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## Artificial Intelligence, Games, and Education

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# Chapter 1

## Introduction

Play is one of the most important learning activities for human cognitive development [1, 2]. Throughout history, we encoded play in reusable and flexible systems, creating games as environments based on rules [3]. Since then, many games intrinsically assume a relevance beyond pure entertainment, punctuating human history as tools for escapism, community building, activism and others. Subsequently, with the development of digital technologies, the rise of video games has been observed, mixing characteristics of traditional games and interactive arts. Many aspects contribute to the popularisation of video games. One of these is the increasing processing power available throughout the second half of the 20th century. However, what fascinates many is the potential of video games to transport players to previously unattainable situations. In this regard, it is relevant to think that the first popular video games were mostly set in space [4, 5] or in ancient history settings [6]. Moreover, video games, as a product of play, inherited characteristics typical of role-playing, allowing players to impersonate characters with different potentials and problems from their own. Similar lines of reasoning can be carried on for experiencing different rules, abilities, and interactions. Therefore, video games stand out as a medium to create different realities and envelop players. This envelopment is typically conveyed by various aspects of engagement, which consists of occupying the willing player's attention. The willingness of attention is very relevant since it is one of the aspects that most of all allows video games to reach uses beyond entertainment; in layman's terms, games can make activities that are not inherently fun enjoyable. This aspect is studied and used in innumerable contexts, including education, citizenship, and research. Nowadays, video game research is an established, interdisciplinary, and popular field of academia. It is

## 1.1. Video games

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able to confront itself with different subjects and bring necessary knowledge and skills to perform experiments that would have hardly achieved ecological validity otherwise [7]. Yet, the history of games has not been characterised exclusively by enthusiasm and acceptance. Throughout the eighties and nineties, we witnessed a raging debate about the impact of video games on youth, with the aforementioned opportunities eclipsed by concerns related to changes in entertainment habits and, in some cases, poorly substantiated research [8]. Such is the nature of playful interactions, as their pleasurable side is often associated with a lack of productivity and futility. In turn, video games as media were, and in part still are, met with scepticism and questions about their relevance. The present dissertation aims to show possible interactions between programming education and artificial intelligence (AI) through the lens of video games. The goal is to provide a perspective that highlights how these media can be tools to moderate and empower the interaction between the two. To do so, we first explore affordances in video games and programming education. Then, we dive into opportunities arising from video games and artificial intelligence. Finally, we analyse the impact of generative AI on programming education and introduce the challenges and opportunities for games to intervene in this context.

## 1.1 Video games

The first step, albeit banal, is to define the subject medium of this thesis. Defining video games in one sentence is quite complex, as the immediate answer intrinsically requires more clarification: they are digital and interactive games, often with a playful design [9]. Defining games, however, is far from straightforward. Most definitions focus on salient aspects of games, defining characteristics and boundaries. However, these boundaries have been repeatedly pushed and argued throughout the development of video games. For example, Salen and Zimmerman [10] define games as *systems in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome*. Their definition fits a vast number of games, and it includes essential elements such as the necessity of rules. On the other hand, certain elements can be viewed as restrictive if confronted with modern games; consider city-management video games (e.g., *Cities Skyline* [11]), which often have blurred end conditions, making outcome evaluation arguable. A different approach was taken by Frasca [3]. As we cited above, he defined games as *simulations of rule-based systems*. This definition has a broader scope than the previous one and arguably covers all games. Moreover, it does mention the simulated relation between games and reality, which is a highly

fascinating aspect of the medium. However, some would consider the definition too broad, apt to cover also non-playful systems (e.g., climate models used for weather forecasts). In this debate, we take a pragmatic approach; while we are aware of the importance and limitations of these definitions, we believe that they are all relevant for the (video) games involved in our research.

