Designing with Fantasy

in Augmented Reality Games for Learning

Tengjia Zuo

A catalogue record is available from the Eindhoven University of Technology Library

ISBN: 978-90-386-5664-9

All images in this thesis are drawn by Tengjia Zuo unless otherwise specified.

Designing with Fantasy in Augmented Reality Games for Learning

PROEFONTWERP

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven,
op gezag van de rector magnificus prof.dr.ir. F.P.T. Baaijens,
voor een commissie aangewezen door het College voor Promoties, in het openbaar
te verdedigen op donderdag 9 februari 2023 om 13:30 uur

door

Tengjia Zuo

geboren te Jiangsu, China

De documentatie van het proefontwerp is goedgekeurd door de promotoren en de samenstelling van de promotiecommissie is als volgt:

Voorzitter:	prof.dr. L. Chen
Promotor:	dr. J. Hu EngD MEng.
Copromotoren:	dr. E.D. van der Spek.
	dr. M.V. Birk.
Promotiecommissieleden:	prof.dr. R.C. Veltkamp (Universiteit Utrecht)
	prof.dr.ir. M.M. Bekker
	prof.dr. X. Sun (University of Nottingham Ningbo China)
	dr. P.M.E. Van Gorp

Het onderzoek of ontwerp dat in dit proefontwerp wordt beschreven is uitgevoerd in overeenstemming met de TU/e Gedragscode Wetenschapsbeoefening.

Summary

Contemporary young generations face numerous 21st-century learning challenges. Young students living in a technologically and information-rich culture benefit from advances in educational technology yet are distracted by the clutter that information technology brings. Previous work suggested that educators showed concerns about the effect of learning with digital technology in schools, and many students were disengaged and unsatisfied with e-learning environments.

Game-based learning, integrating entertainment with instructional content, invites players to immersive and engaging contexts to acquire 21st-century skills with fewer geographical and time limits, as well as a more creative and a cognitively interesting manner. As a technology that also brings novel experiences and alternative views, Augmented Reality, which enhances tangible reality with virtual content, is considered a promising solution for motivating and situated game-based learning.

Despite the potentially positive impact of AR game-based learning, designing an efficacious and engaging learning game is still challenging. Game-based learning differs from entertainment video games in that participants do not always voluntarily engage in gamified learning activities and may not perceive the activities as playing. Well-blended game elements with learning content can transition participants from a task-oriented to a play-oriented mindset and subsequently from adapting the game rules or fiction, to constructing meaning in the fictional reality. Designing with fantasy in games and creating imaginative and fictional situations that deviate from real-life has shown positive effects on engaging young players. However, little is known about how to design an enticing fantasy with pervasive AR technology in a way that capitalizes on technological affordances, engenders a motivating and satisfying experience, stimulates learning, and fits well into the educational context.

Empirical research on the effect of fantasy on player experience, educational contextual adaptation, learning motivation and efficacy is required to establish design strategies for incorporating fantasy into AR game-based learning. In this research, we first conducted a literature review to identify what constitutes fantasy and classify the aspects of fantasy in game-based learning that can be designed. With what we defined as fantasy elements in games, we designed and developed four games for learning Mathematics, English, and Chemistry in four studies we conducted. For each consecutive study, we conducted a quasi-experiment comparing fantasy and non-fantasy game elements.

Through a literature review, we initiated our research by investigating the

constitution of fantasy in serious games. We found two major perspectives to explain fantasy, the imaginative concept that deviates from reality, in serious games: mental activity and artifacts. Fantasy in mental activities, an internalization process of fictional concepts, is mainly researched in psychology with respect to fantasy orientation, fantasy proneness, fantasy states, and player experience. Fantasy in artifacts, reflecting human-created fictitious themes, concepts, and circumstances, has various aspects in serious game design and research, including innovation of fantasy, fantasy game elements, fantasy genres, and integration strategies. With a structured understanding of fantasy in serious games, we performed four studies to investigate our research topics and provide design solutions for before, during, and after gameplay, as well as for classroom integration.

In study 1, we used our own design Mathmythos AR2 to explore the effect of avatar design (fantasy and similarity) on player identification and motivation. We discovered several correlations between player identification, motivation, and the similarity and fantasy settings of games in this study with 34 individuals aged 9~10 from Changzhou, China. We summarised several strategies to design avatars that entice students into the gameplay. This study inspires further research on the fantasy state, player experience, and motivational effect of fantasy avatars and narratives.

In study 2, we conducted research regarding fantasy states, autonomy, presence, and enjoyment using MathmythsosAR2 with 31 participants aged 9~11 from Qingdao, China. We constructed mediation models that explain the relationships between fantasy settings, fantasy states, player experience, and motivation. We synthesized several design strategies to engage players during the gameplay. We also reflect on this study. We found that exploring through qualitative perspectives on situating fantasy could help us understand children's play and learning.

In study 3, we present our study regarding the possible learning effects of AR fantasy using our design Chemikami AR. We conducted a quasi-experiment with 124 participants aged 11-14 from the Netherlands and China. We found positive effects of AR and fantasy on declarative knowledge recall under different situations. We also compared age groups and cultures to generate diverse design solutions for different target groups to achieve effective learning after the gameplay.

In study 4, we introduce MathymythosAR2 and FancybookAR to investigate situating learning in fantasy for different educational subjects and learning contexts. Through qualitative and quantitative analyses, we summarised several design strategies for balancing players' experience, engagement, and comprehension, as well as effectively integrating the role of teachers when situating learning in the fantasy of AR.

In general, this research presents 4 game designs and a theoretical framework. Through 4 studies with our designs, we identify relative concepts and explore and experiment with different stages of play and contexts of learning with AR fantasy. This research aimed at learning in the classroom with children aged from 7 to 14. We reflect on the design choices made and generalize practical design strategies that can benefit the future design of fantasy in AR game-based learning.

Table of Content

Introduction

Chapter 1

*Please read the story from left to right, top to button.

1.1. Research Background

1.1.1. 21st Century Skills for Young Learners in a Digitalized Society

Our changing world brings about evolving values for present and future education (Trilling & Fadel, 2009). 21st century skills cover many educational aspects, including critical thinking, collaboration, creativity, and communication. According to the United States-based National Education Association, over 80% of CEOs in job marketplaces polled feel that 21st century education prepares students for future workplaces when joining society (Erdoğan, 2019). The development of 21st century learning requires utterly different learner-centered classrooms compared to classrooms where teachers are at the center stage (An & Reigeluth, 2011). Classrooms are being reshaped to be flexible spaces that facilitate social and learner-centered instruction (Adedokun et al., 2017). Learner-centered instructions in turn value children's motivation (An & Reigeluth, 2011) as essential to guiding learning goals, inducing continuous effort in learning behavior, deepening understanding, and improving learning performance (Lin et al., 2017; Trilling & Fadel, 2009). Motivating academically unmotivated students and stimulating students' intrinsic motivation, i.e., motivating via inherent pleasure and interest, is critical for 21st century learning (Hidi & Harackiewicz, 2000).

The shift to contexts that facilitate 21st century learning is supported by advanced educational technologies that provide real-time feedback, powerful computing, enhanced experiences, and authentic applications (Vedechkina & Borgonovi, 2021). Authentic learning, learning activities that "focus on real-world, complex problems and their solutions," is further enabled by technology and information-rich contexts (Lombardi & Oblinger, 2007). With technology and information-rich environments, students can understand abstract concepts with digital visualization, communicate and cooperate with fewer temporal and geographical barriers, actively apply knowledge to authentic simulation contexts, and receive dynamic assessments and support (Shabani, 2012; Spector & Merrill, 2004).

Despite the benefits of technology-enriched 21st century learning, educators and parents still have concerns about learning with digital instructions. In offline teaching, educators doubt the learning effectiveness of using digital technologies in schools (Selwyn & Aagaard, 2021). Mobile phones being banned from classrooms and schools is not a rare sight due to the digital distraction that phones cause (Selwyn & Aagaard, 2021). Children and teenagers are especially more prone to be distracted from their schoolwork than adult students (Manly et al., 2001). During the COVID-19 pandemic, remote digital learning was the only choice for 91% of learners (UNESCO, 2020). A survey of 1,226 respondents showed that 51% of students were satisfied, whereas 49% of students were unsatisfied with e-learning (UNESCO, 2020). Some students experienced a lack of motivation, stress, and boredom while remotely learning in a digital environment, such as through virtual lectures, video, and animation (Abu Talib et al., 2021). One of the primary reasons for children's low motivation and poor experience and teachers' concerns about ineffective learning contexts with digital media is that they are insufficiently interactive, especially in a digital environment where tangible interaction is absent (Winarto et al., 2020).

1.1.2. Educational Benefits of Augmented Reality

One solution to increase tangible interaction in a digital learning context is Augmented Reality (AR) (Taufiq et al., 2021). AR supports interactive experiences in the real world while presenting a virtual interactive overlay over the real-world object (Wu et al., 2013). By superimposing graphics, 3D models, and animation (Radu, 2014) into physical materials like books, blocks, or physical spaces, AR bridges the virtual and physical world with interaction and immersion (Li et al., 2017). As a tool that enhances students' experience, AR has been widely adopted in nature and science education, language and mathematics learning for primary school students (Fotaris et al., 2017a; Li et al., 2019;; Zuo et al., 2020), geometry, science, reading, and physics education for middle school students (Ibáñez et al., 2020; Pavonetti et al., 2000; Sahin & Yilmaz, 2020). AR can benefit learning 21st century skills by 1) offering students better knowledge and understanding of science learning from alternative perspectives, improving critical thinking (Syawaludin et al., 2019); 2) allowing students to experience the world in a collaborative and interactive approach (Lukosch et al., 2015); 3) fostering students' imagination and creativity (Wu et al., 2013); and 4) encouraging social communication during learning (Rivu et al., 2020).

1.1.3. Game-Based Learning

Digital interactivity and learners' motivation to learn can be further improved through game-based learning. Game-based learning, a type of serious game—games that are designed for serious purposes other than pure entertainment (Pertierra et al., 2017), integrates learning materials with games and playful features. Game-based learning allows participants to acquire skills and knowledge by taking a lusory attitude, i.e., an attitude that stimulates participants to overcome unnecessary challenges (Michalos, 1981). Taking a lusory attitude, players step into a space created by games called a "magic circle," meaning "a temporary world within the ordinary world, dedicated to the performance of an act apart," as described by Huizinga (2014), where players' suspension of disbelief occurs (Nieuwdorp, 2005).

However, some poorly designed serious games prevent players from stepping into a magic circle due to negative experiences, e.g., limited control, frequent interruptive instructional content (Wouters et al., 2013), and unappealing narratives (Sanford et al., 2015). AR technology can be a valuable complement to game-based learning by enhancing the immersive experience. AR creates a natural context for game-based learning (Klopfer & Yoon, 2005) in which playful games, tangible learning materials, and authentic situations are seamlessly blended. With well-blended game elements and learning materials, players transit between telic, paratelic, and paraludic domains (Nieuwdorp, 2005), meaning a transition from a task-oriented to a play-oriented mindset and subsequently from adapting the game rules or fiction to constructing meaning in this fictional reality.

1.1.4. AR Game-Based Learning

Enriched by AR, game-based learning engages participants to play virtual games embedded in real-world surroundings. Therefore, the boundaries of the magic circle are expanded from a virtual world to the real world. With these expanded boundaries of magic circle, AR game-based learning can enhance the player experience and allow instructors to naturally fine-tune participants' learning focus in the real world. Research finds that both AR technology and digital game elements promote affective-motivational states, i.e., enjoyable responses of participants toward games and novel technology that motivate them to engage in learning (Brehm et al., 2009; C. H. Chen, 2020). Children particularly favor AR game-based learning, playful ways of learning supported by AR and game design principles (ChingHui Chen et al., 2015). Previous research suggests that in informal learning, children prefer AR game-based learning-enhanced textbooks over regular textbooks (Hung et al., 2017) and AR games over non-AR games for learning (Sotiriou & Bogner, 2008).

With an adequate understanding of the educational affordance and benefits of AR game-based learning, it is still challenging to utilize the intriguing qualities in design that can improve AR game-based learning experiences. Game-based learning differs from entertainment video games as its participants do not always voluntarily engage in the gamified learning activities and may not perceive the activities as playing (Botte et al., 2020). Research indicates that a design that successfully blends game elements with learning theories can increase motivation and achieve effective learning (Qian & Clark, 2016). To stop utilizing an educational game as a tool for learning and instead start playing, one needs to enter the magic circle by adopting a playful (paratelic) mentality and immersing oneself in the game environment (Nieuwdorp, 2005). One vital trigger for establishing a pervasive and compelling "magic circle" is a separation from everyday life, i.e., fantasy in games (Huizinga, 2020).

1.1.5. Fantasy in AR Game-Based Learning

Fantasy, unreal experiences, being fueled by imagination in games, engenders a fun and playful experience, enabling children to approach the design as a game rather than a learning tool (Ryan et al., 2006). When imaginary or unrealistic experiences are implemented in games, users can experience narratives, visuals, and actions, that they would never experience in real-life (Schwartz, 2006). Malone and colleagues (1981) define fantasy settings as "contexts that evoke mental images that are not present." Fantasy elements in game-based learning can make learning emotionally appealing to its users (Lee & Liu, 2017). Malone & Lepper (1987) introduced the term "endogenous fantasy," meaning a fantasy aligned with the instructional content. Endogenous fantasy can lead to intrinsic motivation for learning. In contrast, "exogenous fantasy" refers to a fantasy unrelated to the subject matter being studied and thus serves as more of an extrinsic motivator.

Games with predominantly real-world settings are classified as simulations, whereas games with fictional settings are classified as fantasy (Schwartz, 2006). Such a classification is altered by AR. AR game-based learning provides alternative contexts where players' perceptions of the physical world and digital game fantasy can exist simultaneously, bringing different states of immersion to participants than full virtual experience.Full virtual experience with VR can trick participants into perceptually believing they are somewhere other than their physical locations (Patrick et al., 2000). Such experience of full immersion is close to the concept of transporting participants into the "magic circle" (Huizinga, 2014) of a world with a temporal and spatial boundary separating users from the real world. Such boundaries are blurred by AR technology, where the physical surroundings are altered or augmented by fantastical digital overlays. With the blurred boundary of a "magic circle," classroom instruction can be situated into contexts. However, it is uncertain how this situation will affect participants' experiences like immersion, which would subsequently influence their enjoyment. Previous research shows some positive sides of fantasy in AR games for learning applied to informal education for all age groups' biology and science museums in the USA, suggesting that mixed reality technology like AR can facilitate the suspension of disbelief and engage players in an experience with rich mixed fantasy, an experience with mixed reality fantasy (Stapleton et al., 2003), which requires further investigation and clarification.

1.2. Recent Research and Objectives in This Work

1.2.1. Recent Research: Challenges and Opportunities

Despite the benefits of AR fantasy in game-based learning, there are still challenges in integrating AR fantasy into learning. As Habgood and colleagues (2005) claimed, previous work did not fully justify the educational effectiveness of endogenous fantasy, i.e., integrating fantasy with learning intrinsically in digital games. To understand the motivational effect of AR fantasy in game-based learning, we should first identify a clear concept of fantasy. Investigating the effects of fantasy elements on the player experience and understanding the affordances of AR fantasy specifically, will help designers to create more engaging learning games. With such clarification of concepts related to players' experience and engagement, we can identify how to design AR fantasy to achieve educational effectiveness.

There are also concerns regarding the learning effectiveness, both with respect to individuals and the classroom as a whole, when it comes to integrating fantasy elements. Regarding learning effectiveness with individuals, some education researchers think that fantasy might increase cognitive load for children (Ang et al., 2007), challenge the connection to prior knowledge of the learners (van der Spek et al., 2014), and subsequently lead to learning with AR inefficiently (Lee, 2015). Regarding learning effectiveness in classroom situations, some are unconvinced that fantasy in AR game-based learning will meet the pedagogical requirements for effective situated learning. For example, some learning games were considered "built with flaws" that contain more fun than learning and are not closely related to subject-specific knowledge (Ladley, 2010). Educators also have concerns about classroom learning situations, including the teachers' roles in scaffolding and integrating instructional game content with fantasy contexts (Barzilai & Blau, 2014). We, therefore, contended that addressing concerns regarding the learning effect and situated learning with AR fantasy necessitates empirical research with specific learning contexts.

