gameplay in *World of Warcraft* is outlined above in Table 1 and includes three interactive gameplay features: Player vs. Environment (PvE), Player vs. Player (PvP), and Trading. Gameplay in *World of Warcraft* begins by establishing player identity in the world and that identity defines how each player will master content, learn to use tools and resources, develop skills and abilities, and connect the dots between all of the interrelated gameplay mechanics that comprise the system as a whole. Scholars interested in DGBL argue that problem solving, and similar associated cognitive processes are affected by player interactivity during gameplay (Eseryel et al., 2014; Hung & Van Eck, 2010). Organized within each interactive experience are the associated gameplay behaviors. Several examples of common gameplay behaviors include the following: exploring new terrain, evaluating skills and abilities for each class, planning, and executing various strategies to vanquish enemies, and reflecting and adjusting character skills and abilities after receiving feedback from combat. Over time, players refine their skills during gameplay through repeated problem-solving behaviors and develop a deeper understanding of game mechanics and relationships among different systems within the game environment. The steps and activities listed below outline the procedural steps for the instructional framework using the digital game *World of Warcraft* and indicate how instruction combines DGBL with instructional design to enhance student understanding of complex systems.

Instructional Steps and Activities to Support Systems Thinking Skills

The following sections indicate procedural steps and activities in the proposed framework that can support the development of systems thinking skills through video gameplay using *World of Warcraft*. Instructors can outline the relationship between DGBL and systems thinking skills. The first step for educators begins by defining systems thinking skills and how systems thinking skills can be developed through gameplay in *World of Warcraft*. The second step outlines the key DGBL elements of the game like a pre-instructional tutorial such as identity formation, character creation, goals, behavior, and norms, the learning context, using tools and resources, skills and abilities, feedback and interactivity, and keyboard and mouse controls for player movement and actions. Educators need to show students how each of the game elements are interconnected, and that understanding the relationships among various interrelated components of complex systems during gameplay is aligned with the definition of systems thinking skills. For example, the next step involves helping students explore the game environment while using the map, which is a useful tool for navigation, questing, and combat. Educators can provide students with an example of how to use spells and abilities to defeat opponents, which is a part of questing that increases a player's level over time. As players increase their level, they unlock new spells and abilities that can be used to support new strategies, abilities, and hypotheses for defeating more powerful opponents. Players also collect in-game currency in the form of silver and gold by completing quests and defeating opponents, which can be used to create goods and services as well as trade on the auction house with other players. Trading goods and services in the economy can help students learn more about how resources can be used to improve their player performance.

The next step involves communication and chat, where players can form teams or groups that are required to engage in dungeons, which are gameplay scenarios that require coordination, teamwork, and collaboration. Similar to how research teams operate or use training simulations in workplace settings, educators can offer examples of how video games can be used for problem-solving skills, conflict resolution, and leadership outside of the game context (Entertainment Software Association, 2023). The final step involves creating assessments for evaluation from digital gameplay. One example may include stealth assessment, which is grounded by an assessment design framework referred to as evidence-centered design (ECD; Almond et al., 2015; Mislevy et al., 2003). Educators can use ECD to gather data which will support valid claims about how students are developing competencies learned from gameplay. The ECD framework consists of four core models and can be applied to gameplay in *World of Warcraft* to assess systems thinking skills: the competency model (CM) that defines the competency being assessed like systems thinking skills, an evidence model (EM) that provides data as to how students learn systems thinking skills from gameplay such as observations, think aloud protocols, and self-reports of how students engaged in systems thinking skills from gameplay, the task model (TM) that indicates the type of gameplay

in which students learned systems thinking skills including quests or dungeon scenarios through collaboration, and an assembly model (AM) which indicates the frequency, type, and sequence of gameplay tasks that can begin with questing followed by completing dungeons collaboratively (Shute et al., 2020). Gathering data from each of these models allows educators to assess how students are developing systems thinking skills while playing digital games with an unobtrusive approach that does not disrupt the flow of gameplay (Shute et al., 2016).

- *Step 1*: Introduce and Define Systems Thinking.

