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Abstract This chapter investigates the dynamic synergy between pedagogy, social dynamics, and technological developments in Digital Game-Based Learning (DGBL), which is enhanced by artificial intelligence (AI). The chapter navigates through educational modifications, learner profiling challenges, social enhancements, and technical considerations, emphasising AI's revolutionary influence. The topic expands on the critical interaction between learning analytics and machine learning, demonstrating AI's promise for personalised and adaptable DGBL experiences. The practical ramifications of real-time feedback in AI-driven DGBL are discussed, with the goal of providing timely instruction

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and encouraging positive behaviours. Finally, the chapter sheds light on the collaborative evolution of AI-enhanced education, providing useful insights for educators, instructional designers, and developers in creating optimised digital learning environments.

Keywords Learning analytics · Digital Game-Based Learning · Affordances · Feedback · Learner modelling

Introduction

Playful learning environments, particularly those utilising Digital Game-Based Learning (DGBL), have reunited a diverse community of research which aims to design and evaluate the use of DGBL in different educational settings. With the advent of learning analytics and artificial intelligence (AI), these environments now offer enhanced pedagogical and social affordances. This chapter explores the intersection of these affordances, pedagogy, and AI within playful learning environments, delving into the technical, pedagogical, and social aspects that contribute to their effectiveness.

Design Affordances for AI Tools in Education

Game design is an essential activity in game studies which aims to provide the frameworks for ensuring the alignment between the game objectives, learning mechanics (Menon & Romero, 2020; Nadolny et al., 2017; Proulx et al., 2017), game mechanics, and the playful experience of learning. In game design, affordances are not always explicitly defined. We can consider three types of affordances including pedagogical, social, and technical affordances. These three types of affordances are intricate and interdependent. Technical affordances provide the foundation, offering support for the implementation of pedagogical and social design activities. However, the effectiveness of learning is significantly influenced by the thoughtful integration of pedagogical and social affordances. Effective game design can support the synergy between these

three types of affordances, facilitating a dynamic and adaptive learning environment.

Pedagogical Affordances in AI Tools for Education

The integration of AI into DGBL introduces a transformative approach to education, offering dynamic and personalised learning experiences. AI's adaptive capability allows for real-time modifications in response to the learner/player's profile, ensuring a customised and engaging journey through the DGBL. This adaptability operates at the speed of the learner's progression, contributing to the enrichment and improvement of data accuracy for more effective, actionable, and adaptive feedback and flow balancing (Gaurav et al., 2022).

Affordances derive from the information structure of the environment and the sensory capabilities of the AI agent (virtual or physical), emerging through the interaction between the learner–player and the DGBL system integrating AI capabilities. In the context of game-based learning, AI-driven learning analytics can leverage these affordances to enhance the interactive and adaptive elements of the gaming environment. Pedagogical affordances in playful learning environments encompass various pedagogical approaches and learning activities facilitated by information and communication technology (ICT) tools.

Essentially, an affordance means the property of a system which allows certain actions to be performed, and which encourage specific types of behaviour that might determine how technology could possibly be used (Lameras et al., 2012; Kalmpourtzis & Romero, 2020). The concept of affordance may have a positive impact in terms of providing a richer understanding of the pedagogical design inherent to AI tools that would profoundly lead to an enhanced AI-based learning experience. The hallmark of AI in DGBL encompasses its adaptive capability, enabling real-time modifications aligned with the learner's profile. This adaptability operates at the learner's pace, contributing to enriched data accuracy and fostering more effective, actionable feedback. The affordance of personalisation (e.g. Lameras et al., 2021; Luckin & Cukurova, 2019) may

discern customised and engaging learning journeys, tailoring content and challenges based on individual learner profiles. This affordance creates a dynamic and responsive in-game learning interaction by modifying content and challenges on-the-fly. Furthermore, this adaptability ensures that the learning journey remains challenging yet attainable, catering to the individual needs and pace of each learner (e.g. Hou et al., 2021).

Examples include problem-based learning, project-based learning, case-based learning, inquiry-based learning, and game-based learning. AI, when integrated into DGBL environments, enhances the adaptability and customisation of these pedagogical approaches, providing personalised learning experiences tailored to individual student needs (Lampropoulos, 2023).