Investigating the effect of incorporating fantasy with AR game-based learning on player experience can help construct contexts to improve players' motivation and experience. It facilitates a technology-rich classroom with well-positioned scaffolding, situated learning, engaging learners, and effective learning. Eventually, we believe this research can construct an environment of technology-enriched 21st century learning that connects educators and learners, facilitates critical thinking with problem-based game situations, encourages creativity and imagination, and virtual and physical collaboration. However, such relevant empirical research has barely been conducted previously, as fantasy itself is too ambiguous to be defined (Choi et al., 2013). A comprehensive analysis and a great load of empirical research are required regarding game-based learning with fantasy from aspects of experience design, learning effect, subject-matter contexts, and classroom situations. With wide coverage of types and aspects of fantasy applicable in AR serious games, it is challenging to construct a design guideline but meaningful as it will benefit research, game design, and the education domains.

1.2.2. Research Objectives Addressing Current Gaps

Reviewing the research above, we uncover a number of gaps in the research. Those gaps are: 1. With the need to transition from a teacher-centered to a learner-centered context, designers still find it challenging to fully activate the motivational effect of serious games in terms of inviting learners to the game-based learning application. 2. Some serious games cannot fully engage participants, as they are perceived as learning tools rather than games that create immersive and autonomous experiences. 3. With potential digital distractions caused by mobile phones and more cognitive load brought by games, education researchers question the efficiency of AR game-based learning. 4. There is a lack of design guidelines for AR game-based learning in the classroom that facilitates scaffolding and subject-matter contexts through a persistent, compelling AR fantasy. Consequently, this research aims to explore the effect of fantasy in AR games for learning, and address the research gaps above.

Generating design guidelines to design compelling fantasy in the context of AR game-based learning requires structured analyses of the game elements, interaction experience, and learning contents (Pellas et al., 2019). The starting point is to understand what constitutes fantasy in serious games. Then, we can apply different aspects to our design, with which we explore the effect of fantasy from aspects of player experience and learning efficacy, both individually and in the classroom context. Based on the findings, we want to generate design strategies for employing fantasy in AR game-based learning.

1.2.3. Game Design

Throughout this thesis, we introduce the design and development process of our own designed games, MathMythosAR1 and MathMythosAR2, for Mathematics learning, ChemiKamiAR for Chemistry learning, and FancyBookAR for English as second language learning. By exploring several disciplines, we want to have a general understanding of how fantasy contexts could be integrated with the instructional content.

We design a fantasy version and a real-life version for each game. Each fantasy version of the game is developed with fantasy aspects from the classification we concluded from the literature review in Chapter 2,. Among the wide coverage of aspects and styles of fantasy in game design, we specifically focused on the narratological aspect of fantasy, including avatar and narrative design, in our research. This was done primarily for reasons of scope, but there is a potential connection between the narratology genre of fantasy to previous research on thematic-fantasy play (Pellegrini & Galda, 1982; Saltz et al., 1977; Thibodeau et al., 2016), a form of role- and theme-enacting by children that is not based on their own experiences. In our design, we employ the genre of "magic" for the fantasy versions of the game design, a representative theme of "high fantasy", imaginary stories that happen in a secondary world rather than the real-world (Sullivan, 2018), and the alternative fictional world settings derived from literature.

1.2.4. Design Choice and Research Focus

The design of each game was tailored for the research focus mentioned above, i.e., avatar or narrative. To conceptually divide different phases of play, we divided the player's journey of interacting with AR game-based learning into four phases (Figure 1.1): 1) before playing, i.e., attraction to gameplay and starting to play; 2) during gameplay, i.e. when players immerse themselves in play; 3) after gameplay, i.e., when players recall knowledge of gameplay; and 4) the social context of gameplay, i.e., fitting the game into the classroom context. We call each phase of research a study.

Figure 1.1: Player's journey

For each study, we explore the effect of fantasy on aspects of player experience and learning situations by comparing the fantasy and real-life versions. In MathMythosAR1 and ChemikamiAR, we compare fantasy avatars and real-life versions of the avatar. In MathMythosAR2 and FancyBookAR, we move our design focus to the narrative design by comparing everyday life stories to fantasy stories.

At an initial research stage, with MathMythosAR1, we want to understand how fantasy works to attract participants. Players' identification of avatars is considered an essential factor in whether specific types of fantasy appeal to individuals (Choi et al., 2013) and in determining whether players will choose to engage with the game or not (Birk et al., 2016). To explore the motivational effect of fantasy through player identification, we focus on avatar design with MathMythosAR1.

As we gained insights about attracting participants at an initial stage, we were curious about the next stage, players' engagement, and experience during gameplay. Key factors of player experience, including autonomy—the freedom of control, and immersion—the sense of being there, are key indicators of whether players perceive the serious game as a game rather than a learning tool (Deterding, 2016). Through an investigation of player experience, we wanted to explore approaches to creating appealing and engaging games. Therefore, we designed MathMythosAR2 in the form of an augmented storybook. As an extension of MathMythosAR1, MathMythosAR2 adds extra animated storytelling content overlaid over the storybook, increasing total playtime and allowing us to collect more complete data about the play experience.

While fantasy motivates learners to engage with serious games with an enjoyable, autonomous, and immersive experience, educators may subsequently be concerned about the effect of learning with AR fantasy games. To address concerns about the learning efficacy of fantasy in AR-game-based learning, we investigate how well players recall instructional content after the gameplay. Recalling and temporarily operating on information is an effective learning factor (Jarvis & Gathercole, 2003). In order to test the effect of employing the "magic" fantasy genre on learning, we chose the subject of Chemistry to design the game around because learning chemistry requires memorizing many chemical elements. The forms of elements do not have a concrete visual representation to refer to, creating space for us to design a fantasy avatar representing each chemical element. As we focused on avatar design, we returned to the card game design and simplified the narrative, which can also meet our research need of presenting large numbers of chemical elements to be memorized.

With the knowledge of inviting and engaging learners with effective learning, we consequently wanted to explore how fantasy with AR game-based learning would impact classroom learning situations. The challenge of employing AR fantasy in game-based learning for classrooms includes situating learning of the subject matter, teachers' role of scaffolding, students' engagement, and experience. With MathMythosAR2, we have gained insights into the relationship between fantasy, player experience, and engagement. In addition, we designed FancyBook AR with a gameplay mechanic similar to MathMythosAR2, focusing on a similar narrative genre of fantasy for another learning subject, viz. English as a second language. We subsequently identified how learning should be situated in AR serious games with fantasy by comparing two games for two distinct learning subjects with or without fantasy.

With the reflections we gained in each previous game, we improved our design in the next design iteration. For example, we chose children's favorite characters and expanded the game with a narrative in MathMythosAR2 and Fancybook AR according to participants' feedback with MathMythosAR1. We removed certain AR interactions like virtual buttons according to feedback with MathMythosAR2. A detailed reflection on each design choice is summarized in detail in Chapter 8.

1.2.5. Research Questions

Before investigating the influence of fantasy in AR game-based learning, we first established the definition of fantasy and its contribution to the greater serious games literature. As a response, a well-structured review is required to identify the prerequisite question:

RQ1: What constitutes fantasy in serious games?

With a general comprehension of fantasy's contribution, we were able to include fantasy more accurately in our design. Using our design, we could further investigate the application of fantasy in AR serious games from four key phases in a game-based learning journey's overarching structure:

1. How can fantasy attract/invite children to an AR game for learning?
2. How can fantasy support engagement during AR gameplay?
3. How can fantasy support learning as a result of AR gameplay (after)?
4. How do AR fantasy games for learning fit in a classroom environment?

Through the research of related work regarding children's affective motivation (phase 1), engagement (phase 2), learning outcome (phase 3), and learning environment (phase 4), we found relevant key concepts, including player identification, the player experience of need satisfaction, working memory and situated learning. We will further introduce these related concepts in detail in Chapter 3. We present four studies from Chapter 4 to Chapter 8 that refer to the four phases proposed above. Specific research questions regarding the four directions can be found below:

RQ2: How can fantasy and similarity influence player identification and motivation?
RQ2.1: Do players have distinct avatar identifications (similar and Wishful Identification) for a fantasy or a real-life avatar setting, for a similar or a dissimilar avatar setting?
RQ2.2: How does participants' avatar identification affect motivation when playing in different fantasy or real-life game settings?

RQ3: What's the mediating effect of fantasy on engagement in an AR game for learning?
RQ3.1: How do two AR fantasy settings (fantasy/real-life) in games influence the general experience?
RQ3.2: What are the mediation effects of fantasy states on the relationship between fantasy settings and enjoyment?
RQ3.3: What are the mediation effects of need satisfaction on the relationship between players' fantasy states and motivation?

RQ4: How does the incorporation of fantasy in AR game-based learning influence learning and recall of declarative knowledge?
RQ4.1: Is AR with fantasy more effective at improving recall than AR with real-life content?
RQ4.2: How do participants perform with AR in comparison to their recall without AR?
RQ4.3: After playing with AR, will the recall of the augmented content be activated by content on cards?
RQ4.4: Do age groups, genders, and locations associate with any difference in the

recall?

RQ5: How does AR fantasy in game-based learning need to be designed to fit in the classroom context?
RQ5.1: Does fantasy or real-life narrative in AR game-based learning in the classroom provide a more engaging and immersive experience for participants?
RQ5.2: What is the teachers' role in scaffolding fantasy construction and learning?
RQ5.3: How to situate learning with AR fantasy in games to improve participants' engagement, experience, and the teachers' scaffolding?

1.3. Research Methods

Since fantasy in serious games does not explicitly define its contribution, little empirical research has been conducted on this topic. To understand the constitution of fantasy, we first explored different definitions of different taxonomies of fantasy in serious games through a thematic literature review. Using the forward and backward literature search strategy, we gathered relevant literature on fantasy in serious games and synthesized a classification of fantasy for future research and design.

We conducted exploratory design research with "research through design", a process of generating knowledge through "action and reflection approaches", and "research about design," types of analytical activities that are conducted under other disciplines (Frankel & Racine, 2010). With "research through design," we generated "explanations and theories inside broad contexts" (Michel, 2007) toward design challenges that happen in human-computer interaction and experience design. With "research about design", we identified challenges and provided strategical solutions for game designers with cross-disciplinary insights from psychology, social science, pedagogy, and computer science.

To construct solutions for design issues, we explored the interventional effect of employing fantasy in children, aged from 7 to 14, through the design of experiments. This research is exploratory research in pedagogy, experience design and human-computer interaction (HCI), and our target group is children. Therefore, we applied quasi-experiment methods to gain and evaluate feedback from participating children. These scientific methods allowed us to compare the effect of fantasy and investigate the relationship between input factors, i.e., fantasy design or real-life design, and output factors like player experience, learning effectiveness and situations.

We included several questionnaires to collect children's self-reported data and conduct quantitative analyses. Questionnaires of intrinsic motivation were applied to investigate players' motivation. We used player identification and the Player Experience of Need Satisfaction (PENS) questionnaires to explore players' identification with game avatars and their experience during gameplay. The questionnaire of fantasy states was employed to analyze participants' mental activities of fantasy in digital gameplay. We also employed qualitative analyses like observation and video analyses to enable additional investigation perspectives regarding the complex contexts of education in classrooms.

1.4. Thesis Structure

Chapter 2 initiates our research by investigating the constitution of fantasy in serious games. We structure the classification of fantasy to guide our game design in future studies and for designers to refer to when designing their serious games with fantasy. The taxonomy of fantasy we concluded in this work enables us to focus on the avatar and narrative design in the narratology of fantasy genres in our subsequent design research studies.

Chapter 3 presents related work regarding players' motivation, experience, recall of learning, and situated learning, which connect to the "before, during, after, classrooms" aspects of a game-based learning journey's overarching structure. We examine the impact of fantasy from these aspects through previous work to build theoretical foundations for the following studies.

Chapter 4 presents our first design study. We employ fantasy avatars in our design MathMythosAR1. We explore the effect of avatar fantasy and avatar similarity on player identification and motivation. This research inspires further research on mental activities influencing players' engagement, including the fantasy states and player experience triggered by fantasy narratives.

Chapter 5 presents our second study regarding fantasy, autonomy, presence, and enjoyment using MathMythosAR2. We explore further the relationship between fantasy states, fantasy game design, players' experience, and engagement. We summarize strategies for design with fantasy narrative in AR game-based learning, considering players' fantasy states, experiences, and engagement.

Chapter 6 introduces fantasy avatars with our design ChemiKami AR. We present our third study regarding the possible learning effects of AR fantasy using Chemikami AR. Through a quasi-experiment with participants from the Netherlands and China, we want to investigate the effect of AR and fantasy on learning and recall of declarative knowledge. We try to investigate diverse design solutions for different age groups and cultures using fantasy and AR to facilitate efficient learning.

Chapter 7 introduces the fourth study using MathMythosAR2 and Fancy book AR regarding situating learning for subjects including Mathematics and English as the second language in AR fantasy of game-based learning. Through qualitative and quantitative analyses, we try to understand design strategies for balancing players' engagement and comprehension, as well as effectively integrating the role of teachers and generating design considerations for situated learning with different learning subjects and AR fantasy.

Chapter 8 presents reflection on our experiments and design choices. We recap all the research findings and then discuss general design strategies for incorporating fantasy into augmented reality game-based learning. While highlighting our contributions to several fields, we also explain our limitations and propose future research. We present our design strategies for designing with fantasy in AR game-based learning within the framework of the general research process and the structure (Figure 1.2, p30-31).

Introduction
- Background
- Research Question

Literature Review
- What constitutes fantasy in serious games?

Design Study 1

- How can fantasy and similarity influence player identification and motivation?

Design Study 2

- What's the mediating effect of fantasy on engagement in an AR game for learning?

Design Study 3

- How does the incorporation of fantasy in AR game-based learning influence learning and recall of declarative knowledge?

Design Study 4

- How does AR fantasy in game-based learning need to be designed to fit in the classroom context?