  Begin with an introduction and definition of systems thinking, and its connection to understanding larger complex systems. Help players establish their identity in the game and explain how that will support their understanding of gameplay elements that can foster systems thinking skills.
  Explain foundational systems thinking concepts such as variables, feedback loops, and the importance of considering the whole system. Provide examples of using different skills and abilities from a class talent tree, like the shaman example highlighted above in Fig. 1.
  Engage students in discussions and activities that highlight the actions of gameplay with relevant contexts such as natural ecosystems, workplace sectors, or smart technology devices. Indicate how gameplay behaviors impact their environment.

- *Step 2*: Establish the Game and Initiate Pre-Instructional Activities.

  Discuss how the game simulates a complex system that aligns with content relevant to the lesson goals. The game must provide an interactive environment where students can explore how each of the system's components, relationships, and characters are connected to each other.
  Choose a game that incorporates feedback, rules, mechanics, an open environment to explore and allow students to reflect on the consequences of their choice during gameplay.
  Clearly explain the following during gameplay; rules, actions, mechanics, and objectives, communication, and reflection on how various game elements interact.

- *Step 3*: Facilitate Digital Gameplay and Exploration.

  Let students play and interact with the game while encouraging them to think about their choices and how they impact the environment as a system.
  Empower students to test different strategies, discuss hypotheses aloud, and document the outcomes of their decisions during gameplay.
  Guide students to connect their gameplay experiences with systems thinking concepts introduced earlier, encouraging them to identify feedback loops, causal relationships, and unintended consequences.

- *Step 4*: Create Opportunities for Collaboration and Communication.

  Foster collaborative learning by organizing group discussions or project work where students can collectively analyze the system and reflect on their discoveries.
  Facilitate frequent reflective discussions among students during and after gameplay, where students discuss their observations, insights, and emerging patterns within the system.
  Organize discussions on potential pitfalls, barriers, challenges, and ethics within the game, generate topics for students to think critically and anticipate responsible gameplay behavior.

- *Step 5*: Transfer Gameplay to Natural Contexts.

  Connect DGBL experiences with educational and workplace applications of systems thinking.
  Design projects or field work where students can investigate and study complex systems in their communities, such as environmental changes.
  Demonstrate examples to students of transfer of systems thinking skills from gameplay to natural contexts, and support analysis of these skills to effect systemic change.

- *Step 6*: Provide Feedback, Assessment and Evaluation.

  Build assessments that are interactive and similar to gameplay to test students' understanding of systems thinking skills.
  Document student growth through an ePortfolio or Journal that includes students' reflection on their gameplay experiences.
  Create a survey that elicits students' feedback on how the DGBL lesson can be improved, provide space for students to express how the game helped foster systems thinking skills to non-game contexts.

Educators and practitioners can apply these instructional steps to help students develop their systems thinking skills during gameplay while using *World of Warcraft*. The goal of implementing these steps is twofold; help support systems

thinking skills for learners with meaningful interactions through gameplay, and provide an understanding of the complex interactions between different characters, objects, and the game environment. The activities and guidelines suggested below are based on current research in the field and my own experiences as a scholar, instructor, and practitioner. Instructors can modify or design activities that complement the previously listed steps. The instructional activities outline specific gameplay learning scenarios to help facilitate the development of systems thinking skills for students through digital gameplay.

- *Activity 1*: Situate Systems Thinking with DGBL.

  Connect gameplay with systems thinking: Link the concepts by aligning gameplay behaviors and mechanics to feedback loops, causal relationships, and how interrelated components work within the game environment. One possibility is using concept maps to illustrate the relationships of gameplay variables and systems thinking skills.
  Generate gameplay goals: Clearly communicate with students the specific objectives in gameplay that align with systems thinking skills and how they can be developed through repeated practice and experience. Provide a list of initial objectives in gameplay that are similar to learning objectives.
  Establish gameplay rules: Identify gameplay rules that align with the learning goals, curriculum standards, or assessments and provide opportunities for students to explore, interact, and apply rules with the game environment.