The challenge of learner/player profiling is substantial, considering the multifaceted influences of intrinsic and extrinsic factors such as personality, motivation, interest, mood, and external events (Nacke, 2018; Tondello & Nacke, 2020). Understanding player traits becomes crucial for tailoring personalisations that influence both gameplay and learning experiences, recognising the diverse composition of individuals. Future endeavours should focus on leveraging AI to comprehensively understand players and learners through incremental and iterative profiling.

DGBLs serve as invaluable sources of data for training AI, aiming to deepen the understanding of learners and enhance personalised experiences. Current efforts predominantly centre on utilising video games to train AI algorithms, leveraging the structured progression inherent in game design. Google's DeepMind AI exemplifies this approach, building predictive models based on extensive learning from thousands of 'Go' games (Silver et al., 2017) and achieving 'Grandmaster' status in 'Starcraft II' (Vinyals et al., 2019).

AI advancements in mastering real-time strategy present opportunities for intelligently staging and scaffolding the learning experience. Rather than focusing solely on creating AI players excelling at specific games, a similar approach can be applied to develop models that progressively support and offer actionable feedback to learners throughout the gameful learning process. This feedback is not only beneficial to learners but also empowers teachers to provide personalised support, fostering continuous adaptation for improved retention and learning outcomes.

Personalised and adaptive support extends beyond player interactions, as AI-driven, non-player characters (NPCs) play a pivotal role by contributing to a game's depth and storyline. Games like 'The Elder Scrolls V: Skyrim' are at the forefront of developing NPCs that learn and evolve from interactions with players and other NPCs (Yannakakis &Togelius, 2018). This industry-driven development aligns with academic research interests, signalling a shift towards more meaningful, responsive, and adaptive interactions between learners and in-game characters in the context of gameful learning scenarios. The prospect of intelligent NPCs enhances the realism of educational game environments, fostering a more immersive and personalised learning experience.

Social Affordances in AI for Education

AI systems can intricately develop, analyse, and leverage player/learner profiles in an incremental and iterative manner, aiming to deliver intentional experiences that consider various factors influencing motivation (Arnab, 2020). This evolving landscape in AI aligns with the exploration of social affordances, emphasising the potential for AI in education to foster tailored and socially connected learning experiences.

Social affordances focus on creating a conducive social context within ICT tools for learners' interactions. Safety, comfort, and convenience are crucial aspects. Ensuring students feel safe to express themselves involves considerations such as privacy settings and moderation. Establishing a comfortable environment requires clear ground rules, which can be supported by the presence of moderators or by a DGBL design in which the social interaction is modelled in order to be monitored and regulated by an adaptive system. Convenience is facilitated by supporting various communication modalities (text, audio, video) and synchronous/asynchronous discussions. AI can contribute by analysing emotions (Li et al., 2023) and social interactions, ensuring a positive and inclusive online atmosphere.

Technical Affordances in AI for Education

Technical affordances pertain to the capacity and usability of ICT tools. The availability of different versions, each catering to specific needs, ensures flexibility. Usability, including interface design, ease of use, and technical support, directly influences the effectiveness of the tool. While technical affordances are necessary, they alone do not guarantee successful learning outcomes. The interplay of pedagogical and social affordances is crucial, emphasising that effective design relies on the synergy between technology and instructional and social designs.

Affordances Perception, Learning Analytics, and Machine Learning

The recognition and utilisation of affordances in human interaction with playful learning environments constitute a pivotal aspect of adaptive digital game-based learning (DGBL). The literature review of Banihashem et al. (2023) shows the capacity of learning analytics to support dynamic and adaptive DGBL environments where learners can follow and adjust their learning based on their own specific needs.

As individuals engage with DGBL adaptive environments, they can benefit from learning analytics when they engage with the designed affordances during their play activity. This interaction sets the stage for the generation of specific learning analytics, opening avenues for diverse analytical approaches, with machine learning emerging as a particularly promising avenue.

In DGBL, machine learning based on learning analytics refers to the utilisation of machine learning algorithms to enhance the analytical process of assessing learning analytics to identify certain aspects of the learning process during DGBL interactions. The primary objective is to leverage these insightful learning analytics to inform the adaptive DGBL environment in support of learning processes. This application of machine learning holds the potential to provide additional opportunities to support the way learning analytics are analysed, offering educators and administrators a data-driven approach for adaptive DGBL.