Conclusion
- Answers to the RQs
- Design Guideline
- Reflection of the Design Choice
- Conclusion/ Contribution/ Limitation

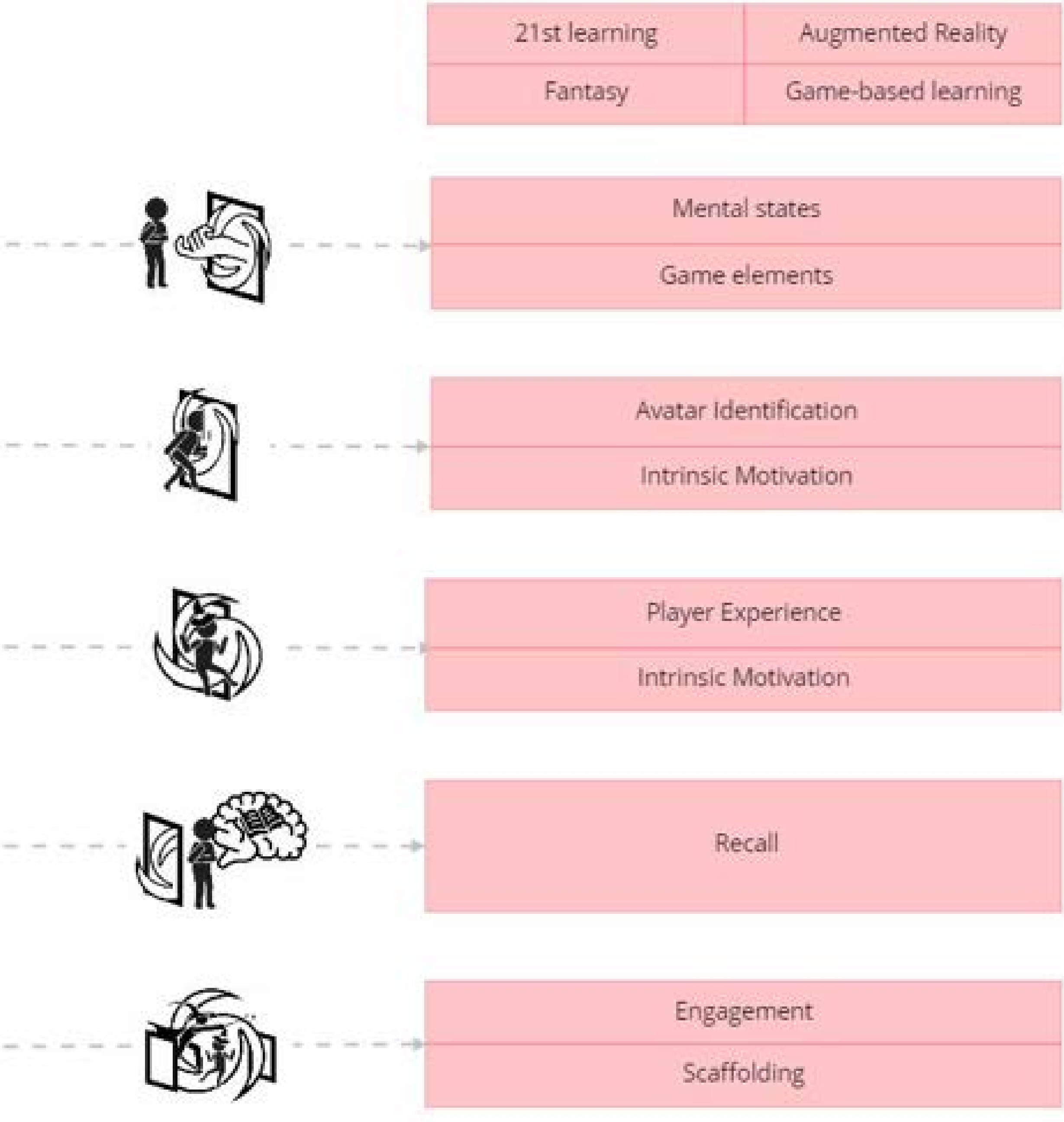
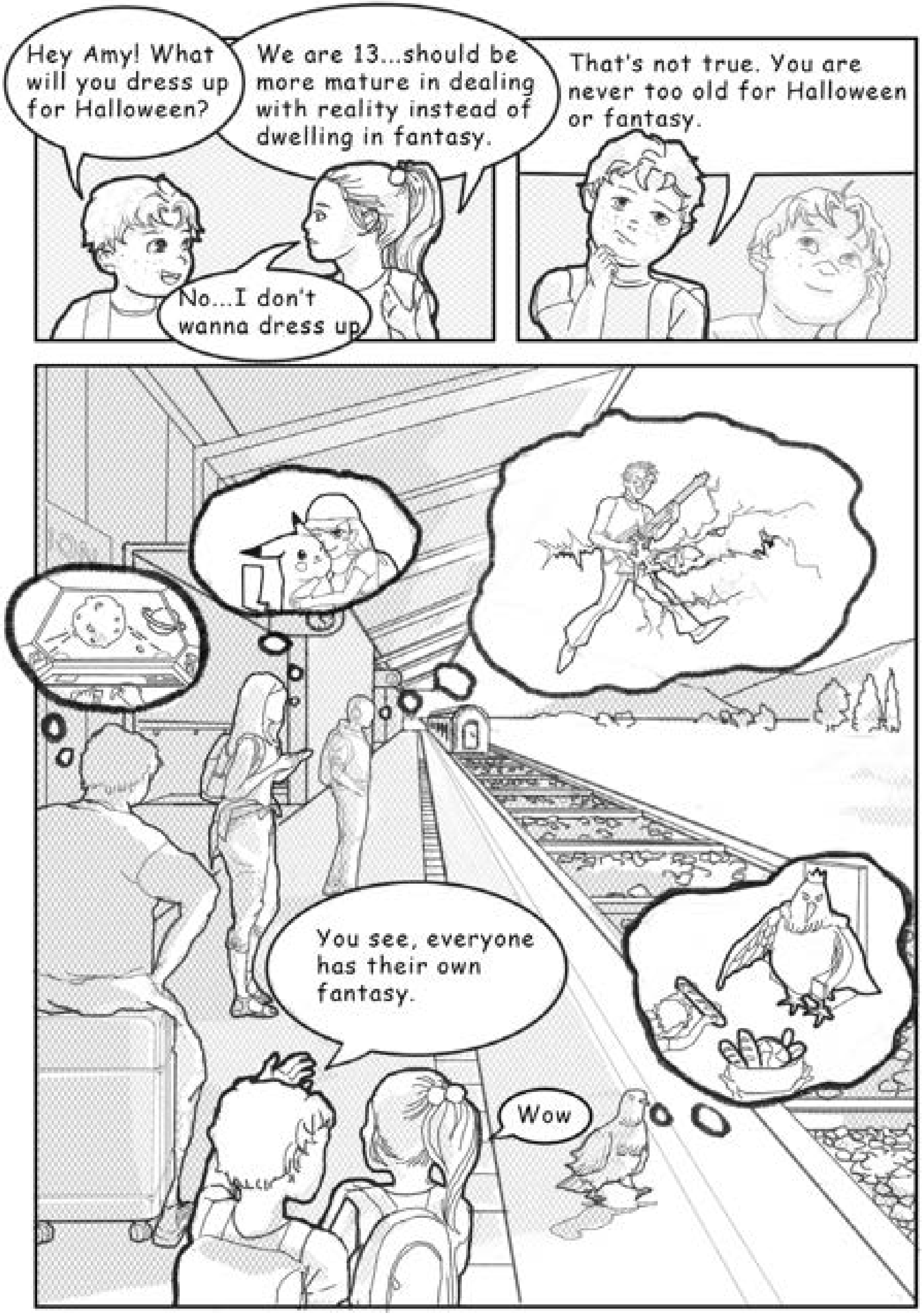


Figure 1.2: Research process and structure

Fantasy in Serious Games

*This chapter is partially based on Zuo, T., Feijs, L., Van der Spek, E. D., & Hu, J. (2019, October). A classification of fantasy in serious games. In Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts (pp. 821-828).

Chapter 2


Hey Amy! What will you dress up for Halloween?
No...I don't wanna dress up.
We are 13...should be more mature in dealing with reality instead of dwelling in fantasy.
That's not true. You are never too old for Halloween or fantasy.
You see, everyone has their own fantasy.
Wow

As Chapter 1 introduced, despite the trend and requirements of 21st century learning, there are still issues regarding poor experience, low student motivation, and situating learning within digital contexts. The combination of serious games and Augmented Reality provides a promising avenue to increase learning motivation by creating an immersive magic circle where players can experientially and authentically learn in a playfully augmented world. However, in order to immerse students in such a mixed reality magic circle, we need to understand how to create a compelling fantasy that engages students in all aspects of serious gameplay, namely before, during, after, and in a classroom context.

Before investigating intriguing qualities in designing fantasy with AR serious games, it is necessary to understand what fantasy is. This chapter offers a literature review regarding our research focus: fantasy in serious games. The categorization of fantasy that we reached at the end of this chapter will point us toward features that we can design for in our future studies. As fantasy is the key to constructing a pervasive and persuasive magic circle, understanding the constitution of fantasy can shed light on experience design with AR and serious games for future research.

2.1. Introduction

Fantasy, as a vital game element making games engaging, allows users to experience things that would never happen in real life (Malone & Lepper, 1987; Schwartz, 2006). It plays an essential role in determining whether a user wants to play a game (Waal, 1995). Game designers use fantasy to enrich player experiences, contextualize learning, and design engaging games (Wouters & van Oostendorp, 2016). However, it is still a big challenge to blend entertaining game features such as fantasy with pedagogy successfully (Susi et al., 2007). Serious game designers sometimes struggle to align serious learning content with an engaging fantasy (van der Spek et al., 2014; Wouters & van Oostendorp, 2016).

There are many perspectives on fantasy, and there are many fantasy themes. It is difficult to integrate fantasy into serious games (Bateson, 1922). It is a problem compounded by the fact that introducing fantasy may lower the efficacy of learning games (Schwartz, 2006). Although the adaption of fantasy becomes a dilemma for game designers, it is still mostly believed that “the use of fantasy elements is important for crafting engaging and instructionally-sound challenges” (Iuppa & Borst, 2012). When engaging in fantasy play, positive social competencies such as affective role-taking or peer social skills grow, and story comprehension is enhanced (J. A. Connolly & Doyle, 1984). Vygotsky (1978) highlights the importance of play, discusses the effects of play on development, and observes that “in play, the child is always ahead of its age, ahead of its own normal behavior.” Fantasy play in learning is a promising direction with the potential to provide different

perspectives on how today's educational content could be designed to engage children. From a higher-level perspective, previous research indicates that fantasy is not only a game element but a connection, a container of different game characteristics that shapes the outside experience and the fundamental purpose of a game. "It serves as a 'hook' to engage the learner so that other game features can be activated such as interactivity, competition, control, curiosity, challenge and feedback" (Asgari & Kaufman, 2010). Our aim in building classification is not to clarify the limitation of other taxonomies but to synthesize related theories and terms, to provide an overall framework for research on fantasy in serious games. It can be a framework to refer to while reviewing existing experiences and a guide for initial steps before digging into specific directions. Therefore, the research question we address in the context of serious games is:
What contributes to fantasy? Knowing the constitution of fantasy can help us further investigate which parts of fantasy work and which do not, enabling us to explore design approaches that facilitate engagement with fantasy in serious games. In the next section, we identify two distinct approaches to fantasy, which are essential for our work plan.

2.2. Two Types of Definitions

Malone and Lepper (1987) define a fantasy environment as "mental images" that one evokes of "a physical or social situation that is not actually present." Lee (2015) distinguishes two perspectives:

- "mental activities to internalize unusual external objective stimulus."
- "byproducts of human imagination such as narratives, learning environments, environmental objects, or even sound effects within an educational game." (Lee, 2015) As "byproducts" is pejorative, in this chapter, we will use "artifacts" instead.

There is a rich body of literature on fantasy in mental activities stemming from psychological research, as well as on fantasy in artifacts written by game designers or researchers (Figure2.1), but a unified perspective is missing.

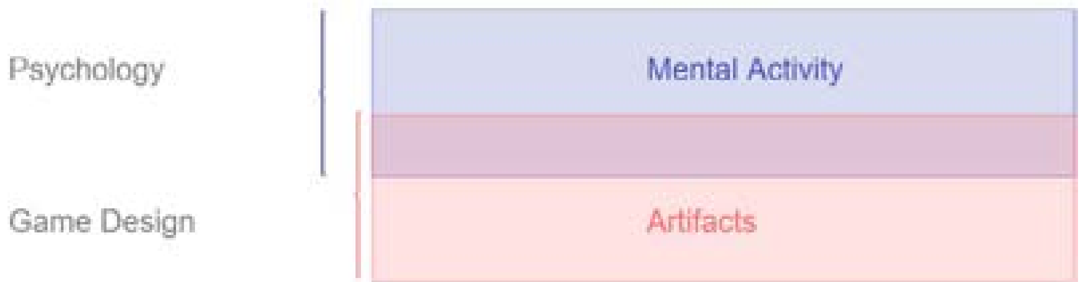


Figure 2.1: Two perspectives of fantasy

2.3. Research Process

Chapter 1 mentioned that our research focuses on fantasy in AR game-based learning. However, when identifying the constitution of fantasy in previous work, we want to explore the concept of fantasy discussed in general areas of games or other playful contexts used for serious purposes. Therefore, we discuss the general concept of "serious games" in this work. Intending to search for literature that discusses mental activities and artifacts of fantasy, we used search terms including "fantasy," "playful learning," "edutainment," "serious games," and "game-based learning" via Google Scholar. Sorting the results according to topic relevance, we conducted an overview of the top 100 results. We found little research focuses on fantasy in serious games. Due to the limited number of works regarding the theoretical frameworks, models, and methodologies concerning the topic of fantasy, we conducted forward and backward research to see the development of theories and expand knowledge from different perspectives. In the end, there were 40 articles selected. To extract the essential aspects of fantasy, we used NVIVO to cluster the longest branch of research (fantasy genres). Lastly, we used thematic analyses to organize various aspects of fantasy together in a classification scheme, as shown in Table 2.1.

Table 2.1: An overall classification based on the outcome of the literature review

Mental Activities					Artifacts									
Player Characteristics		Player Experience			Innovation		Element of Fantasy				Fantasy Genre		Strategies for Adaption	
Orientation	Proneness	Immersion	Emotion	States	Creative	Portrayal	Mechanic	Stories	Aesthetic	Technology	Ludology	Narratology	Entertainment	Instruction

2.4. Fantasy in Mental Activities

2.4.1. Player Characteristic

Fantasy orientation "describes an individual's tendency to think and play in different fantastical worlds." It is divided into four constructs: cognitions (fantasy thinking), toys and games (and their fantasy themes), entities (e.g., belief in imaginary ghosts), and pretense (e.g., pretending to be a warrior) (Barber et al., 2013). Research proves that with different fantasy orientations, children's activities of playing with fantasy, i.e., "fantasy play," in their everyday lives "facilitate development in their cognitive domains (Thibodeau et al., 2016)."

Fantasy proneness is an individual characteristic that shows one's willingness to engage in imaginary activities (Merckelbach et al., 2001). It represents "a range of experiences considered to be related to a deep involvement in fantasy." It can be measured with, e.g., the fantasy subscale of the Inter-personal Reactivity Index (IPRI), which is a measure of the tendency to transpose oneself into fiction (Davis, 1983), or the Creative Experience Questionnaire (CEQ) (Merckelbach et al., 2001), for fantasy proneness measurement. McDaniel and colleagues (2005) address psychological phenomena related to fantasy proneness, such as impulse seeking, cognition need, and change seeking.

We found that many fantasy-related scales, such as CEQ and IPRI mentioned above, are for all age ranges. The nuance between adults' and children's attitudes toward fantasy or representation has also been discussed previously. Previous work suggests that younger children prefer cartoon-style avatars, while older adolescents prefer more realistic versions of human-like avatars (Segaran et al., 2021). However, previous research also suggests that children's age does not affect their fantasy orientation (Bunce & Woolley, 2021a). Children can also be reality-oriented thinkers as adults are (Sobel et al., 2013). With potential age difference toward fantasy, it is suggested to adapt the all-age scales for children, and to exam the effect of age group in future studies.

2.4.2. Player Experience

We can distinguish between narrative and ludic immersion. Narrative immersion represents the circumstance when players indulge so much in the game's story that they experience less of the real world surrounding them. Ludic immersion includes players' immersive experience of the behaviour and actions in games (McDaniel et al., 2005). Similarly, presence (King & Krzywinska, 2006) is the feeling of being in the world of fantasy, which is proven to be gained readily during gameplay. The suspension of disbelief, however, indicates a mental activity of relinquishing doubt and questioning the reliability of the fantasy context. It is regarded as an essential process that players go through.

In addition, Mendlesohn (2013) constructs a taxonomy of fantasy concerning narrative in her book Rhetorics of Fantasy, identifying "portal-quest fantasy," "immersive fantasy," "intrusion fantasy," and "liminal fantasy." "Portal-quest fantasy" describes a state where readers step into the fantastical world through a portal, navigating and exploring. "Immersive fantasy" indicates a situation where readers entirely believe the setting of the fantastical world without questioning it. "Intrusion fantasy" means a sudden intrusion of fantasy in real life. The real-life condition is considered a base of fantasy (e.g., Batman). "Liminal Fantasy" presents a context that allows readers to be aware of the unreal, where fantasy "disconcerts and estranges the reader (Mendlesohn, 2013)."

Emotion is furthermore important in the experience of fantasy. Malone (1982) believes that fantasy in games “derive their appeal from the emotional need to satisfy players .” Dillon concludes a “6-11 Framework” to specify 6 emotions and 11 instincts in terms of gameplay (Dillon, 2010).