- *Activity 2*: Outline Digital Gameplay with Lesson Concepts.

  Game Introduction: Provide an overview of the game mechanics, including its characters, environment, skills and abilities, controls, settings, and audio-visual settings as system components. Allow students to customize and create their character.
  DGBL concepts: Link systems thinking concepts to behaviors in gameplay that will help students understand system dynamics in the game environment. Explain how quests can be completed by interacting with NPCs.
  Interactive tutorial: Include an interactive tutorial in the first lesson or guided practice session. Verify that students can access and play in the game environment with their character including basic combat, movement, and communication.

- *Activity 3*: Play and Discussion.

  Digital play: Allow students to engage in gameplay sessions and reinforce interactivity with other players, objects, and terrain in the game environment. Show students the talent tree available for each class and encourage them to try different skills and abilities.
  Reflective journals: Provide a space for open discussion and reflection on gameplay sessions with an emphasis on causal relationships, trends, patterns, clues, and repeated behaviors within the game environment. Provide students with feedback to reinforce the connections between gameplay, the environment, combat skills, and systems thinking skills.
  Collaboration: Facilitate open discussions for students to co-construct knowledge by sharing their gameplay experiences, performances, rewards, and strategies, promoting collaborative play and multiple student perspectives. Demonstrate to students how they can collaborate by completing dungeons during gameplay as a group.

- *Activity 4*: Mapping Tools, Models and Analysis.

  Mapping tools: Use concepts maps or similar tools to instruct students on systems thinking and causal loop diagrams, or feedback cycles, to visually represent the system components and their interconnections. Indicate how students can access the map in the game to locate quests, achieve objectives, and find dungeons for collaborative play.
  Catalog system behavior: Store and catalog student data including think aloud protocols, reflective journals, discussions, debates, or statistical tools to analyze gameplay interactions, feedback loops, and emergent properties from student actions. These tools will provide valid inferences when making claims about learning progress.
  Conceptual analysis: Encourage students to identify skills as strategies that are linked to learning theories or models within the game environment, and generate discussions on the alignment between gameplay and problem solving. Encourage students to share their findings from each character and their talents such as optimal skills and abilities to improve performance.

- *Activity 5*: Link Gameplay to Natural Contexts.

  Transfer to natural contexts: Strengthen student connections between gameplay experiences to academic and non-academic contexts relating to complex systems in education. Demonstrate how collaborating in games can lead to prosocial and team-building behaviors.

Portfolios and projects: Create digital portfolios for students to catalog and curate their gameplay experiences over time and encourage iterative reflective practices on gameplay and systems thinking.
Develop solutions: Provide opportunities for students to generate solutions to ill-structured problems and how the skills they develop from gameplay can be useful in academic and workplace environments. Indicate how teamwork during gameplay can help achieve greater rewards than by completing quests alone.

- *Activity 6*: Student Performance and Reflection.

Formative and summative assessment: Incorporate formative and summative evaluation throughout the gameplay process, engage students while they play from beginning to end, including data collection, discussion, ePortfolio to document learning and a survey to receive student feedback that can inform future gameplay activities.
Innovative assessment: Use games as a vehicle to assess learning by cataloging student data during gameplay using *stealth assessment* (Shute & Rahimi, 2021) or similar immersive assessment techniques.
Feedback and Evaluation: Provide feedback during gameplay and after gameplay sessions. Encourage students to test new strategies, develop solution pathways to overcome obstacles, and document how gameplay supports systems thinking skills. Generate a collaborative discussion at the end of gameplay to connect gameplay features with systems thinking skills.