In the context of digital game-based maths learning environments (maths DGBLE), Dai et al. (2023), used unsupervised machine learning (Gaussian Mixture Model), which permitted six clusters of 'learning-support-use' behaviours including skills development, conceptual knowledge, metacognitive connections, metacognitive regulation, information selection using cognitive aids, and sustained motivation for necessary practices. Thanks to the identification of these six clusters of 'learning-support-use' behaviours researchers proposed an adaptive system, which has improved learners' performance in the maths DGBLE environment.

In DGBL, the affordances embedded in game-based learning tools wield significant influence in learner-player interactions within the system, and as such, will also influence the type of learning analytics the system can produce. The learner's perception and utilisation of these affordances contribute to the creation of distinct learning analytics. These analytics, once generated, serve a dual purpose—they become valuable tools for the in-depth analysis of learning activities and, simultaneously, facilitate the dynamic adaptation of the DGBL system. This adaptive capability is pivotal in tailoring the educational experience to individual learner needs, enhancing the overall efficacy of digital learning environments.

The work of Hallifax et al. (2021) adds depth to this discourse through the introduction of a dynamic gamification framework. In their framework, engagement indicators play a pivotal role, functioning as the linchpin for the adaptive capabilities of the DGBL system. The proposed framework aligns with the contemporary shift towards personalised and engaging educational experiences. By leveraging engagement indicators, the system not only gauges learner involvement, but also actively adapts, ensuring sustained engagement and fostering an enriched learning process.

In the broader context of educational technology research, the exploration of affordances, learning analytics, and dynamic adaptation mechanisms represents a crucial frontier. As technology continues to shape the educational landscape, understanding how learners perceive and engage with digital tools becomes paramount. This research not only contributes to theoretical frameworks, but also holds practical implications for

educators, instructional designers, and developers seeking to optimise digital learning environments for enhanced educational outcomes.

Discussion

The integration of pedagogical, social, and technical affordances, augmented by AI capabilities, transforms playful learning environments into dynamic spaces conducive to effective and personalised learning experiences. Emphasising the importance of a balanced approach, this chapter underscores the collaborative relationship among these affordances, shedding light on the evolving landscape of AI-enhanced education.

We have highlighted the importance of learning analytics as a construct for student progress visualisation and representation into DGBL. This systematic collection, analysis, and interpretation of data generated by learners' interaction with the game environment may lead to identifying the root of any misconceptions or lack of prior knowledge that a learner may experience during game play (de Freitas et al., 2023), thereby deriving meaningful insights into individual and collective learning patterns, and areas of strength or challenges (Holstein et al., 2018). Performance metrics through dedicated AI algorithms can track progression and completion rates (Kent & Cukurova, 2020), accuracy in collaborative problem solving (Sun et al., 2020), or efficiency in learning through inquiry (e.g. Lameras & Arnab, 2021). It can be argued therefore that feedback in AI-driven DGBL, as an affordance, goes beyond traditional assessments. It is a dynamic and continuous process, providing timely and relevant information to learners and educators alike. This particular affordance may increase the quality of the feedback process by placing the focus, not only on the informative aspect of identifying potential student misunderstandings, but more importantly, by generating feedback that is actionable and contributes to a continuous improvement cycle. For example, by enabling real-time, formative feedback, learner actions may be addressed, analysed, and represented as they occur within the game. This immediacy enhances the learning experience by providing instant guidance, corrections, reflections, or reinforcement,

encouraging positive behaviours, and promptly correcting misconceptions, leading to an increased understanding of the problem and how it can be resolved (Mavrikis et al., 2007; Neto & Fernandes, 2019). This aligns with the notion of personalisation, afforded by AI, as an extension to feedback mechanisms. When tailored to individual learner profiles, this feedback can target insights that guide learners towards improvements in areas requiring attention. Finally, when affordances are coupled with gamified elements such as achievements, missions, and rewards, and aligned with a playful learning environment, they may contribute to a positive and immersive learning experience, helping learners to persist in their educational journey (Conati & Kardan, 2013; Pareto, 2014).

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