Choi and colleagues (2013) developed the fantasy state scale to investigate the mental states of the players when interacting with digital games from aspects of imagination, analogy, identification, and satisfaction. The fantasy state of imagination is defined as the mental activities of imagining and experiencing fictional events that are unlikely to happen in real life. In contrast to the imagination, the analogy of the fantasy state represents players’ extent of feelings evoked by real-life related experiences. The satisfaction part represents the feeling of satisfaction about game elements.

2.5. Fantasy in Artifacts

Different researchers explore the form of fantasy in multiple dimensions. Fantasy is a characteristic of games and other media. We find 4 perspectives:

- Innovation
- Elements of fantasy
- Genres of fantasy
- Strategies of adaption

In serious games, fantasy is integrated with instructional content. Thus, we discuss innovation, elements, and genres of fantasy in the context of general games to provide a list of fantasy forms to be related to serious purposes in serious games. Adaption strategies and effects of fantasy in entertainment games and game-based learning are differentiated in the corresponding sections.

2.5.1. Innovation

Creton (2005) coined the terms “evolution” and “rupture” as modalities for fantasy innovation. Evolution represents “the adaptions, ameliorations, and recombination” of existing innovation, the rupture of “spectacular creation” (Dillon, 2010). Evolution and rupture are called portrayal fantasy and creative fantasy, respectively. Portrayal fantasy, or “evolution,” means a recreation of fantasy based on existing work. Creative fantasy or rupture means a novel creation. It has been shown that the portrayal fantasy is better at enhancing alien information acquisition, factual information learning, user motivation, and engagement because users are more familiar with the fantasy content (Lee, 2015). However, we hardly find any example in recent research focusing on how creative fantasy facilitates serious games.

2.5.2. Elements of Fantasy

Games with well-integrated fantasy elements can positively affect the user's engagement and "increase the use of cognitive strategy as well as the users' overall performance" (Wilson & Joseph, 2018). The application of fantasy elements vary in games. So far, to our knowledge, there has not been formal research on the taxonomy of the elements of fantasy in games. However, fantasy elements in games and other media have been exemplified a lot in multiple areas of research.

Fantasy elements include physical and social situations (Malone & Lepper, 1987), stories, and events (Asgari & Kaufman, 2010). With respect to human sensation, elements of fantasy can also be categorized as visually presented or non-visually presented (e.g., music, sound) (Lee, 2015). Regarding specific groups of target users, it is believed that fantasy is key in children's literature. "parallel world, magic being, supremacy, quest of objects or power, magical abilities, heroic character, magic items and power, magical animals" are fantasy elements frequently appearing in media targeting children as users (Wilson & Joseph, 2018). We listed all examples we found in recent literature (see Table 2.2) and categorized them by 4 types as per the Elemental Tetrad of Game Design by Schell (Schell, 2014): mechanic, stories, aesthetic, and technology (Table 2.3). In this four basic elements, mechanics represent the goal of the game ,and the approach and interactions of players trying to achieve it. Stories is related to" events that are unfolded in the game." Aesthetics describe "how the game looks, sounds, smells, tastes, and feels." Technology refer to any means that enable the gameplay, digital or not, tangible or not.

Table 2.2: Fantasy elements mentioned in different game research

Game elements	Reference
physical condition, social situation	(Malone & Lepper, 1987)
storytelling, audio, visuals	(Parker & Lepper, 1992)
landscape, geography	(McGregor, 2007)
characters, activities, gameplay, narrative, events, sound, cultural identity, death, dialogue, avatar, textual materials	(Schwartz, 2006)
clothes, personality	(Richard, 2010)
body, food, technology, habitat, dwelling, communication	(Lee, 2015)
tasks, power, fate	(Korhonen et al., 2009b)
narrative (storyline, game background), sensation (3D imaging technology, audio-visual effects)	(Shi & Shih, 2015)

Table 2.3: Four types of fantasy game elements

Mechanic	Stories	Aesthetic	Technology
Interaction activities	storyline/fate/ game background	audio/ music/ sound	3D imaging
viewpoint	habitat/dwelling	visual effect	VR/AR
death/birth/round	geography	cultural identity	motion sensing
communication	characters/personality/avatar/body	textual/	hologram
rules (manipulation rules, goal rules, meta rules)	events/tasks	material	AI
	dialogue		
time	Items (food/armor/spells weapon)		
	force/power		tangible
space	history		toolkits
objects, attributes, and states	physical condition, social situation		

2.5.3. Fantasy Genres

This perspective is rich in content but presents serious difficulties for thematic analyses. The major difficulty is that the fantasy genres have very diverse origins: literature, film, and games.

literature, film, and game genres

Genres of games are believed to be influenced by film genres (Apperley, 2006), for their similarity in the aspects of visual and narrative representations (Frasca, 2003a). However, the genres of games are also considered “substantially different from film or literature genre” as their interactivity is emphasized. It is common for different game genres to exist in one game. Therefore, some researchers prefer to use game genres as multiple tags that describe game features (Breuer & Bente, 2010). In the context of serious games, learning modes, target audience, educational content, and the application domain are also considered in the classification of the game genres, yet these ‘genres’ are not strictly related to fantasy (Michael & Chen, 2005).

2.5.3.1. Fantasy genre and game genre

Some typologies regard fantasy as fairy tales and cartoons (Grace, 2005). But usually, fantasy genres are related to narrative, visual, or interactive styles that do not exist in the real world. Since fantasy is in opposition to realistic simulation (Ma & Oikonomou, 2011), in this research, we believe fantasy genres in games can refer to game genres with unreal traits separated from real-world rules and phenomena (Figure 2.2).

Fantasy genres represent types of fiction that "evoke wonder, mystery, or magic sense" (Mathews, 2016). They are widely discussed in the area of literature and film yet barely addressed in the field of games. However, game genres, in general, have been studied widely. These game genres can be classified according to their platform, modes of players, viewpoints, rules and goals, and representational themes (Carr et al., 2006). The primary two categories refer to games' interactivity (ludology), and the last one leads to the narrative and aesthetics of games (narratology).

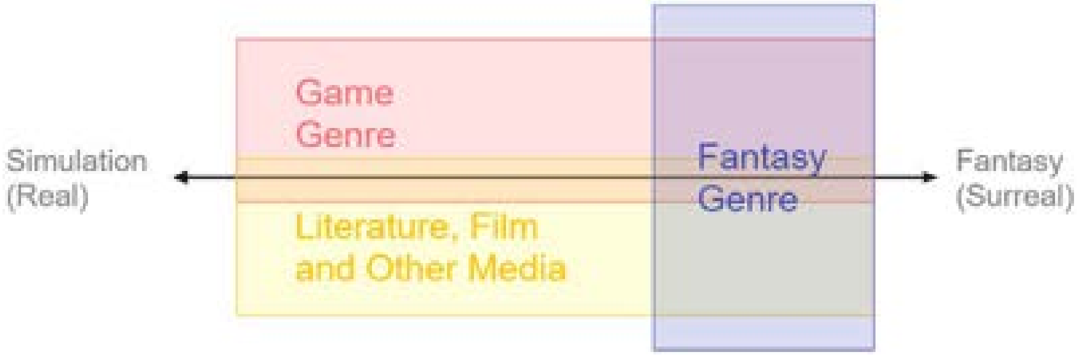


Figure 2.2: Fantasy genre among game genre and other media

2.5.3.2. Ludology and narratology

The debate between ludology and narratology has been shown to be largely a misunderstanding (Frasca, 2003b). However, it can be useful here to use the two categories to classify genres.

From the aspect of ludology, game genres represent mostly the mechanics and rules of games (Frasca, 2003a). These include terms like adventure games, puzzles, role-playing games, strategy, sports, first-person shooters (FPS) (Charsky, 2010), beat-'em-up, open-world, sandbox, strategy, simulation, serious games (Yusoff et al., 2009), action (Apperley, 2006), adventure, artificial life, board games, capturing, card games, combat, demo, diagnostic, dodging, driving, educational, escaping, fighting, flying, gambling, interactive movies, management simulation, maze, programming games, quiz, shooting, target, text adventure, training simulation, and utility (Wolf, 2002).

Traits of fantasy from the aspect of interaction in games can sometimes be directly exemplified by game genres. However, the level of fantasy in interaction sometimes depends on the adaption of fantasy elements themselves. For example, disregarding the huge distinction in narrative and aesthetic style, the unreal physics engine has been used in the making of PUBG Battlegrounds (PlayerUnknown's Battlegrounds) and Fortnite (figure 2.3), two Battle-Royale games with completely different fantasy settings (G. Choi & Kim, 2018).

Figure 2.3 (A): In PUBG: Battleground, players can only jump as they would in real life and need to climb to achieve higher places.

Figure 2.3 (B): In Fortnite, the players jump way higher than they would in real life.

From the viewpoint of narratology, the narratives of games are often influenced by other media like literature and film (Wolf, 2002). Some narrative themes in games are inspired by other media, such as “Thriller, Survival, Spy, Romance, Horror, Healthcare, Detective/Mystery, Crime, Comedy, and Adult” while others are based on real-world events, geography, or history (e.g., Industrial Age, World War 1 and 2, Cold War, Medieval, Steampunk, Sea Pirates, Aztec, Inca, Maya Culture). Some depict future themes (Cyberpunk, Dark Sci-Fi, Post-Apocalyptic). However, games are also mixtures of different media (Arsenault, 2009); thus, they show uniqueness in their narrative style: e.g., pre-scripted, branching, and emergent (Wolf, 2002).

Consequently, we collected everything from a Ludological and Narratological viewpoint but excluded realism, for example, simulation gameplay. We subsequently used Nvivo to categorize the fantasy genres in games (Figure 2.4).

2.5.4. Strategy of Adaption

Different strategies of fantasy adaption can distinguish each game fundamentally. While we did not find a general guideline for the adaption of fantasy, there are specific strategies discussed in each case. With different choices of fantasy innovation, elements, and genres, the strategy of adapting fantasy is distinguished by two different purposes: for entertainment and for instruction.

2.5.4.1. Adapting fantasy for playful experiences

Adapting fantasy for playful experiences involves designing fantastical narratives, worlds, or characters in games that trigger make-believe experiences (Korhonen et al., 2009a). People appreciate the entertainment with fantasy in games for the unique narrative, unexpected experiences, sensory experiences, exploring and solving mysteries, and more. Previous research suggests fantasy can foster gameplay engagement (Jacob Habgood & Ainsworth, 2011). Previous work also connects fantasy to immersive and autonomous experiences, suggesting a separation from real life can enable players to step into the “magic circle” of the game world (Huizinga, 2020) and freely explore and immerse in the fantastical world (Ferguson & Olson, 2013). However, there is little research found regarding the guidelines of adapting fantasy to achieve certain playful experiences.

2.5.4.2. Adapting fantasy for instruction

Malone & Lepper (1987) categorize two ways of adapting fantasy for a serious purpose: Exogenous fantasy and endogenous fantasy. Exogenous fantasy is mostly in the form of “rewards” for learning or training. Endogenous fantasy is a form of internal integration of fantasy with the learning content in games that allows them to influence each other. Although Malone & Lepper hypothesize that endogenous fantasy can be more educational and exciting, the experiment results of the DARTS game in their work still show that people’s attitude towards two types of fantasy is diverse according to different user genders and the types of fantasy. Moreover, different users have different motivations. The users in need of self-efficacy and self-regulation are different from users seeking instinctive joy, yet the same person’s attitude can change over time. Research findings describe the potential of fantasy and imaginative gaming experiences in transferring knowledge. However, specific guidelines for designing fantasy in serious games to achieve educational purposes remain to be explored (Habgood et al., 2005; Lee, 2015).

2.6. An Overall Classification

To answer the question we posed previously: “what is the constitution of fantasy?” we construct the overall classification of fantasy in serious games. We identify mental activities and artifacts related perspectives of fantasy that can be referred to during design process. For designers of serious games, it is meaningful to understand the player idiosyncratic and experience aspects of fantasy as mental activities. Investigating fantasy in artifacts, including creation, elements, genre and strategies of fantasy design will help designers manage their work in a structured way. It is also meaningful to explore the correlation of fantasy with mental activities and artifacts, as it allows designers to incorporate fantasy into a design that strikes a proper balance between serious study and playful fun. For game researchers, our framework shows different research directions of fantasy in games. It provides a catalog of relevant theories and literature related to fantasy in games. It is also useful to adapt such a framework to conduct futher reviews and case studies as well as research on the influence of specific types and integrations of fantasy in serious games.

In the following chapters, the presented classification will serve as a foundation to differentiate perspectives on fantasy and provide guidance in our design research. We focused on artifacts of fantasy due to the potential advantages of fantasy for learning. In the design of the games presented from Chapter 4 to Chapter 7, we consider mechanics, stories, aesthetics, and technology. Systematically integrating fantasy elements into gameplay allows us to differentiate fantasy and real-life settings (Figure 2.2). For example, our integration of “magic” as a representation of “high fantasy” (Sullivan, 2018) inspired the design of the games used from Chapter 4 to Chapter 7.

Reviewing previous adaptions of fantasy for entertainment and instructional purposes, we found that player experiences are an essential path to constructing game-based learning in AR. Consequently, we have lined out a design guideline for adapting fantasy in game-based learning in AR. In the following chapters, we will refer to the classification presented in this chapter to differentiate perspectives on fantasy and their consideration in our design research.
Through an investigation of fantasy mental activities, we found previous work on summarizing traits of our target groups, children. Children often have high fantasy proneness and their own types of fantasy orientation. For example, some children with high fantasy proneness often enjoy a narrative of superpowered humans (Bunce & Woolley, 2021b). These findings offer a good reference for later game design in our studies.

Game-based learning in classroom situations often requires instruction from teachers, which frequently leads to students’ stepping out of the magic circle, which risks lowering players’ immersion. We find the potential of AR game-based learning regarding improving player experiences like immersion. Player experiences with AR game-based learning, especially immersion and fantasy states, differ from experiences with a non-AR entertainment game. AR leads users to engage with a “liminal fantasy” experience, an experience with awareness of both fantasy and real-life contexts. There is a potential for AR-supported fantasy in classrooms. With the support of AR, fantasy creates enhanced physical interaction and a blurred boundary between the real and the fantasy world, which is promising for improving experiences, motivation, learning effect, and classroom collaboration. These directions, however, require further exploration.