Discussion

The alignment between DGBL elements and systems thinking skills are highlighted and summarized in Table 2. The DGBL elements are included in the instructional steps and activities that align with the development of systems thinking skills from digital gameplay in *World of Warcraft*. Well-designed digital games like *World of Warcraft* provide goals and quests, game mechanics to understand and master, rule identity and application, feedback mechanisms, decision-making opportunities, discovery and exploration, multiplayer collaboration, reflective thinking, using tools and resources, and challenges that support the understanding of interconnections, cause-and-effect relationships, emergent properties, and system dynamics (Emihovich et al., 2020; Gee, 2004, 2008; Shute & Emihovich, 2018). Collaborative discussions and reflective analysis can help students analyze system behavior and develop a holistic understanding of complex systems. Systems mapping tools assist in visually representing system structures, interdependencies, and feedback loops. The goal is for students to transfer their systems thinking skills to natural contexts and be able to make informed decisions within complex systems. The instructional steps and activities aligns DGBL with pedagogy, practice, teaching, instructional strategies, critical thinking, problem solving, systems thinking skills, and assessments for learning. Learning during digital gameplay occurs when students engage in simulations of complex systems and interactions, and understand how different parts of a system work together through feedback and causal relationships.

The goal for developing this framework is to assist educators that want to engage their students to develop systems thinking skills within immersive digital environments. Several examples of systems thinking skills emphasized for student learning include the following: interrelationships of components within a system, examining causal relationships among system components, learning how to recognize feedback loops and emergent behaviors in a digital environment, and shift thinking to a holistic perspective on understanding system components. Instructors can adapt this instructional framework to be used in university classrooms by implementing their own pedagogical strategies, activities, and assessments that align with course curricula. The steps and

Table 2 Digital game-based learning elements and systems thinking skills in *World of Warcraft*

DGBL elements	Systems thinking skills
Game mechanics	Building connections between various components that support player behavior during gameplay
Internal and external feedback	Testing cause-and-effect relationships among variables during gameplay and recognizing feedback loops within the system
Rule identification and application	Analyzing givens and constraints of the game environment
Goals and quests	Locating game objectives, exploring game environment boundaries, and linking activities together
Discovery and exploration	Identifying patterns, clues, tools, and resources that guide player movement in the game environment
Multiplayer collaboration	Sharing knowledge, insights, innovations, experiences and developing shared understanding of complex ecosystems
Reflective thinking	Testing and evaluating the consequences of player actions when facing challenges in the game environment
Using tools and resources	Interacting with system tools, characters, and reacting to feedback in the game environment

activities presented above aligns game-based instruction, systems thinking skills, problem-solving skills, teaching, assessment, and evaluation. In addition, this instructional framework does not require any additional professional training or development for educators to implement in their own classrooms. Educators can implement these steps and activities outlined above in multiple disciplines including math, science, literacy, geography, and language development. Providing opportunities for students to interact with complex systems through immersive and engaging digital game environments can help foster deeper more meaningful learning. Repeated practice with problem-solving scenarios through interactive gameplay sessions can help this generation of students develop system thinking skills needed to navigate complex challenges in the twenty-first century.

Declarations

Research Involving Human Participants and/or Animals This article did not involve contact with human participants or animals.

Informed Consent This article does not require informed consent.

Conflicts of Interest The author declares that they have no conflicts of interest.

References

Activision Blizzard. (2023). *World of Warcraft. [Digital video game]*. Blizzard Entertainment, Inc.

Alessi, S. M. (2000). Designing educational support in system-dynamics-based interactive learning environments. *Simulation & Gaming, 31*(2), 178–196. https://doi.org/10.1177/104687810003100205

Almond, R. G., Mislevy, R. J., Steinberg, L. S., Yan, D., & Williamson, D. M. (2015). *Bayesian networks in educational assessment*. Springer-Verlag.

Arnold, R., & Wade, J. (2015). A definition of systems thinking: A systems approach. *Procedia Computer Science, 44*, 669–678. https://doi.org/10.1016/j.procs.2015.03.050

Baek, Y. M. (2008). What hinders teachers in using computer and video games in the classroom? Exploring factors inhibiting the uptake of computer and video games. *Cyberpsychology & Behavior, 11*(6), 665–671. https://doi.org/10.1089/cpb.2008.0127

Bakhanova, E., Garcia, J., Raffe, W. L., & Voinov, A. (2020). Targeting social learning and engagement: What serious games and gamification can offer to participatory modeling. *Environmental Modelling and Software, 134*, 104846. https://doi.org/10.1016/j.envsoft.2020.104846

Barbara, J. (2017). Measuring user experience in multiplayer board games. *Games and Culture, 12*(7–8), 623–649.