## 1.2 Serious games

At this point, we can enter the field of games outside entertainment purposes. In this case, we are not simply talking about games designed with "serious" objectives, but also games as objects of study beyond entertainment. The practice of attaching additional values and goals to games began a long time ago. For example, board games like Go or Chess were designed to mimic military strategy. Throughout the 19th century, this evolved further with the game genre *Kriegsspiel* developed by the Prussian army to train officers [12]. Furthermore, games represent playful media for serious political changes. Examples include *Pank-a-Squith* [13], a fundraising tool for the British Women's Social and Political Union. The game depicts the conflict between suffragette leader Emmeline Pankhurst and British Prime Minister H. H. Asquith (hence the name). The game uses similar rules as *Chutes and Ladders*, associating tiles with the several challenges suffragettes needed to overcome to bring their petition to the Houses of Parliament (see Figure 1.1). We also have similar examples designed to raise awareness; *Womanopoly* [14], follows again a *Chutes and Ladders* structure with the rule variation that tiles have different effects depending on the gender of players. The game aims to communicate the challenges faced by women in modern society by expressively pushing men to play *the woman's part* (see Figure 1.2). In academia, games are well-recognised tools in psychological research. One of the most well-known types of games used in the field's experimental research is, in fact, the cooperation game. A type of cooperation game is the *game of trust*. In its most generic version, this game revolves around a first player deciding whether to cooperate or not; if the former is selected, the second player can decide whether to exploit the other player or share a reward [15]. This type of game has been studied extensively with numerous variations, and it is just one example of many experimental games used to study human behaviour. In psychology, games are appreciated for their inexpensiveness, complexity and, especially, for their ecological validity [16].

### 1.3. Games and Learning

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Figure 1.1: Pank-a-Squith, from the People's History Museum of Manchester

### 1.3 Games and Learning

As a subcategory of serious games, serious **video** games go beyond strictly digitalising existing opportunities and applications. With the development of the field of interaction design, game patterns have become common elements in the digital landscape. Moreover, thanks to the Internet, video games are appreciated in a serious context for their ability to easily reach people from different parts of the world. In general, games in digital environments evolve along two trajectories: **gamification** and **game-based learning** (or serious video games). The former represents the use of game elements outside of entertainment contexts [9]. The latter consists of fully fledged video games in which entertainment is not the main goal. Today, gamification is widely integrated into many aspects of daily life. The rise of digitalisation has made it easy to implement game elements in applications; it is enough to think about all the services that provide badges as rewards for specific behaviours. Other examples would be the ubiquity of leaderboards and various playful tools to stimulate competition [17]. Gamification has spread due to its well-documented effectiveness as a persuasive technique, particularly in enhancing user motivation [18], while remaining relatively inexpensive and simple to implement. However, this also opens to legitimate criticism of gamification; in fact, it is at times defined as *exploitationware* for its potential to tap into users' behavioural biases, persuading them to behave in a way they normally would not [19]. Within the



Figure 1.2: Womanopoly, by Stella Dadzie, from the Black Cultural Archive collection

context of this thesis, gamification is a direct example of the effect of games, or game elements more precisely, on motivation. Serious video games are arguably a more complex medium than most gamified environments; they require game design expertise as well as other topical knowledge. They are inherently interdisciplinary systems. They are fully fledged and developed games, designed with more or less classical basic requirements (engaging, interactive, etc.) [20]. However, their goals or motivations go beyond simple entertainment. Serious games are adaptable and are applied to several other fields. An excellent example is *EndeavorRx* [21], the first FDA-approved video game treatment for attention deficit hyperactivity disorder. The game is considered an effective medium for cognitive training therapy, even though it has initially been met with scepticism by some [22]. Moreover, there is a strong connection between serious games and the transmission of knowledge and training: this is the broad field defined as *game-based learning* [23]. This thesis has as its object of study this specific field,

#### 1.4. Games and Artificial Intelligence

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intended not only as the domain of video games designed for learning but also learning conveyed by video games beyond their design purpose. In Chapter 2, we first present a literature review to describe the state of the art regarding the use of video games for higher scientific education experiments. Subsequently, we study the inherent connection between video game design patterns and computational thinking, arguing that video games can transmit important digital skills even when not expressly designed for it.

### 1.4 Games and Artificial Intelligence

Games and artificial intelligence mutually influence each other’s development. On the one hand, games have accompanied the development of artificial intelligence, representing ideal environments for challenging, training and demonstrating new algorithms’ effectiveness. On the other hand, artificial intelligence has taken a more and more important role in the development of new opportunities for play, most notably in video games. A well-known example is Procedural Content Generation (PCG). In this case, AI algorithms can generate new unique content based on the player’s interactions with the video game [24]. This is such an established technology that has been implemented in numerous commercial video games [25, 26]. In academic contexts, we can define two main roles that games can take when it comes to intelligent systems: challenges and modeling. Games act as benchmarks for testing artificial intelligence’s ability to solve complex problems traditionally handled by humans. In this regard, notable mentions are the game of *Go* and the corresponding algorithm AlphaGo [27] or *StarCraft II* and AlphaStar [28]. Other games are used or expressly created as models to train artificial intelligence. A notable example is OpenAI’s work with reinforcement learning agents playing hide-and-seek, revealing emergent strategies [29]. In this thesis, we take an intermediate approach, studying specifically generative AI’s potential as an interactive agent in video games. The interaction between the player and the AI can be interpreted as a challenge. At the same time, video game environments are also models, intended as models for interaction with humans. In Chapter 3, we present a study about open-world games as future challenges for intelligent systems and propose a framework to tackle them. As mentioned above, artificial intelligence can also have an impact on games. Video games present the most intuitive affordances, in particular when it comes to non-player characters (NPCs). Whether we refer to rivals or allies, artificial intelligence can empower gameplay by providing depth and proficiency to video games. However, it is often disregarded how digital technologies can also