Ludology

Figure 2.4: Fantasy genre :Ludology

Narratology

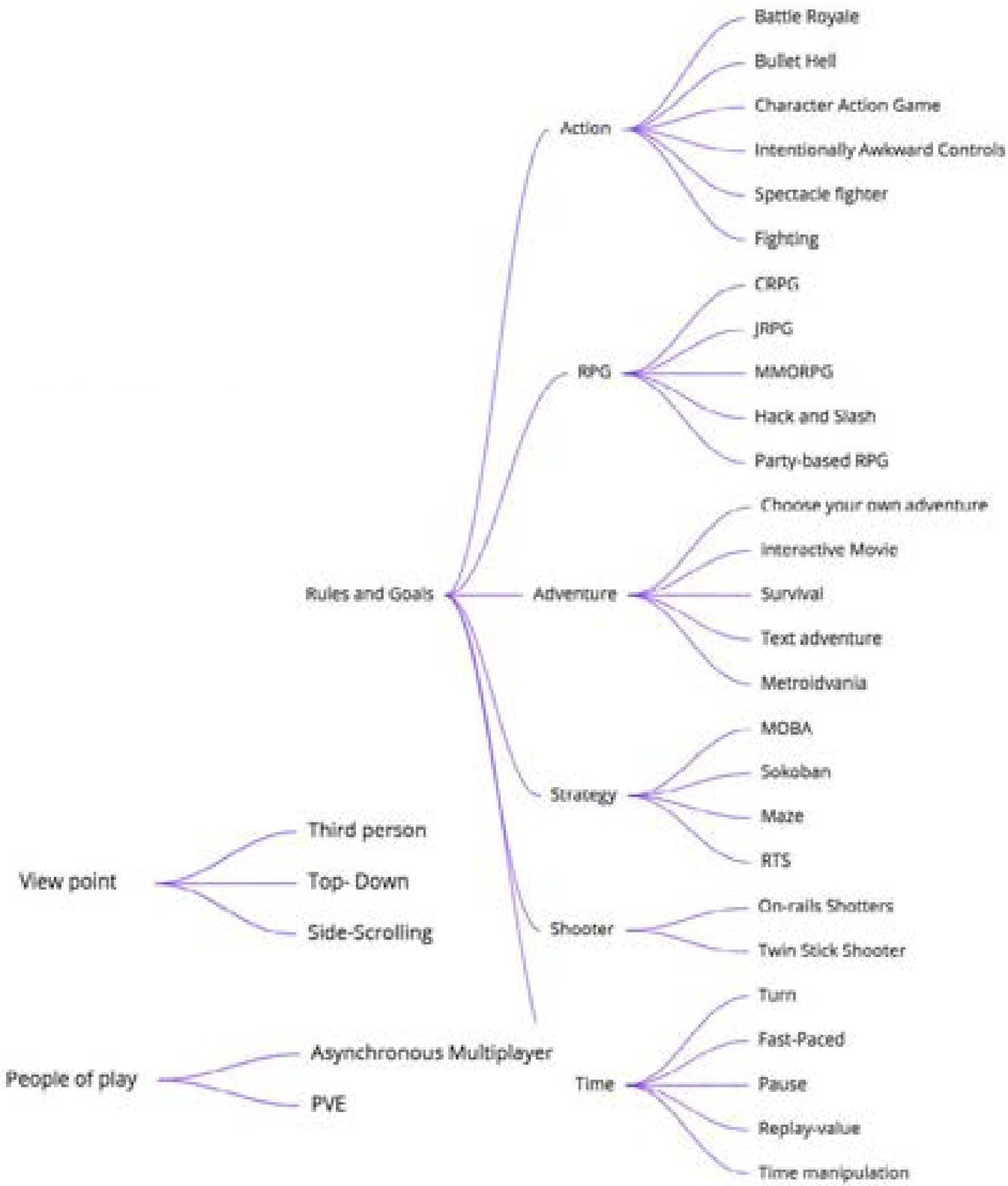
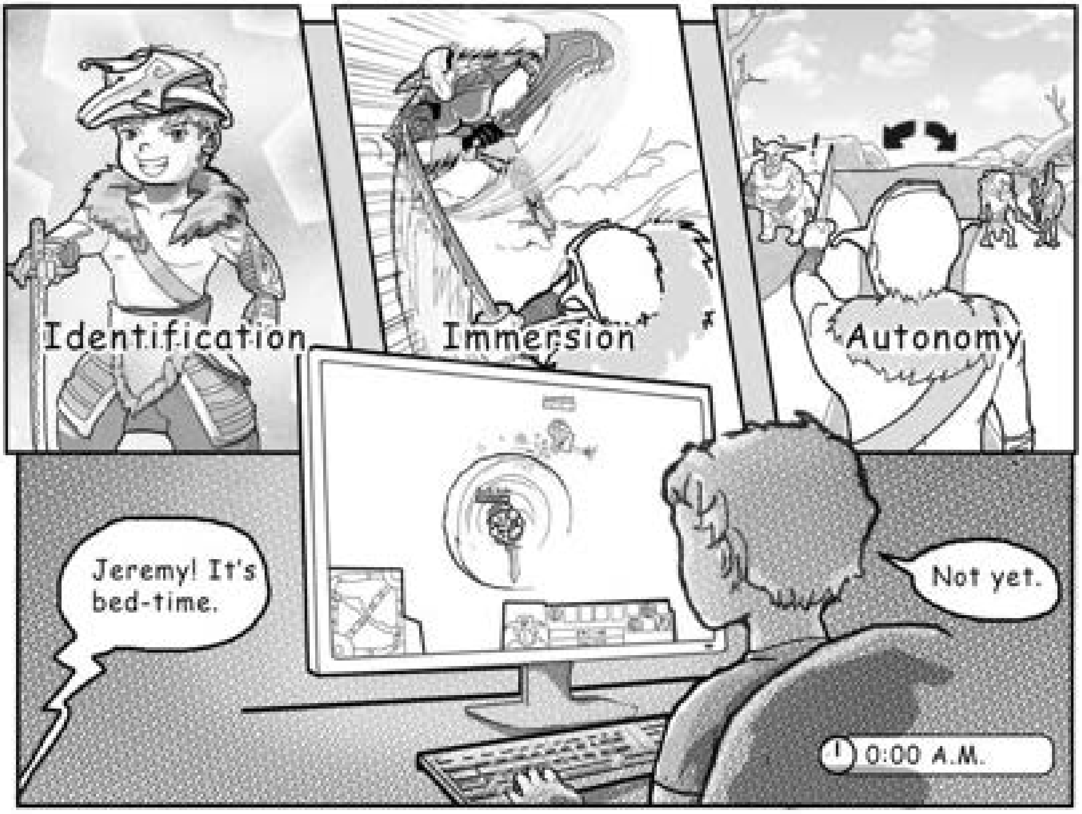
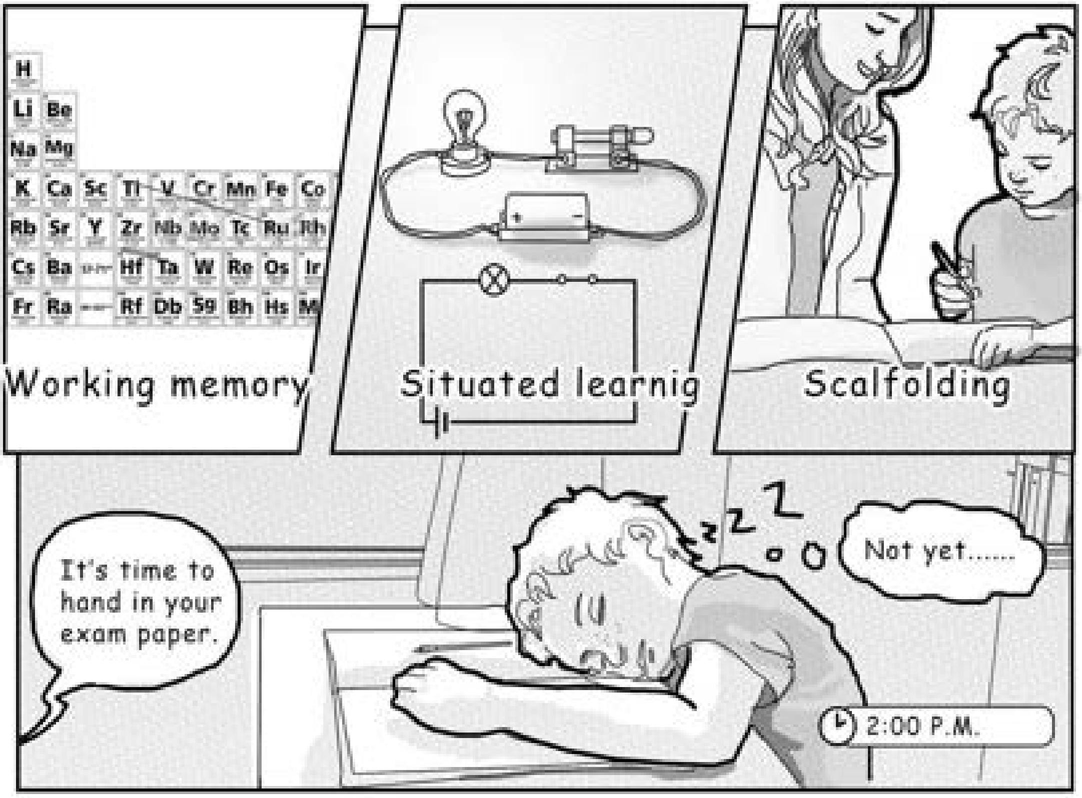


Figure 2.4: Fantasy genre: Narratology

Related Work

Chapter 3


Identification
Immersion
Autonomy
Jeremy! It's bed-time.
Not yet.
0:00 A.M.


H
Li Be
Na Mg
K Ca Sc Ti V Cr Mn Fe Co
Rb Sr Y Zr Nb Mo Tc Ru Rh
Cs Ba Hf Ta W Re Os Ir
Fr Ra Rf Db Sg Bh Hs
Working memory
Situated learnig
Scalfolding
It's time to hand in your exam paper.
Not yet......
2:00 P.M.

This chapter introduces several key concepts (marked pink in Figure 3.1) related to evaluating whether players are attracted, engaged, and able to learn with fantasy in AR game-based learning during their player journeys. We want to investigate the definition of these concepts and how specific effects are evaluated. We explore to what extent these ideas build on prior findings and discuss their potential relation to our focus: fantasy in AR game-based learning.

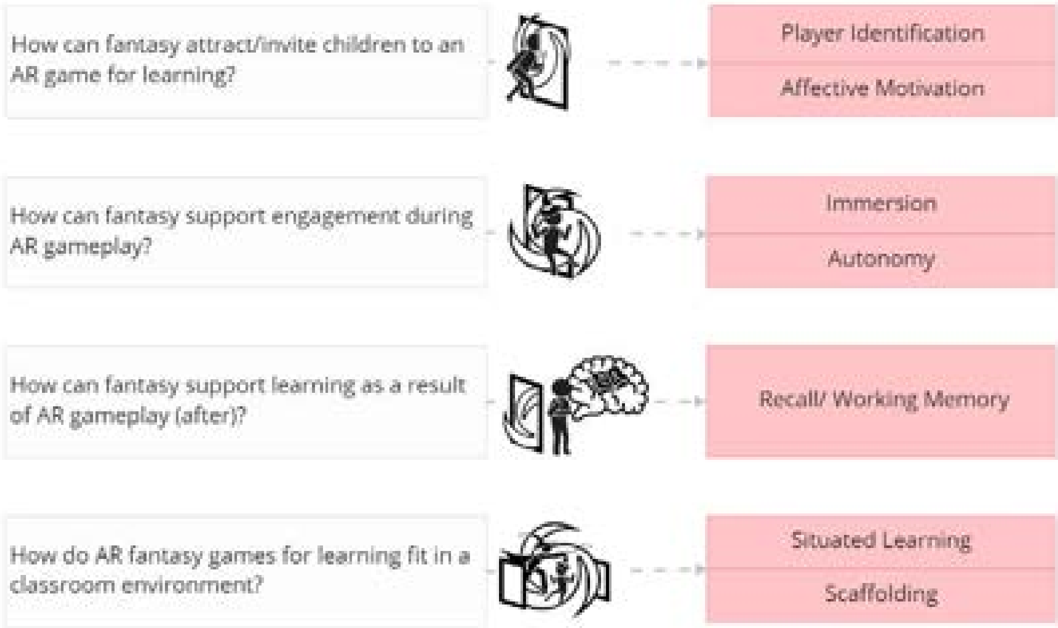


Figure 3.1 Player journey and relevant concepts

3.1. Inviting Learners

Stimulating learners to enter a magic circle through the use of fantasy requires a thorough understanding of their points of interest and evidence of active engagement and high motivation. The introduction of avatars is key to attracting players at the beginning of gameplay. The design of avatars is one way to include fantastical aspects which might elicit a range of distinct identifications, possibly resulting in different motivations and engagement for and with gameplay. For example, players can be motivated to “escape” from the real world to the game world when the gap between their real and ideal selves is reduced when gaming (Li et al., 2013). In the following section, we want first to understand the definition of affective motivation, discussing the possible correlation between motivation and fantasy in AR game-based learning. We dive further into the idea of avatar identification and how avatar identification might be used to entice and engage players from the start of a game.

3.1.1. Affective Motivation

Previous research has shown motivation to be directly linked to the experience and outcomes of game-based learning. Ryan & Deci (2000b) differentiate two types of motivation in their refined and expanded self-determination theory: intrinsic motivation and extrinsic motivation. While the first describes a kind of motivation that derives from one's inner satisfaction of needs, the other refers to motivation caused by external rewards. Based on motivational factors found in previous research, the self-determination theory continuum (Deci & Ryan, 2012) was designed to understand different motivations. In the self-determination theory continuum (Figure 3.2), with increased self-determination, participants' motivation range from Amotivation to extrinsic motivation and eventually to intrinsic motivation. Amotivation is a human's unmotivated or non-autonomous state (Vallerand et al., 1992). As self-determination increases, extrinsic motivation is followed by intrinsic motivation, where a move from passive compliance to active personal commitment is described (Ryan & Deci, 2000b). A change of the regulations (marked black in Figure 3.2) and regulatory process (marked gray in Figure 3.2) is also indicated in the continuum.

Research indicates autonomy, competence, and relatedness are three vital psychological needs that facilitate intrinsic motivation, of which a sense of autonomy is the most critical key to eliciting intrinsic motivation (Ryan & Deci, 2000b). An intrinsic motivation inventory (IMI) for gameplay was developed to quantify motivation levels (McAuley et al., 1989). Aspects of interest (enjoyment), perceived competence, effort (importance), and tension (pressure) are included in the IMI. To explore motivation toward playing in virtual worlds, IMI was later converted to a version that suits the context of gameplay (Ryan et al., 2006).

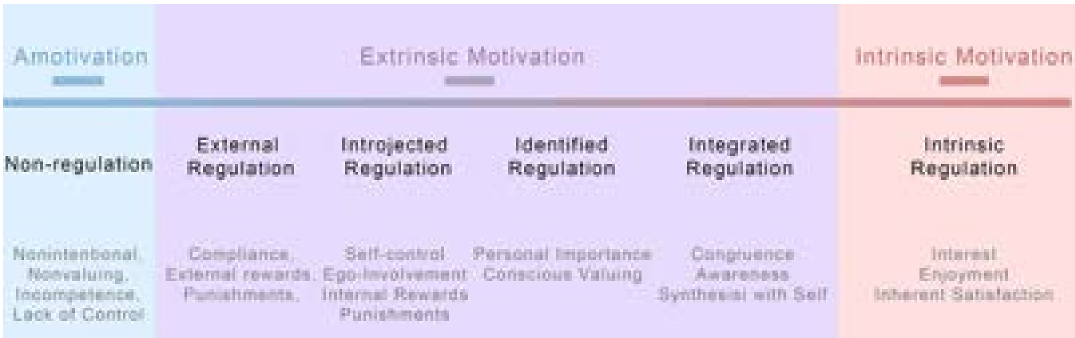


Figure 3.2 The self-determination-theory continuum (Deci & Ryan, 2012)

3.1.2. Motivation in Children's Education

Motivation in children's education is a topic that has raised increasing attention since Malone & Leppers' work (1987). Children's motivation in learning has been valued as one of the cores of 21st education (An & Reigeluth, 2011). Increased motivation leads to higher levels of engagement, lower dropout rates, and a higher likelihood of achieving academic and professional success in children's later lives (Kori et al., 2016; Vallerand & Blssonnette, 1992). However, children's lack of intrinsic motivation is a common issue in a classroom with teacher-centered tutoring. Teacher-centered tutoring draws from external outcomes, such as rewards, regulation, recognition, and peer pressure, to motivate students (Garrett et al., 2015). As individuals mature, life choices are more influenced by extrinsic reasons such as societal obligations and academic and career choices. Extrinsic motivation, particularly when internalized in the form of extrinsic values such as academic aspirations, does increase learning engagement and facilitates the development of self-efficacy (Ryan & Deci, 2000a). Despite the positive effect of extrinsic motivation, it can also be a pathway to anxiety and frustration among learners (Stoeber et al., 2009). Intrinsic motivation, which occurs more frequently in a student-centered context (Garrett et al., 2015), has great potential to engage students with pleasure derived from the learning process (Stoeber et al., 2009).