Boyle, E., Hainey, T., Connolly, T., Gray, G., Earp, J., Ott, M., Lim, T., Ninaus, M., Ribeiro, C., & Pereira, J. (2016). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education, 94*, 178–192. https://doi.org/10.1016/j.compedu.2015.11.003

Boyle, E., MacArthur, E., Connolly, T., Hainey, T., Manea, M., Kärki, A., & Van Rosmalen, P. (2014). A narrative literature review of games, animations and simulations to teach research methods and statistics. *Computers & Education, 74*, 1–14. https://doi.org/10.1016/j.compedu.2014.01.004

Byun, J., & Joung, E. (2018). Digital game-based learning for K-12 mathematics education: A meta-analysis. *School Science and Mathematics, 118*(3–4), 113–126. https://doi.org/10.1111/ssm.12271

Castronova, E., & Knowles, I. (2015). A model of climate policy using board game mechanics. *International Journal of Serious Games, 2*(3), 41–62. https://doi.org/10.17083/ijsg.v2i3.77

Clark, D. B., Hernández-Zavaleta, J. E., & Becker, S. (2023). Academically meaningful play: Designing digital games for the classroom to support meaningful gameplay, meaningful learning, and meaningful access. *Computers & Education, 194*, 104704. https://doi.org/10.1016/j.compedu.2022.104704

Clark, D., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning. *Review of Educational Research, 86*(1), 79–122. https://doi.org/10.3102/0034654315582065

Clark, K., & Sheridan, K. (2010). Game design through mentoring and collaboration. *Journal of Educational Multimedia and Hypermedia, 19*(2), 125–145.

Coleman, T. F., & Money, A. G. (2020). Student-centered digital game–based learning: A conceptual framework and survey of the state of the art. *Higher Education, 79*(3), 415–457. https://doi.org/10.1007/s10734-019-00417-0

Connolly, T., Boyle, E., MacArthur, E., Hainey, T., & Boyle, J. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education, 59*(2), 661–686. https://doi.org/10.1016/j.compedu.2012.03.004

Corredor, J., Gaydos, M., & Squire, K. (2014). Seeing change in time: Video games to teach about temporal change in scientific phenomena. *Journal of Science Education and Technology, 23*(3), 324–343. https://doi.org/10.1007/s10956-013-9466-4

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. Harper and Row.

Danish, J. A., Saleh, A., Andrade, A., & Bryan, B. (2017). Observing complex systems thinking in the zone of proximal development. *Instructional Science, 45*(1), 5–24. https://doi.org/10.1007/s11251-016-9391-z

Elsawah, S., McLucas, A., & Mazanov, J. (2017). An empirical investigation into the learning effects of management flight simulators: A mental models approach. *European Journal of Operational Research, 259*(1), 262–272. https://doi.org/10.1016/j.ejor.2016.10.011

Emihovich, B. W. (2017). *Improving undergraduates' problem-solving skills through video gameplay*. [Doctoral dissertation, Florida State University]. ProQuest Dissertations Publishing.

Emihovich, B., Roque, N. A., & Mason, J. (2020). Can video gameplay improve undergraduates' problem-solving skills? *International Journal of Game-based Learning, 10*(2), 1–18. https://doi.org/10.4018/ijgbl.2020040102

Entertainment Software Association (2023). *2023 essential facts about the U.S. video game industry*. Retrieved October 14, 2023, from https://www.theesa.com/2023-essential-facts/

Eseryel, D., Law, V., Ifenthaler, D., Ge, X., & Miller, R. (2014). An investigation of the interrelationships between motivation, engagement, and complex problem solving in game-based learning. *Educational Technology & Society, 17*(1), 42–53.

