Artificial Intelligence, Games, and Education

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Chapter 5

Discussion and Conclusions

5.1 Discussion

We now reach the concluding chapter of our thesis. In the following pages, we go back to the research questions presented in chapter 1; using the articles we presented so far, we try to answer them. We then draw conclusions about:

- The importance of video games for programming education.
- The importance of video games for AI development.
- How video games are central meeting points between AI and programming education.

5.1.1 RQ1; How effective are video games in the field of higher scientific education?

Video games are an effective medium in the context of higher scientific education. This includes all the natural sciences, life sciences and engineering from secondary education to university-level courses. Overall, empirical studies in the field show a positive effect on students' motivation and their willingness to engage with the study material. However, the effectiveness on students' performance is still debated, and different studies yield different results. The effect on motivation is probably the most noticeable. As engaging media, video games make learning more enjoyable. Current research tends to minimise this aspect while focusing on its impact on performance. We argue that, although performance is an important indicator of success for empirical

studies in the field, the positive effects on students' motivation already demonstrate the effectiveness of video games in education. It is relevant to remark here that, even though performance is not necessarily improved using video games, it is also not negatively affected. Therefore, as educators, we need to question whether making classroom activities more pleasurable is not already an important achievement. As mentioned, the final performance is often unaffected. However, some studies do indicate positive effects, while a few report negative ones. Our research points out that performance is mostly impacted by game design per se; well-designed games tend to yield better results also in terms of students' performance. Alternatively, it could be relevant to focus on individual design patterns and their impact.
Finally, we should consider the main drawbacks of game-based learning. First, most research in the field is carried out in contexts in which participants are usually more or less familiar with the video game medium. While this is a fair assumption considering the availability of video games today, attention should be paid to completely generalising the starting conditions of participants. For example, video games would need to be introduced differently in contexts where the digital divide is more marked; in this case, precautions in development (e.g., reducing the processing power required, designing for mobile play) should be taken when designing educative video games. However, as we mentioned in 4, this issue represents an important challenge in safely incorporating LLMs in games.

5.1.2 RQ2; How is research in the field currently carried on?

Controlled experiments in the field of higher scientific education and games are usually carried out by experts in the respective educational fields. In turn, this causes a great variety of methods and considerations, especially when it comes to game design. However, considering the impact of game design on final students' performance, we argue that the involvement of experts from the field of games is necessary in order to make video games more effective. Serious video games are naturally interdisciplinary and, therefore, require a variety of skills and knowledge in order to ensure proper functioning. Another point of concern, which derives from similar causes, is the challenges in terms of comparability. Differences in methodology and design processes make studies difficult to compare. This is also caused by a lack of conventions and care with regard to game design. How can we compare two different games when we cannot identify their individual components? In this case, solutions and frameworks can vary. In this thesis, we suggest that game design patterns can be a good starting point to describe

and, subsequently, analyse video games. Similar considerations are valid for the description of the control groups. Because of the inherent interdisciplinarity of serious video games, studies in the field often omit detailed descriptions of how normal teaching in the specific context is carried on. In turn, this represents another challenge for comparability. In general, the field would greatly benefit from better knowledge about game design procedures and more detailed descriptions of standard education techniques.

5.1.3 RQ3; What common affordances connect video games and computer science education?

In chapter 2, we highlighted similar mental affordances between computational thinking and video games. In this regard, we argue that certain game design patterns can require similar mental work to computational thinking skills to be proficiently used. For example, video games often include iterative and recursive design structures. Obviously, there is also the foundational element of the nature of the medium; video games are inherently played on computers, fundamentally engaging users in interacting with them. In other words, if frequent utilisation of computers gets people accustomed to them, video games can be more pleasant than most other software to do so.

5.1.4 RQ4; How do games present challenges for artificial intelligence development and study?

As mentioned in chapter 1, games have historically been a fertile ground for AI experimentation due to their ease of implementation and evaluation. As AI technology developed, so did video games. Nowadays, new challenges arise from video games with non-linear structures. Open-world games, for example, do not have a linear narrative or prescribed objectives. These characteristics present great hurdles for AI systems. However, they also raise opportunities for development; in order to study how intelligent algorithms can tackle these challenges, we can look at human gameplay as an example of problem-solving in complex contexts. Codifying and generalising human strategies can provide valuable insights for AI development.

5.1.5 RQ5; How does artificial intelligence impact the development of hybrid games?

Hybrid games are games that build a bridge between the digital and the real world. Already today, intelligent agents are present in multiple roles, such as adversaries to allies. Current technological developments, in particular the rise of generative AI, will probably further extend the digital features of hybrid games. Generative AI can enhance agent behaviour and introduce innovative game mechanics. Hybrid games stand out as an interesting medium because they retain the AI-human interaction potentials of games while they transfer this interaction to a middle ground between the digital and the real.

5.1.6 RQ6; How does AI impact programming education?

Recent AI developments in the field of generative intelligence have a definitely disruptive effect on programming education. Current research in the field indicates that applications of generative AI in the classroom are usually met with relative enthusiasm, and they positively affect students' motivation. However, other empirical studies highlight a negative effect of the unrestricted use of generative tools on students' retention. Even though they feel more confident and engaged using AI tools, they seem to learn less compared to their peers who are not allowed to use these systems. Conversely, alternative research directions highlight potential applications. In particular, generative AI seems to be quite effective if used as a programming tutor, provided that prompting has been restricted to predetermined inputs. In this case, we argue that the intelligent system does not simply provide the answer but stimulates users to think about a solution while providing relevant hints. We conclude that unrestricted generative AI can have a negative impact on actual students' learning. However, restricted systems can provide relevant guidance while still allowing students to foster their own learning.