3.1.3. Motivation, Fantasy, and AR Game-Based Learning

Children are naturally drawn to novelty and fun (Henderson & Moore, 1980). The combination of augmented reality (AR), fantasy, and game-based learning enable experiences of challenge, enjoyment, and curiosity, which have been extensively explored for their positive effects on children's motivation to learn (Malone & Lepper, 1987; Ryan et al., 2006; Stapleton et al., 2002). Textbooks with AR, offering a novel experience with contexts where real and virtual worlds are blended, attract children more than traditional textbooks (Radu, 2014). Research by Stapleton and colleagues (2002) shows mixed reality technology like AR and VR can facilitate the suspension of disbelief and engage players in a rich fantasy experience. As one of the carriers of fantasy, games are favoured by children. Children prefer game-based learning to textbooks for learning (Waal, 1995). AR game-based learning can boost children's learning motivation and engagement (Yuen et al., 2011). Fantasy in AR game-based learning can stimulate children's fantasy play, and activities related to pretend-play in an imaginary realm and make-believe situations are shown to be beneficial to children's cognitive development (Skovbjerg et al., 2022).

However, there are still some concerns regarding the potential negative effect of AR game-based learning and game fantasy. Parts of game-based learning have been shown to be motivating, while others have not (Wouters et al., 2009). Poorly designed game-based learning is sometimes considered sugar-coated learning with game characteristics (Charsky, 2010). Some poorly designed game-based learning applications are regarded more as learning tools and have been widely criticized for failing to effectively promote digital games' engagement power (Kerawalla & Crook, 2005). AR game-based learning experiences that foster intrinsic motivation requires endogenously integrating attractive fantasy with learning contexts (Sotiriou & Bogner, 2008). However, detailed guidelines on how to apply endogenous fantasy to game-based learning that motivates and engages participants are missing. To construct such guidelines, researchers need to investigate how fantasy play influences player experience and engagement.

3.1.4. Player Identification

A critical catalyst for fantasy play (Choi et al., 2013) is player identification, defined as players getting absorbed in the story and connecting with the character (Cohen, 2001). One way to understand how avatar design influences players' engagement is by investigating avatar identification. Identifying a fictional character is a pivotal driver of user experience and attraction (Regnath & Elmezeny, 2019). Van Looy and colleagues (2012) propose a scale to measure player identification. They validate the player identification questionnaire across three dimensions: avatar identification, group identification, and game identification (van Looy et al., 2012). Avatar identification, including wishful and similarity identification in video gameplay, allows players to temporarily adopt different game roles. Playing a fictional character with background stories and settings can encourage avatar identification. Research suggests that character customization (Turkay & Kinzer, 2014), and real-life escaping (van Looy et al., 2012) appear to be positively associated with avatar identification as well. Birk and colleagues (2016) showed that identification increases self-reported motivation and behavioral engagement over time in an infinite runner game. However, before investigating the motivational effect of different fantasy genres, it is still uncertain whether a fantasy avatar or a real-life avatar will benefit players' immersion and enjoyment. Contextual research regarding players' identification and affective motivation can help designers identify the strategies of employing fantasy avatar design endogenously that attract players in the first place.

3.2. Supporting Engagement During the Game

Recent studies demonstrate a growing need to comprehend player experiences since an accurate evaluation of player experience may aid in creating a pleasant gaming experience and utilize gameplay's motivational pull for learning (Connolly et al., 2012). However, designing a serious game with satisfactory experiences is more challenging, as there are serious factors such as obligatory learning. The feeling of obligatory playing and learning potentially thwarts player experience and engagement (Deterding, 2016). Serious games that fail to achieve engagement often show low levels of experienced autonomy and immersion, i.e., feeling forced to play and disconnected from the gameworld (Charsky, 2010). Player experiences like perceived autonomy and presence are two essential indicators of intrinsic motivation (Ryan & Deci, 2000b). They can facilitate understanding of whether the design choice made in the serious game supports engagement and player experience.

Perceived autonomy and presence are closely related to fantasy in game-based learning; they are regarded as interest-enhancing embellishments (Reeve et al., 2002) and can potentially encourage intrinsic motivation. Autonomy-supportive learning contexts bring curiosity and willingness to be challenged to learners (Deterding, 2016). When students are fully immersed in an experience, they suspend their disbelief in the fantasy. To some extent, the observed presence of players reflects the degree to which the story captures them as their awareness accepts the fantasy as a reality they are in (Barbosa Lima, 2016). Investigating players' autonomy and presence can help to identify 'the engaging and motivational effects of fantasy in game-based learning.

3.2.1. Autonomy

Autonomy indicates the willingness to engage out of our own volition (Miller et al., 1988). A highly autonomous state occurs when individuals are determined to interact based on their interests and values (Deci & Ryan, 2012). Autonomous motivation in an educational context is beneficial to students and educators (Deci & Ryan, 2004). It predicts higher academic achievement (Flink et al., 1990), positive emotional experiences like enjoyment (Ryan & Grolnick, 1986), and creativity (Amabile, 1985). Since games have an evident appeal to the people who play them, the motivational effect of game-based learning has been widely researched. In gameplay experiences, higher autonomy during play can indicate that the player stepped into the magic circle. It is hypothesized that we can only enter the magic circle of our own volition (Deterding, 2016; Huizinga, 2020).

Players' feeling of autonomy is commonly measured using a 5-item scale, the Player Experience of Need Satisfaction (PENS) questionnaire (Rigby & Ryan, 2007). The questionnaire includes questions such as "I did things in the game because they interested me."

3.2.2. Presence

Presence representing the users' perception of themselves is sometimes also described as immersion in a game world (Rigby & Ryan, 2007). It is a concept that denotes the experience of "being there" in a mediated environment (Wirth et al., 2007). A higher experience of presence would indicate relinquishing doubts toward the context, called suspension of disbelief (Christoph et al., 2009). Suspension of disbelief in the game world could be seen as indicators of crossing through the paraludic interface, i.e. the semiotic domain of the pervasive game (Nieuwdorp, 2005), and being fully engrossed in a play activity. The experience of presence is greatly influenced by the context in which the user personally interacts. Ryan and colleagues (Ryan et al., 2006) showed that intuitive game control and immersive gameplay could bring stronger autonomy, and autonomous states can foster enjoyment in gameplay. They developed an assessment of presence in the PENS questionnaire (Ryan et al., 2006) associated with intrinsic motivation. In line with Ryan and colleagues's definition of presence, Augmented Reality can increase users' presence and immersive experiences (McCall et al., 2011; Radu, 2014). Additionally, McCall and colleagues (2011) found that an AR environment that is only somewhat interactive could cause a lower sense of presence.

3.3. After the Gameplay

Educators and academics have long been concerned about the ability of game-based learning to accomplish their teaching objectives. Depending on learning contexts, there is a somewhat positive or negative influence on various learning outcomes. Wouters and colleagues.'s (2009) review reveals a range of findings on facets of the learning impact, suggesting a possibly beneficial influence of serious games on cognitive learning outcomes. As a key cognitive process of selecting and integrating information in learning, working memory is one of the determining factors in efficacious learning (Jarvis & Gathercole, 2003).

3.3.1. Working Memory

Working memory refers to a process of storing information temporarily (Baddeley & Hitch, 1974). An Individual's working memory capacity, the ability to hold information, is relatively constant, usually ranging from 3 to 5 items (Nelson, 2010). With such capacity unchanged, extra information around the essential data to be stored can sometimes help individuals compress and memorize the information more efficiently (Brady et al., 2009), improving memory performance by redirecting attention to the items. However, some extra information around the essential data that requires the learners to use their mental processes can also lead to cognitive overload, which might bring about poor memory performance (Pappas, 2014). The key to improving recall of knowledge is learning the essential data with a well-designed form of extra information that includes visual and auditory modalities of working memory in cognitive processing (Schnotz & Kürschner, 2007).

Baddeley and colleagues (1974). developed a multicomponent working memory model consisting of the phonological loop, visuospatial sketchpad, and episodic buffer. The phonological loop, which refers to the temporary storage of sound, is a rehearsal process that is constantly refreshing to prevent its decay (Baddeley & Hitch, 2019). The visuospatial sketchpad stores the image and spatial information. Research suggests that words with a high imageability are easier to remember than abstract words (Baddeley & Lewis, 2017). The episodic buffer temporarily stores source information coded into a coherent episodic representation (Baddeley, 2000). These three components also serve as important stages for long-term memory (Figure 3.3).

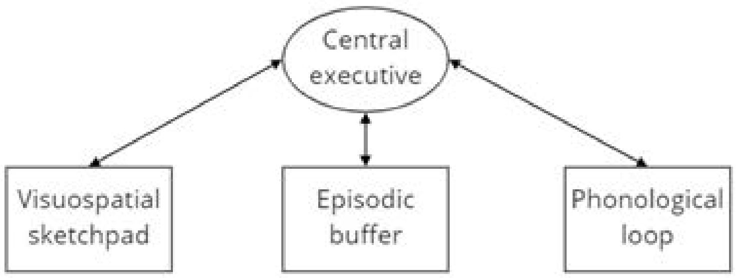


Figure 3.3: The multicomponent working memory model (Baddeley, 2000)

Considering the properties of working memory, we find a potential connection to the learning effect with AR in game-based learning. A context supported by AR allows learners to perceive complicated spatial connections and abstract ideas (Arvanitis et al., 2009), offers immersive and interactive narratives (Stapleton et al., 2003), and provides accessible and immediate context-aware audio in a learning environment (Liu, 2009). With these affordances, AR can facilitate better information processing by elaborating to-be-learned material that enables multi-modal sensory, including visual, verbal, proprioceptive, and tactile memory (Vincenzi et al., 2003). However, educators are also concerned about whether incorporating fantasy and game-like features into learning can increase the amount of irrelevant information in processing, decreasing the learning effect (Ang et al., 2007).

3.4. Fitting the Context

Fitting AR game-based learning into a classroom could be beneficial for social connections between teachers and students as students engage in natural cooperation in the real world (Li et al., 2020). Yet how to leverage AR to facilitate student-teacher connections is an open challenge. It requires game designers to be familiar with educational goals, provide contexts to engage students, and situate knowledge while allowing educators to stimulate knowledge transfer. Prior research on the use of AR serious games in classrooms reveals challenges in students' appreciation of the game features, technology, knowledge, instruction of teachers, and games (Fotaris et al., 2017b). Structured research regarding the requirements of situated learning and scaffolding can help designers construct game-based learning in classroom settings that address instructors' and students' technological, organizational, and cognitive challenges (Dunleavy et al., 2009).

3.4.1. Situated Learning

Situated learning refers to learning practical applications through communication and interaction with environments (Lave & Wenger, 1991). Immersive technologies like AR can potentially provide various contexts and alternative perspectives to support situated learning. However, some questions remain about situating learning with AR and fantasy. Guidelines of situated learning often suggest designers embed learning in an authentic context, where students explore, discuss and construct concepts of real-world issues they can relate to (Council et al., 1999). Some scholars perceive authentic context as an inverse of fantasy, suggesting that only real-life contexts can draw learners to engage instead of passively receiving knowledge (Ladley, 2010). However, the original definition of authentic learning context only criticizes memorizing abstract knowledge as passive listening (Newmann et al., 1995). As others have argued, fantasy scenarios could, in fact, favorably engage students more (Lee & Liu, 2017; Liu & Kang, 2014). The trick here is to connect the topic of learning to fantasy contexts to create a convincing and immersive magic circle for the classroom while also considering the teacher's instructional role and students' motivation and comprehension.

3.4.2. Scaffolding

The role of teachers in situated game-based learning differs from a traditional tutoring context. In traditional education, teachers guide students through scaffolding, which means offering temporary support to complete learning targets (van de Pol et al., 2010). In a game-based learning context, players can also be guided by instructional content through a natural progression of the game's storyline (Wouters & van Oostendorp, 2016). Students fully immersed in the environment require fewer directions from teachers to explain abstract concepts at first, especially while learning tedious and repetitive skills (Young, 1993). Certain circumstances, such as allowing teachers to turn over controls of the learning context to students, encourage autonomous learning by students (Garrett et al., 2015). However, it also challenges teachers in terms of assisting students and focusing students' attention on the learning content without interfering with their autonomy (Wouters & van Oostendorp, 2016) and their determination to interact based on their interests and values (Ryan et al., 2006). AR, a technology that engages participants with virtual content, maintains a portion of their attention in the real-life classroom (Yuen et al., 2011), allowing students to seamlessly move between virtual exploration and real-world interaction, creating spaces to insert teachers' scaffolding. However, it is still unclear how to situate fantasy in AR game-based learning while considering the teacher's role in such contexts.

Incorporating the role of teachers necessitates a detailed assessment of how students perform in different educational contexts. Pivec and colleagues (2003) summarize the criterion for different degrees of problem-solving skills of tasks from Vygotsky's (1978) theory: (1) tasks that can be accomplished alone by a student; (2) tasks that can be completed with the assistance of others; and (3) tasks that cannot be performed even with the assistance of others. A further in-depth assessment of students' task completion using this criterion, in combination with their experience analyses, can help situate teachers' roles in scaffolding towards specific contexts.

3.5. Summary

Reviewing the related work on the possible learning and motivational correlates of a player's journey through AR game-based learning, we bring into focus four exploratory research avenues, based on before, during, after, and the context surrounding gameplay, in order to gauge the effect of fantasy on AR game-based learning. These are respectively discussed in the following chapters: Chapter 4 -- Exploring the motivational effect of fantasy and similarity through avatar identification in AR Game-based learning; Chapter 5 --The mediating effect of fantasy on engagement in an AR game for learning; Chapter 6 -- The effect of fantasy on learning and recall of declarative knowledge in AR game-based learning; Chapter 7-- Situating learning in AR fantasy, design considerations for AR game-based learning for children. Noticing above theories related questionnaires including IMI. PI was not specifically designed for Children, Li and colleagues (2019) developed a 4-point animated smiley scale for the PENS and IMI questionnaires for children which will be applied in our following studies.

This page intentionally left blank

Chapter 4

Study 1*

Exploring the motivational effect of fantasy and similarity through avatar identification in AR game-based learning

*This chapter is partially based on Zuo, T., Spek, E. D., Hu, J., & Birk, M. V. (2021, December). Investigating the Motivational Effect of Fantasy and Similarity Through Avatar Identification in AR Game-Based Learning. In International Conference on Intelligent Technologies for Interactive Entertainment (pp. 279-294). Springer, Cham


Shut Down?
Yes
No
Yeah~ New friends! Let's party!
I can sense that new avatars are coming to us......
Have you heard the news? A new game is intalled today.
Hi I'm Peggy. We are from the serious game Math village!

4.1. Introduction

Student engagement is a well-established predictor of subsequent academic achievement (Ryan & Deci, 2000b), while a lack of motivation ('amotivation') can lead to underperformance and dropping out of school (Lee & Shute, 2010; Lee, 2014). Research suggests that game-based learning, which incorporates entertaining and playful elements into learning content, can increase motivation (Pivec et al., 2003a) when, for example, learning mathematics (Li et al., 2018; Zuo et al., 2020), languages (Ritterfeld et al., 2009), or life-skills (Johnson, 2007). However, game-based learning does not always increase motivation to engage with the learning content (Whitton, 2007), and in fact, a meta-analysis found that, on aggregate, game-based learning is not yet more motivating than other forms of instruction for all ages (Wouters et al., 2013). Therefore, more in-depth, empirical knowledge on how to design game-based learning to be more motivating could shed light on why some games fail while others succeed in creating compelling games for learning and subsequently help game designers create more efficacious game-based learning.

An important concept related to player motivation is fantasy play, the act of playing with themes and roles that require imagination and make-believe (Asgari & Kaufman, 2010; Saltz et al., 1977). While performing a cognitive task such as mathematics, fantasy play allows students to enter and stay in the "magic circle" (Pellegrini & Galda, 1982; Salen et al., 2004) of the game world without consciously thinking about mathematical challenges (Montola, 2005). Research suggests endogenous fantasy, i.e., integrating fantasy internally with the learning content, appears to have greater potential for generating intrinsic motivation (Kenny & Gunter, 2007).