Foster, A., Mishra, P., & Koehler, M. J. (2010). The process of learning in a simulation strategy game: Disciplinary knowledge construction. *Journal of Educational Computing Research, 45*(1), 1–27. https://doi.org/10.2190/ec.45.1.a

Foster, A., & Shah, M. B. (2015). The ICCE framework: Framing learning experiences afforded by games. *Journal of Educational*

Computing Research, 51(4), 369–395. https://doi.org/10.2190/ec.51.4.a

Gatti Junior, W., Kim, B., Liu, L., & Lai, X. (2020). Green economy game: A modular approach for sustainable development education. *International Journal of Designs for Learning, 11*(2), 96–107. https://doi.org/10.14434/ijdl.v11i2.25020

Gee, J. C. (2004). What video games have to teach us about learning and literacy. *Journal of Education and Training*, *46*(4), https://doi.org/10.1108/et.2004.00446dae.002

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. Palgrave Macmillan.

Gee, J. P. (2008). Learning and games. In K. Salen (Ed.), *The ecology of games: Connecting. youth, games, and learning* (pp. 21–40). MIT Press.

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of education 4.0 in 21st century skills frameworks: Systematic review. *Sustainability, 14*(3), 1493. https://doi.org/10.3390/su14031493

Groesser, S. N., & Schaffernicht, M. (2012). Mental models of dynamic systems: Taking stock and looking ahead. *System Dynamics Review, 28*(1), 46–68. https://doi.org/10.1002/sdr.476

Gröβler, A., Maier, F. J., & Milling, P. (2000). Enhancing learning capabilities by providing transparency in business simulators. *Simulation & Gaming, 31*(2), 257–278. https://doi.org/10.1177/104687810003100209

Hainey, T., Connolly, T., Boyle, E., Wilson, A., & Razak, A. (2016). A systematic literature review of games-based learning empirical evidence in primary education. *Computers & Education, 102*, 202–223. https://doi.org/10.1016/j.compedu.2016.09.001

Hmelo-Silver, C. E., & Azevedo, R. (2006). Understanding complex systems: Some core challenges. *The Journal of the Learning Sciences, 15*(1), 53–61. https://doi.org/10.1207/s15327809jls1501_7

Hmelo-Silver, C. E., Jordan, R., Eberbach, C., & Sinha, S. (2017). Systems learning with a conceptual representation: A quasi-experimental study. *Instructional Science, 45*(1), 53–72. https://doi.org/10.1007/s11251-016-9392-y

Hmelo-Silver, C. E., Liu, L., Gray, S. G., & Jordan, R. (2015). Using representational tools to learn about complex systems: A tale of two classrooms. *Journal of Research in Science Teaching, 52*(1), 6–35. https://doi.org/10.1002/tea.21187

Hu, Y., Gallagher, T., Wouters, P., Van Der Schaaf, M., & Kester, L. (2022). Game-based learning has good chemistry with chemistry education: A three-level meta-analysis. *Journal of Research in Science Teaching, 59*(9), 1499–1543. https://doi.org/10.1002/tea.21765

Hung, W., & Van Eck, R. (2010). Aligning problem solving and gameplay: A model for future research and design. In R. van Eck (Ed.), *Interdisciplinary models and tools for serious games: Emerging concepts and future directions* (pp. 227–263). IGI Global. https://doi.org/10.4018/978-1-61520-719-0.ch010

Ifenthaler, D., Eseryel, D., & Ge, X. (2012). Assessment for game-based learning. In D. Ifenthaler, D. Eseryel, & X. Ge (Eds.), *Assessment in game-based learning: Foundations, innovations, and perspectives* (pp. 1–8). Springer. https://doi.org/10.1007/978-1-4614-3546-4_1

Jacobson, M. J., & Wilensky, U. (2006). Complex systems in education: Scientific and educational importance and implications for the learning sciences. *The Journal of the Learning Sciences, 15*(1), 11–34. https://doi.org/10.1207/s15327809jls1501_4

Ke, F. (2016). Designing and integrating purposeful learning in game play: A systematic review. *Educational Technology Research and Development, 64*(2), 219–244. https://doi.org/10.1007/s11423-015-9418-1

Kiili, K. (2007). Foundation for problem-based gaming. *British Journal of Educational Technology, 38*(3), 394–404.