5.1.7 RQ7; How does the implementation of AI in video games perform in educational settings?

Implementing generative AI in educational games, whether it is game-based learning or gamification, is an interesting idea with a lot of potential. In particular, NPCs are ideal cases to apply AI technologies to communicate with humans, which makes them also ideal for tutoring. However, there are some criticalities that arise from the

design process to the actual viability of the resulting product. In the design process, particular care should be taken in filtering the type of input accepted in order to retain some control over the output. AI alignment with educational goals is, in particular, a very important aspect. Our findings indicate that LLMs struggle with role-playing in highly specific contexts. However, more generic contexts can conflict with the game narrative and generate off-topic material. Moreover, smaller models tend to output a lot of incorrect or imprecise information. In this regard, larger models are more reliable but require a bigger infrastructure to make them available to a bigger population of learners. Overall, the educational settings create much higher standards, which generative AI still struggles to reach without a big associated investment. Therefore, we argue that an actual implementation of AI in video games for educational purposes is not yet viable and still presents important challenges that need to be overcome.
On the other hand, AI development is advancing rapidly. New models are quickly becoming smaller and more powerful. This leads us to believe that, in the future, the implementation of AI in video games will become a reality. In order to overcome those challenges and shortcomings, we investigated in 3 and 4, AI models will need to improve their reasoning skills. For example, if we aim to allow AI some form of control over a game narrative, we will need it to be able to reflect and explain its narrative structure. In this sense, advancements in the field of explainable AI will be essential for the introduction of LLMs in game development. Another frequent characteristic of video games is that they can easily reach a large and diverse population. AI-game implementations will need to reckon with this and, especially in educational contexts, consider working towards better AI alignment in order to provide safe and culturally relevant information.

5.2 Conclusions

In this thesis, we explored the intersection between video games, education and AI. We highlighted the impact that video games have on human development, personally, but also historically. We also described games that defined important movements and moments in our history. Subsequently, we delved into the research about the use of games and game elements in education. We have seen the diversity in the field and how empirical investigations have flourished in the last decades. However, we found comparing these studies challenging because of the lack of common practices and vocabulary. Moreover, often, these studies are carried on by experts in the respective fields of application without involving colleagues with expertise in game research. We

then moved on to more specific topics, analysing how fundamental game elements have similarities with computational thinking skills. We speculated over the effect of video game design patterns on players and how they can stimulate similar thinking patterns as computational thinking.
In the third chapter, we analysed the relationship between AI and video games. Since video games always represent ideal challenges for AI algorithms, we propose the next one: open-world games. We also explore the characteristics that make this genre particularly fascinating for the study of AI and propose a different approach to study it. We argue that human player-based heuristics can provide valuable information to train the next generation of artificial players. In the second part of the chapter, we start analysing the implementation of generative AI, specifically LLMs, in video games and their impact on humans. We see how we are able to design intelligent agents to behave in very specific ways and, in turn, impact players' emotional states. Moreover, this highlights how video games can be important points of contact for the study of human-AI interaction. The final part of the chapter explores applications of AI in different play contexts, in particular, physical games, which then take the form of hybrid games. We propose a taxonomy with the goal of showcasing possible points of application of AI outside of strictly digital contexts. Often, the intelligent agent places itself as an embodied figure, portraying an opponent or an assistant. This opens to other considerations in terms of believability and role-playing.
Our fourth chapter attempts to analyse the relation between the three pillars we listed above. We start by analysing the impact of AI in education through existing literature. We see how research in the field often struggles to detach itself from the inherent enthusiasm for new AI technologies (in particular LLMs) and proposes metrics that are not representative of learners' performance. We also see how, when performance is actually analysed, the impact of unrestricted generative AI is disruptive and yields worse results compared to traditional methods. However, other researchers obtained more encouraging results applying LLMs in restricted settings and by limiting users' input or framing the interaction in gamified environments. In the second part of the chapter, we tested this approach by designing a simple educational game. We kept notes throughout the design process and reported our considerations. Additionally, we evaluated the final result in terms of its effectiveness in role-playing and accuracy. We then analysed the viability of these systems. We argued that applying LLMs in games for educational purposes presents several weaknesses. The first one is accuracy, intended as the tendency to output likely but incorrect information. There are also important drawbacks in terms of technical implementation and the necessity of invest-

ments that can hardly be justified considering the final performance.
The goal of the thesis was to explore the relations among education, video games and AI. We speculated over many exciting opportunities that arise from these connections. We have highlighted successful applications that are having a positive impact in actual teaching settings. We have also identified challenges in integrating generative AI technologies. We are still confident in the potential for LLMs to be implemented successfully in video games and, more importantly, in the potential of video games to frame LLMs and control their use in order to empower education instead of disrupting it. However, as researchers, it is important to be aware of all the limitations and to be able to see beyond the enthusiasm that new potential opportunities might elicit. We believe that a careful study of the role intelligent agents play, the development of proper design methodologies and practices for educational game research, and critical analyses of the results are necessary to develop effective applications of generative AI in games and education.
Moreover, we should pay attention to the ethical ramifications of these technologies. Video games have proved themselves to be flexible media which can bring education and knowledge to a large population. They can also connect players from very different socio-economic contexts in playful environments. However, LLMs are currently still expensive, especially with respect to safety and privacy measures. The development of educational games with AI components should take this into account and strive to preserve the ecumenical value of game-based learning.