To create game-based learning experiences that incorporate endogenous fantasy, designers should place fantasy game features in an authentic learning context (Grabinger & Dunlap, 1995), the application of which can be assisted by contemporary technologies. Augmented Reality, a technology that enables a virtual overlay on tangible materials and the physical world (Azuma, 1997), could transport users to a world where tangible reality and imaginary virtuality coexist. Such technology brings a more immersive and potentially more motivational experience than Non-AR games for children's education (Radu, 2014). To fully utilize AR's affordances, the judicious design of digital overlays such as avatars and stories is critical (Fan et al., 2020). The unanswered concern is whether more realistic or fanciful stories and avatar settings will lead to more engaging, authentic learning environments.

Research by van der Spek and colleagues (2014) indicates that people enjoy fantasy avatars and dialogues in a learning game. Still, the alien context of the fantasy could impede learning compared with a more grounded real-life setting. While similarity and alienness can exist both in fantasy and real-life settings, two perspectives were considered in our custom-built game MathMythosAR1: fantasy and similarity. In our design, we introduced humanoid avatars as similar to players and animaloid avatars as dissimilar to players. Therefore the game includes four different avatar designs: similar fantasy (fantasy human), dissimilar fantasy (fantasy animal), dissimilar real-life (real-life animal), and similar real-life (real-life human). With this game, we conducted a study to explore children's motivation in game-based learning and how they are influenced by levels of fantasy and similar settings in augmented reality contexts.

To further understand how levels of fantasy and similarity may influence player motivation, we have introduced the concept of player identification in Chapter 3. Player identification, a vital catalyst to fantasy play, has been found to increase users' autonomy and motivation through avatar customization in previous research (Birk et al., 2016). An open question, in this case, is whether children want to "escape" the real-world learning settings in the textbook (Balfe, 2004) and engage in learning when playing with fantasy avatars; or whether the more real-life grounded context makes it simpler to put themselves into the player role. Therefore, we aim to answer the following research questions:

1. Do players have distinct avatar identifications (Similarity and Wishful Identification) for a fantasy or a real-life avatar setting, for a similar or a dissimilar avatar setting?
2. How does participants' avatar identification affect motivation when playing with different fantasy and similarity game settings?

This study focuses on the "Invitation stage" of gameplay (de Valk et al., 2015). Players are invited into the magic circle and become motivated to explore the game. Therefore learning outcomes are not the current primary focus. Through a quasi-experiment using MathMythosAR1, we intended to investigate the effect of fantasy and similarity on player identification and motivation in AR game-based learning design, inspiring the related research and innovation practice of AR fantasy in game-based learning.

4.2. Related Work

This section introduces key concepts employed in the game design and the experiment setup, including fantasy and similarity. A detailed review regarding related work of player motivation and identification can be found in Chapters 2 and 3. A general introduction, including AR and game-based learning, can be found in Chapter 1. In this section, we explain the concept of fantasy avatar design and similarity design in our work.

“Fantasy play” was initially introduced by Saltz & Johnson (1977) as a “thematic fantasy play,” children’s playful behaviors in roles and themes are different from their experiences in real life. Fantasy play has been shown to increase children’s motivation to learn and to engage with the learning material (Ferguson & Olson, 2013). Beyond just learning, fantasy is a key concept of exploration, curiosity, and unrestricted engagement with tasks (Matheson & Spranger, 2006). When performing cognitive tasks such as basic mathematical operations, fantasy play enables players to engage with the task without a continuous perception of their mathematical abilities (Cordova & Lepper, 1996) but through practice and experience (Eraut, 2000).

While children and adults are fantastical thinkers (Woolley, 1997), children also seem to find wonder in realistic stories (Weisberg et al., 2013). In fact, children can identify with a wider range of agents, including common creatures and animals unlike themselves. One important visual feature here is avatar self-similarity, which usually describes a game’s avatar similarity with its players (Jang et al., 2010). When comparing game avatars to their players, aspects of appearance, personality, abilities, and life experience can all be considered. The majority of current research focuses on the similarity of avatar appearances (Jang et al., 2010; Wauck et al., 2018). Since an avatar is a player’s virtual self-representation, avatars with similar traits to players can improve the players’ experience (Wauck et al., 2018). According to research by Parmar (2017), students learned programming concepts more effectively with self-similar avatars in VR game-based learning.

Players’ senses of similarity are not necessarily attributed to games being real-life-based or fantastical. However, the concept of fantasy is often embedded in similar or dissimilar avatars. For example, while both have fantastical superpowers, Spider-Man is designed with more similarity in appearance to human players, while Broodmother in Dota 2 looks more dissimilar to human players (Figure 4.1).

Figure 4.1. The fantasy and similar Spider-Man (left), the fantasy and dissimilar Broodmother (right)

It is still poorly understood how children construct fantasies in a blended space through avatar identification and what's the motivational effect of fantasy and similarity through avatar identification. Therefore, we designed MathMythosAR1 to answer two research questions: 1. Do players have distinct avatar identifications (Similarity and Wishful Identification) for a fantasy or a real-life avatar setting? 2. How do high or low levels of fantasy, and similarity game settings affect their motivation in game-based learning through player identification?

4.3. The Game Design

4.3.1. Design Choices Made

To develop the fantasy version of the game MathMythosAR1, we refer to the classification of fantasy components in serious game design discussed in Chapter 2. Considering the favorable influence of the portrayal of fantasy on learning and the types of fantasy that is well-known to most audiences, we chose a dragon and a magician as fantasy avatars. Inspired by popular card collection games, we design a series of cards as tangible materials, enabling children to play with these cards with or without AR. We refer to popular entertainment games among children, including Fortnite, Animal Crossing, and Minecraft (Games, 2017; Microsoft, n.d.; Nintendo, 2020), to design magic-related, after-school, and animal-related stories with a similar cartoony visual style. We aim to motivate children to practice mathematic addition during the gameplay through an endogenous fantasy design, i.e., internally integrating fantasy with math learning (Malone & Lepper, 1987). We alter different avatar designs to investigate the motivational effect of fantasy, similarity avatar design, and player identification. Figure 4.2 shows an overview of the design choices.

Innovation	Portrayal	Dragon/ Warlock
Elements	Mechanics	Card Game
	Story	Magic Items/ Events/ Spells
	Aesthetic	Carton/ Magic Sound Effect
	Technology	Augmented Reality
Genre	Story	Narratology
Adaption	Instruction	Endogenous Fantasy

Figure 4.2 Design choices made in the MathMythosAR1 under the guidance of the classification of fantasy

4.3.2. Game Settings

MathMythosAR1 was built using Unity (2019, 2.8f1) and the AR Engine Vuforia (2019, 8.5). The game co ntains three versions of cards: the interactive role cards, the item cards with a numerical indicator on each card, and the target cards. The three versions of cards combined tell a narrative; for example, the character

"Luca" buys and delivers food to their brother; see Figure 4.3, the second roll. To accomplish their mission, Luca needs to correctly add up the numbers indicated in item cards, which are the prices for ramen (271¥) and sushi (124¥), to 395¥. Bringing the narrative to life, we set each card tracked using a standard webcam and overlaid it on the screen with a digital object, e.g., an overlay of a ramen bowl appears on the ramen card. Vuforia recognizes visual markers and allows one to specify a digital object's location on the cards. A virtual button—an area constantly tracked and responding to being occluded—on each interactive role card triggers the character to provide options for summing up the item cards. In this case, the options are presented as five cycling numbers within ±2 of the target sum. Releasing the digital button while the correct sum is presented triggers the interactive role to interact with the target card—the character Luca gathers ramen and sushi on a tray and delivers the food to their brother.

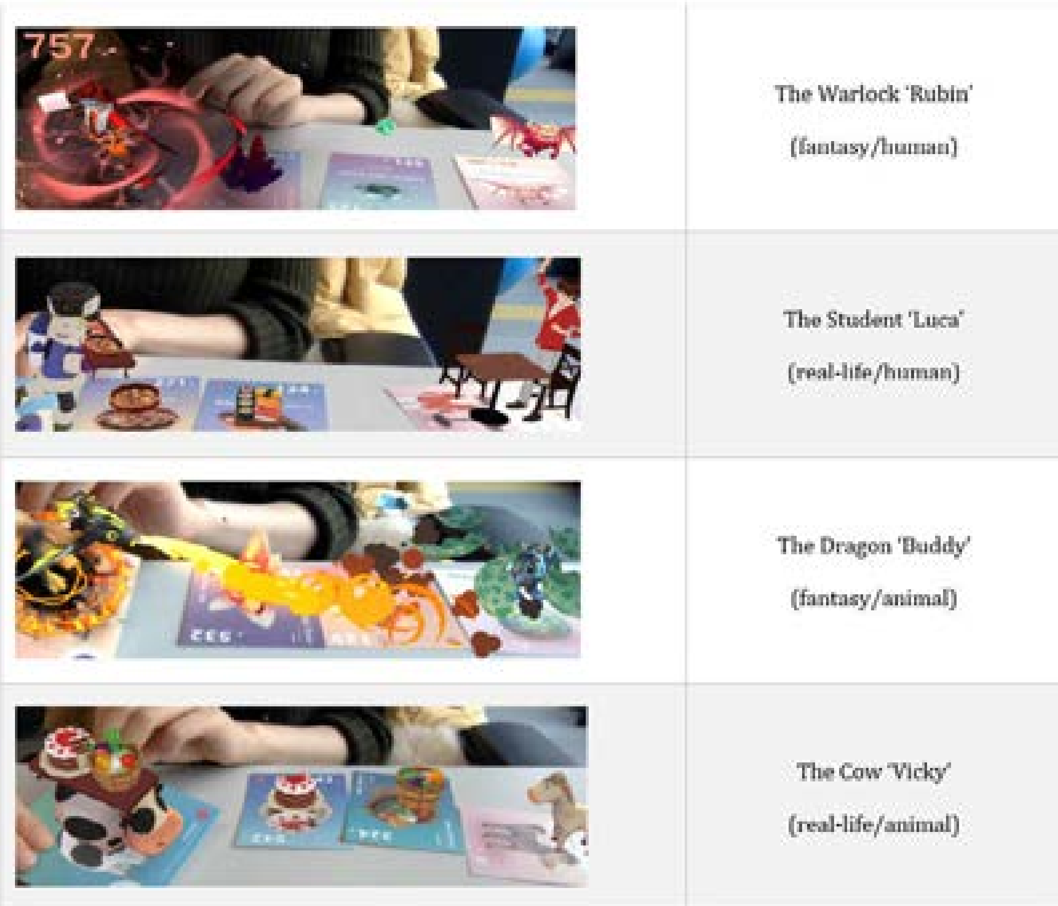


Figure 4.3 Four avatars with related NPCs

To further explore the role of fantasy in identification, we created four scenarios that present a visual narrative involving either a human similar to players or an animal dissimilar to players. The narrative is set in a fantasy or real-life life context.

The four conditions presented in Figure 4.3 (from top to bottom) are the Warlock ‘Rubin’ (fantasy/human), the Student ‘Luca’ (real-life/human), the Dragon ‘Buddy’ (fantasy/ animal), and the Cow ‘Vicky’ (real-life/animal). In the Fantasy scenarios, users play Rubin’s role, the warlock, to calculate the total power of two magic gems that enable the magic spell to free the friend. Playing as Buddy, the dragon, users need to hatch a dragon egg with an adequate amount of firepower. In real-life settings, Luca, the student, needs to add up the food’s total price on two cards and have them delivered to his brother. When playing Vicky’s role, the story is about how the delivery’s total weight that Vicky is carrying is calculated and brought to the Horse.

4.4. The Experiment Design

4.4.1. Participants

A total of 34 primary school students aged 9 to 10 years old (of whom self-identified as Male=19, Female=15) participated in our study (Figure 4.4). All participants from the same classroom at the same primary school were invited to a classroom with settings prepared for the experiment.

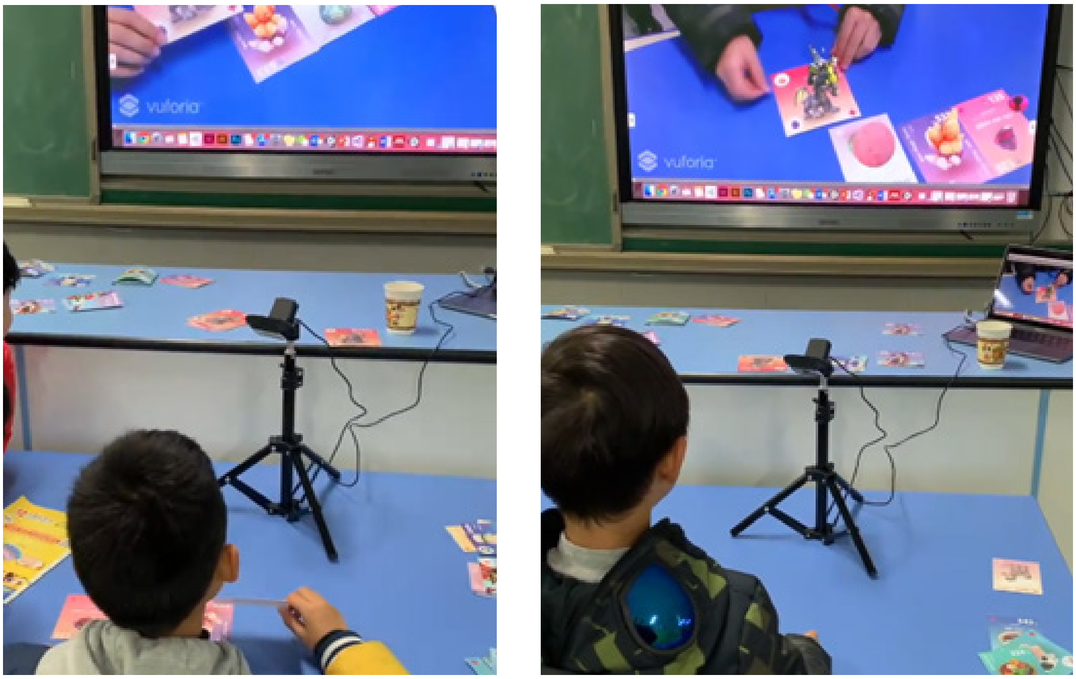


Figure 4.4 The experiment settings

4.4.2. Measurements

The experiment was designed within-subject to explore the effect of fantasy settings and real-life settings. Two 5-points Likert-scale questionnaires were introduced. One was the enjoyment/interest part from the Intrinsic Motivation Inventory (IMI), a dimension that measures children’s interest (enjoyment) in different characters during gameplay. The other was the avatar identification part from the Player Identification questionnaire (PI) (van Looy et al., 2012), which measures Wishful and Similarity Identification regarding different avatars.

4.4.3. Procedure

The study took approximately 20 mins per person. In appreciation of the children's time, researchers offered a lecture about Augmented Reality and Design. The content and the experiment's design were approved by the Ethics Review Board at the Eindhoven University of Technology in advance. The children's and their parent's consent for participation was obtained before the experiment. Their teacher provided demographic information and anonymized it using their student numbers.

	Fantasy	Real-life
Similar (Humanoid)		
Dissimilar (Animaloid)		

Figure 4.5 Four conditions

At the beginning of the experiment, each participant first played a pretest version of the AR card game with only instructional words such as "scan the pattern" and "hold the virtual button." The form of a five-scale questionnaire and ways of handling reversed questions were introduced with the example of rating sentences including "I do not like rainy weather" and "I like rainy weather." Afterwards, participants were invited to play four versions of the MathMythosAR1 game. These four versions of role-playing contrast 2x2 variables, fantasy/real-life versus human/animal player characters (Figure 4.5). All conditions were presented randomly to the children using a 4x4 Latin square to minimize potential order effects. On average, playing a single condition needed approximately 2 minutes. Questions were presented to children in a random sequence supported via the Tencent questionnaire. We designed the questionnaire with images of the condition following each question (Figure 4.6).