Kim, B., Park, H., & Baek, Y. (2009). Not just fun, but serious strategies: Using meta-cognitive strategies in game-based learning. *Computers & Education, 52*(4), 800–810. https://doi.org/10.1016/j.compedu.2008.12.004

Kim, Y., & Pavlov, O. V. (2019). Game-based structural debriefing. *Information and Learning Sciences, 120*(9/10), 567–588. https://doi.org/10.1108/ils-05-2019-0039

Klopfer, E., & Thompson, M. (2020). Game-based learning in science, technology, engineering, and mathematics. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of game-based learning* (pp. 387–408). MIT Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lee, H. J., & Hwang, Y. (2022). Technology-enhanced education through VR-Making and metaverse-linking to foster teacher readiness and sustainable learning. *Sustainability, 14*(8), 4786. https://doi.org/10.3390/su14084786

Lieberman, D., Biely, E., Thai, C. L., & Peinado, S. (2014). Transfer of learning from video game play to the classroom. In F. Blumberg (Ed.), *Learning by playing* (pp. 189–204). Oxford University Press eBooks. https://doi.org/10.1093/acprof:osobl/9780199896646.003.0013

Martinez, L., Gimenes, M., & Lambert, E. G. (2022). Entertainment video games for academic learning: A systematic review. *Journal of Educational Computing Research, 60*(5), 1083–1109. https://doi.org/10.1177/07356331211053848

Martinez-Garza, M. M., & Clark, D. B. (2017). Two systems, two stances: A novel theoretical framework for model-based learning in digital games. In P. Wouters, & van H. Oostendorp (Eds.), *Instructional Techniques to facilitate Learning and Motivation of Serious games*. Springer. Advances in Game-Based Learning. https://doi.org/10.1007/978-3-319-39298-1_3

Mislevy, R. J., Steinberg, L. S., & Almond, R. G. (2003). Focus article: On the structure of educational assessments. *Measurement: Interdisciplinary Research and Perspectives, 1*(1), 3–62. https://doi.org/10.1207/S15366359MEA0101_02

National Research Council. (2012). *A framework for k-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Nordby, A., Øygardslia, K., Sverdrup, U., & Sverdrup, H. (2016). The art of gamification; teaching sustainability and system thinking by pervasive game development. *Electronic Journal of e-Learning, 14*(3), 152–168.

Pan, Y., Ke, F., & Xu, X. (2022). A systematic review of the role of learning games in fostering mathematics education in K-12 settings. *Educational Research Review, 36*, 100448. https://doi.org/10.1016/j.edurev.2022.100448

Pavlov, O. V., Saeed, K., & Robinson, L. R. (2015). Improving instructional simulation with structural debriefing. *Simulation & Gaming, 46*(3–4), 383–403. https://doi.org/10.1177/1046878114567980

Pierce, M., Shelstad, W. J., Rickel, E., & Chaparro, B. S. (2018). Thinking "out-of-the-box" with board games. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 62*(1), 1321–1325. https://doi.org/10.1177/1541931218621302

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist, 50*(4), 258–283. https://doi.org/10.1080/00461520.2015.1122533

Reeves, T. C., & Lin, L. (2020). The research we have is not the research we need. *Educational Technology Research and Development, 68*(4), 1991–2001. https://doi.org/10.1007/s11423-020-09811-3

Reeves, T. C., & Oh, E. (2017). The goals and methods of educational technology research over a quarter century (1989–2014). *Educational Technology Research and Development, 65*(2), 325–339. https://doi.org/10.1007/s11423-016-9474-1

Rogerson, M. J., & Gibbs, M. (2016). Finding time for tabletop. *Games and Culture, 13*(3), 280–300. https://doi.org/10.1177/1555412016656324

Sajjadi, P., Bagher, M. M., Myrick, J. G., Guerriero, J. G., White, T. S., Klippel, A., & Swim, J. K. (2022). Promoting systems thinking and pro-environmental policy support through serious games. *Frontiers in Environmental Science, 10*, 957204. https://doi.org/10.3389/fenvs.2022.957204

Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals*. MIT Press.