be introduced to traditionally non-digital games. In this case, the roles of artificial intelligence vary. Again, in Chapter 3, we present a study about the potential effects of intelligent agents as NPCs. We will also present a taxonomy describing the use of digital technologies in what we define as *hybrid* games.

## 1.5 Artificial Intelligence and Learning

The latest developments in generative artificial intelligence have quickly and deeply impacted education. Recent studies show that the use of large language models (LLM) in computer science education hinders students' retention [30]. Moreover, education techniques are lagging behind the disruption caused by these new technologies [31]. Other perspectives look at the artificial intelligence proficiency of end users (i.e., what critical elements are necessary to use generative artificial intelligence effectively). In this regard, tying new technologies with computational thinking education is fundamental [32]. This thesis takes a critical approach to the use of generative artificial intelligence in programming education. Chapter 4 focuses on bringing together artificial intelligence and video games for educational purposes. This is a new field, seldom explored and speculative in nature; in the chapter, we use existing literature to analyse the state of the art and discuss the impact of generative AI specifically on programming education. We then embark on a simulated design process to develop prescriptive suggestions for future experiments making use of games in education. At the same time, we explore the role of video games as limiters for AI in educational contexts and highlight opportunities and challenges.

## 1.6 Research Questions

**RQ; What is the role of video games in programming education in the era of artificial intelligence?**

The question requires us to investigate three interconnected directions. First, we look at past and current use of video games for scientific and programming education. Then, we explore research in the field of generative AI used in educational contexts. Finally, we analyse video games as potential mediators between learners and education.

## 1.6. Research Questions

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### 1.6.1 Sub Research Questions

**RQ1; (Chapter 2) How effective are video games in the field of higher scientific education?**

We study and compare existing research to clarify the impact of video games on education. In particular, we focus on the effects on students' performance and motivation.

**RQ2; (Chapter 2) How is research in the field currently carried on?**

We discuss the diversity of methodologies between studies in the field and its impact on comparability. We also discuss the lack but necessity of common practices to improve reliability.

**RQ3; (Chapter 2) What common affordances connect video games and computer science education?**

The goal is to identify common thinking patterns between digital gaming and programming. These commonalities compose the framework that supports the use of video games for programming education.

**RQ4; (Chapter 3) How do games present challenges for artificial intelligence development and study?**

We explore and demonstrate the intimate connection between artificial intelligence and video games. We estimate future challenges and build support for the use of video games as a common connection between artificial intelligence and programming education.

**RQ5; (Chapter 3) How can games be ideal meeting points for humans and artificial intelligence?**

We investigate how humans interact with intelligent agents in video games and how artificial intelligence technology can conversely impact players.

**RQ6; (Chapter 3) How does artificial intelligence impact the development of hybrid games?**

We analyse the impact that artificial intelligence can have beyond purely digital games. Conversely, we see how games can be a flexible medium to allow human-AI interactivity outside computer screens.

**RQ7; (Chapter 4) How does AI impact programming education?**

By developing a position on the effect of generative AI on education, we can identify weaknesses and opportunities. The goal is to see how video games can

fit into these systems, overcoming some of the weak points and exploiting the opportunities.

**RQ8; (Chapter 4) How does the implementation of AI in video games perform in educational settings?**

The final goal is to coordinate all the answers to the previous questions into one general reasoning about the role of video games in the future of AI and education.

## 1.7 Structure of the Thesis

Besides the present introduction, this thesis is structured around four more chapters. The first three present articles connected by different topics. Chapter 2 revolves around the role of video games in scientific higher education and programming skills development [33, 34]. In Chapter 3, we focus on interactions between AI and video games [35, 36, 37]. Chapter 4 analyses the intersection of generative AI, (programming) education, and video games. Finally, in Chapter 5, we discuss the research questions mentioned above and conclude by talking about the potential affordances of video games as moderating media to use generative AI in programming education.

## 1.8 Contributions of this Thesis

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## 1.9. Other Work by the Author

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## 1.9 Other Work by the Author

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