Shah, M., & Foster, A. (2014). Undertaking an ecological approach to advance game-based learning: A case study. *Journal of Educational Technology & Society, 17*(1), 29–41. https://doi.org/10.2307/jeductechsoci.17.1.29

Shute, V. J., & Emihovich, B. (2018). Assessing problem-solving skills in game-based immersive environments. In J. Voogt, G. Knezek, R. Christensen, & K.W. Lai (Eds.), *Second handbook of information technology in primary and secondary education* (pp. 635–648). Springer. https://doi.org/10.1007/978-3-319-71054-9_40

Shute, V. J., & Wang, L. (2016). Assessing and supporting hard-to-measure constructs in video games. In A. A. Rupp, & J. P. Leighton (Eds.), *The handbook of cognition and assessment* (pp. 535–562). Wiley Inc.

Shute, V. J., Leighton, J. P., Jang, E. E., & Chu, M. (2016). Advances in the science of assessment. *Educational Assessment, 21*(1), 34–59. https://doi.org/10.1080/10627197.2015.1127752

Shute, V. J., & Rahimi, S. (2021). Stealth assessment of creativity in a physics video game. *Computers in Human Behavior, 116*, 1–13. https://doi.org/10.1016/j.chb.2020.106647

Shute, V. J., Rahimi, S., & Emihovich, B. (2018). Assessment for learning in immersive environments. In D. Lui, C. Dede, R. Huang, & J. Richards (Eds.), *Virtual, augmented, and mixed realities in education* (pp. 71–89). Springer.

Shute, V. J., Rahimi, S., Smith, G., Ke, F., Almond, R. G., Dai, C., Kuba, R., Liu, Z., Yang, X., & Sun, C. (2020). Maximizing learning without sacrificing the fun: Stealth assessment, adaptivity and learning supports in educational games. *Journal of Computer Assisted Learning, 37*(1), 127–141. https://doi.org/10.1111/jcal.12473

Squire, K. (2011). *Video games and learning: Teaching and participatory culture in the digital age*. Teachers College Press.

Takeuchi, L. M., & Vaala, S. (2014). *Level up learning: A national survey on teaching with digital games*. The Joan Ganz Cooney Center at Sesame Workshop.

Tawafak, R., Al-Obaydi, L. H., Klimova, B., & Pikhart, M. (2023). Technology integration of using digital gameplay for enhancing EFL college students' behavior intention. *Contemporary Educational Technology, 15*(4), ep452. https://doi.org/10.30935/cedtech/13454

Tiwari, S. P. (2022). Emerging technologies: Factors influencing knowledge sharing. *World Journal of Educational Research, 9*(2), 68–74. https://doi.org/10.22158/wjer.v9n2p68

Veletsianos, G. (2010). *Emerging technologies in distance education*. Athabasca University Press.

Wasserman, J. A., & Banks, J. (2017). Details and dynamics: Mental models of complex systems in game-based learning. *Simulation & Gaming, 48*(5), 603–624. https://doi.org/10.1177/1046878117715056

Weisberg, M. (2011). Student attitudes and behaviors towards digital textbooks. *Publishing Research Quarterly, 27*(2), 188–196. https://doi.org/10.1007/s12109-011-9217-4

Yoon, S. A., Anderson, E. L., Klopfer, E., Koehler-Yom, J., Sheldon, J., Schoenfeld, I., Wendel, D., Scheintaub, H., Oztok, M., Evans, C., & Goh, S. (2016). Designing computer-supported complex systems curricula for the next generation science standards in high school science classrooms. *Systems, 4*(4), 38. https://doi.org/10.3390/systems4040038

Zagal, J. P., Rick, J., & Hsi, I. (2006). Collaborative games: Lessons learned from board games. *Simulation & Gaming, 37*(1), 24–40. https://doi.org/10.1177/1046878105282279

Zimmerman, E. (2007). Gaming literacy: Game design as a model for literacy in the 21st century. *Harvard Interactive Media Review, 1*(1), 30–35.