Figure 4.6 An example question from the questionnaire

4.5. Results

4.5.1. Reliability

The values for reliability coefficients show good reliability for Similarity Identification (from 0.8 to 0.9 for all conditions). The Wishful Identification scale is acceptable in most situations (from 0.6 to 0.8), except for the humanoid avatar (0.5). Besides, Cronbach’s alpha for enjoyment is poor, with 0.6 for the Fantasy Animal, 0.5 for the animal, 0.5 for the Fantasy Human, and 0.5 for the Human.

Table 4.1. Mean and standard deviation of children’s self-reported data

	Similarity Identification M (SD)	Wishful Identification M (SD)	Enjoyment M (SD)
Fantasy Animal	2.41 (1.12)	2.99 (0.95)	4.44 (0.75)
Fantasy Human	2.68 (1.32)	3.31 (1.10)	4.46 (0.78)
Animal	2.15 (0.97)	2.65 (0.98)	4.35 (0.75)
Human	2.78 (1.16)	3.08 (0.84)	4.44 (0.72)

4.5.2. Descriptive Data and Controlled Factors

In general, most children perceive very high enjoyment when playing with all four versions of avatars. According to the standard deviation, a greater spread occurs in Similarity and Wishful Identification data than in enjoyment data that children reported (Table 4.1). Previous research indicates that different gender may have different attitudes toward gaming (Greenberg et al., 2010). Given the possibility of a gender effect on scores of avatar identification (Rogers et al., 2018) or enjoyment, an independent-sample t-test was undertaken. The finding indicates that there is no discernible gender difference in the enjoyment and avatar identification data gathered.

4.5.3. Two-Way Repeated Measures ANOVA

A two-way Repeated Measures ANOVA, setting Fantasy/ Real-life, Humanoid/ Animaloid as two within-subject factors, is implemented to investigate the RQ1: Do players have distinct avatar identifications for a fantasy or a real-life avatar setting for a similar or a dissimilar avatar setting?

Table 4.2. Results of two-way ANOVA

IV	DV	SS	F	Sig.
Fantasy or Real-life	**Wishful Identification**	**2.77**	**7.02**	**0.01**
	Similarity Identification	0.21	0.26	0.61
	Enjoyment	0.12	0.39	0.53
Similar (Human) or Dissimilar (Animal)	**Wishful Identification**	**4.74**	**21.31**	**0.00**
	Similarity Identification	**6.92**	**13.28**	**0.00**
	Enjoyment	0.12	2.63	0.11
Fantasy or Real-life * Similar or Dissimilar	Wishful Identification	0.09	0.25	0.62
	Similarity Identification	1.12	3.07	0.09
	Enjoyment	0.05	0.63	0.43

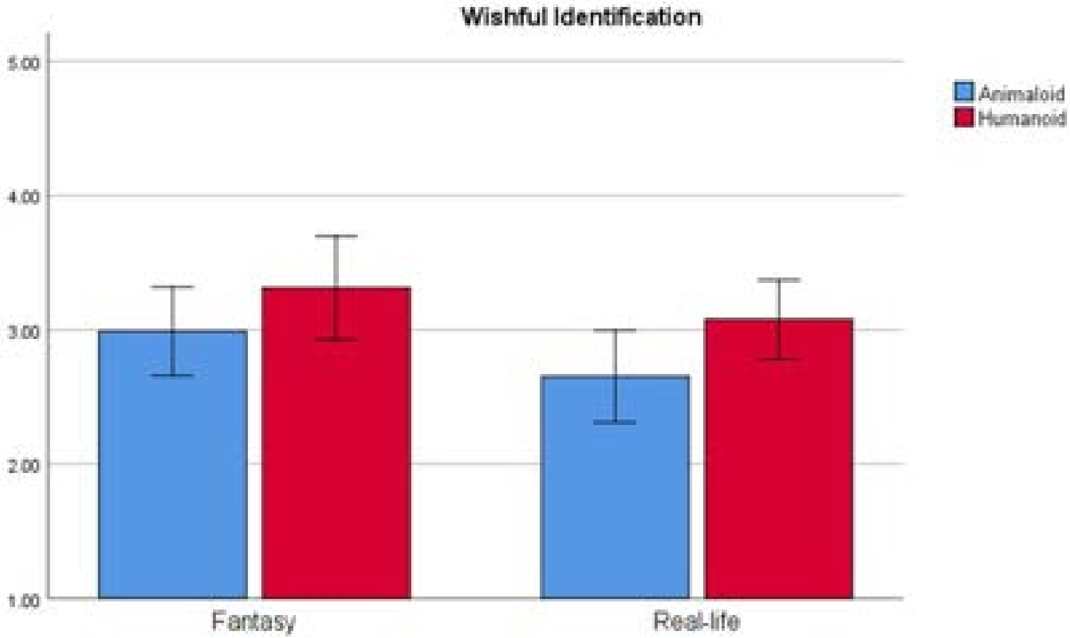


Figure 4.7. Plot for effects of similarity and fantasy on Wishful Identification

The result suggests a significant effect of avatars' fantasy/real-life design on players' Wishful Identification, showing a higher score of Wishful Identification on fantasy avatars than on real-life avatars. A further Bonferroni corrected comparison suggests players score significantly ($p=0.02$) higher Wishful Identification with the fantasy animal than the real-life animal, but there is no difference between the two human avatars. A significant effect of avatars' similar/dissimilar designs on players' Wishful Identification and Similarity Identification is found. Players' Wishful Identification is stronger with humanoid than animaloid avatars. In line with our estimation, users' Similarity Identification is significantly higher $F(1, 33)=13.28$, $p=0.00$ with humanoid avatars than with animaloid avatars. The Bonferroni corrected comparison confirms that players score higher in avatar identification with similar (humanoid) avatars in fantasy and real-life groups. There is no significant effect of the fantasy/real-life and humanoid/ animaloid interaction on enjoyment, Wishful Identification, and Similarity Identification. However, the Bonferroni corrected comparison suggests players perceived significantly stronger enjoyment with the fantasy animaloid (dissimilar) avatar than with the real-life animaloid (dissimilar) avatar.

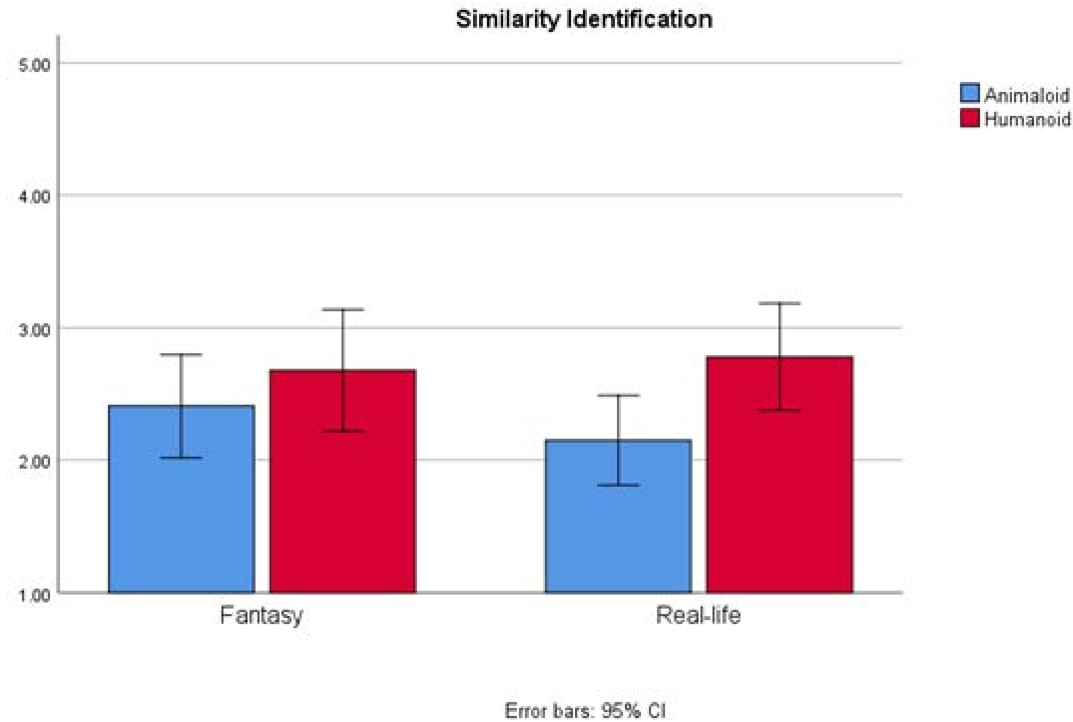


Figure 4.8. Plot for effects of similarity and fantasy on Similarity Identification

4.5.4. Partial Correlation

Since both factors of fantasy/real-life and humanoid/animaloid affect children's identification, the relationship between identification and enjoyment should be explored by one factor and with the effect of the other factor removed. Therefore two sets of partial correlations are conducted to identify RQ2: How do fantasy and similarity settings in games affect their motivation in game-based learning through player identification?

To see the effect of fantasy and real-life avatars, the effect of humanoid and animaloid is controlled. There is a significant correlation between Wishful Identification and enjoyment r (65)= 0.26, p= 0.03, Similarity Identification and enjoyment r (65)= 0.24, p = 0.05, with fantasy avatars. Such associations were found insignificant when users were playing with real-life avatars. From aspects of humanoid/animaloid, controlling the effect of fantasy/real life, a significant correlation between Similarity Identification and enjoyment r (65)= 0.24, p= 0.05 is shown with humanoid avatars. No other significant association is spotted in animaloid avatars.

4.6. Discussion

The descriptive data show that the children enjoyed playing all four conditions of the game. These positive scores could be interpreted as the success of implementing AR game design in math education. In alignment with previous work, children have higher motivation and engagement when learning from AR materials than with traditional textbooks (Li et al., 2019).

4.6.1. RQ1: Do players have distinct avatar identifications (similar and wishful identification) for a fantasy or a real-life avatar setting, for a similar or a dissimilar avatar setting?

Prior research has shown that gamers had greater Wishful Identification with fantasy avatars than with real-life ones. Our results confirm previous work that the fantasy contexts of game-based learning enable participants to admire supernatural talents while imaginatively meeting their emotional needs (Asgari & Kaufman, 2014; Choi et al., 2013). Our finding regarding Similarity Identification confirms our expectation: players perceive more Similarity Identification toward similar (humanoid) avatars than dissimilar (animaloid avatars); the levels of fantasy in avatar design do not influence players' Similarity Identification. In addition, the result suggests players also have stronger Wishful Identification with humanoid avatars corresponds to Higgins' (1987) early formulation of the self-discrepancy theory. Higgins believes the basis of Wishful Identification is the decrease of self-discrepancy through media exposure. A more similar humanoid avatar would have less self-discrepancy between players and avatars, increasing their chances of identifying with the avatars as their desired role.

In many actual instances of game-based learning, designers prefer to utilize little animals as the primary protagonists of games. Our findings, however, demonstrate that for children having animals as the protagonist of a game may hinder identification with the character and subsequently lead to less enjoyment compared to when they are playing with a magical creature or humanoid character.

4.6.2. RQ2: How does participants' avatar identification affect motivation when playing with different fantasy and similarity game settings?

The results suggest our participants' affective motivation for game-based learning derives from fantasy settings where Wishful and Similarity Identification is activated. This finding demonstrates that fantasy allows for an enjoyable experience via avatar identification. As described by Klimmt and colleagues (2010), Similarity Identification facilitates players' mental rapprochement with the avatar. Fantasy avatars in our design fit the child's nature of seeking novelty and enjoyment. Bessière and colleagues (2007) mentioned that Wishful Identification enables players to alter their self-perception and feel better about themselves. Playing with fantasy avatars enables children to perceive enjoyment by identifying with a fictional character, i.e., fulfilling their imaginative wishes via role-playing. Children, in our case, aged 9-10, wanted to use fictitious avatars to represent themselves. Pretending to play as a superpower avatar is more common at this age (Fein, 1981). Therefore, this could explain why fantasy settings also lead to a rise in Similarity Identification, increasing their game-based learning motivation.

At the same time, we have also discovered the importance of similarity in avatar design. Similar avatars can activate parts of the affective motivation through Similarity Identification, i.e., feeling a sense of kinship with the avatars. The avatar self-similarity is suitable for children generally to motivate their game-based learning engagement through Similarity Identification. To maximize both affordances, we will address design strategies involving fantasy and similarity in the next section.

4.6.3. Design with Similarity and Fantasy

As Selen Turkay and colleagues (2014) mentioned in their research, games create contexts that allow players to perceive themselves in worlds of imagination. Fantasy settings create a fictional world, and similar settings allow players to reflect and relate to themselves. We suggest employing a similar fantasy avatar design to activate the affective motivation of unmotivated learners. With the advantage of enabling players' interest through identification, fantasy settings with an authentic learning context supported by AR can lead to motivational play without consciously thinking about learning challenges.

Although fantasy has a greater driving effect on avatar identification and motivation, avatar self-similarity has additional advantages that should not be neglected. Similar humanoid avatar settings can inspire players to reflect on themselves through Similarity Identification (Konijn & Hoorn, 2005), which might be useful in reflecting on what they have learned. Furthermore, previous research has shown that Similarity Identification improves intuitive control, which is ideal for players who have never previously participated in AR game-based learning (Birk et al., 2016).

In summary, it is primarily advised that designers employ similar fantasy settings, such as the magician avatar in our example, rather than dissimilar and real-world settings, such as animals. Prioritizing fantasy and similarity in the design of avatars should consider the learning contexts and target user groups. Fantasy settings should be prioritized in design for youngsters, particularly those highly driven by creativity and novelty, where the games' main objective is to entice gamers at the invitation stage. Meanwhile, self-similar characteristics in the design of AR avatars should be considered since they can aid players in rapidly getting familiar with the game world. For self-motivated learners, particularly those with a high level of incentive to learn, a similarity-based learning game design should be explored to enhance additional experiences such as learner reflection.

4.7. Limitation

Although two dimensions were considered in designing four avatars, the influence of different avatars on enjoyment was subtle. One reason for the similar positive results on enjoyment could be that children tend to give extreme scores and have trouble expressing or understanding neutral attitudes (Li et al., 2019). This could be because the questionnaire selected does not specifically target children. The tension caused by the age difference between experimenters and children makes them reluctant to give negative reviews of others' work (Miller, 2005). Future studies should choose or adjust measures for children's participants. In previous work of Cohen, and colleagues (2018), it is indicated that demographic similarity including age, nationality and gender may not influence participants' perceived similarity. However gender and nationality might includence participants' self-identity. In our work, we create gender neutral characters to avoid any effect caused by gender, and it worked as expected. However, there might exist effects of gender, cultural background and age that requires further investigation.

Additionally, this study provides just two instances for each dimension. There are more aspects of avatar design that remain unexplored. In this research, we examined only the motivational effect of fantasy. The influence of AR fantasy on learning outcomes, such as working memory, will be explored in future work.

4.8. Conclusion

A design study using the game MathMythosAR1 is conducted to explore the influence of using fantasy/real-world and similar/ dissimilar avatar designs on children's identification and motivation in AR game-based learning. We discover that when players play as fantasy avatars or avatars that resemble them, their Wishful Identification increases. Players place a higher premium on Similarity Identification with avatars who resemble them, regardless of whether they are fantasy or real-life-based. Players perceived stronger enjoyment with fantasy animals than with real-life animals. Additionally, it shows from this study found that children's Wishful Identification and Similarity Identification are strongly linked with their enjoyment in fantasy settings. In similar (humanoid) settings, only Similarity Identification corresponds with enjoyment. Designers are encouraged to create avatars in similar fantasy settings to achieve a motivational effect through avatar identification in game-based learning. Considering fantasy and similarity in the design of AR game-based learning, the design of avatars should consider the learning contexts and target user groups. If the primary objective is to boost the children's motivation, design with fantasy contexts could be a primary choice.

We hope this study can inspire more researchers to explore more aspects of AR fantasy play, including storytelling, visual effect, immersive technology, etc. Hopefully, this work would offer solutions to transferring enjoyment and curiosity into learning motivation, making AR game-based learning meaningful and engaging experiences.

Study 2*

The mediating effect of fantasy on engagement in an AR game for learning

*This chapter is partially based on: Zuo, T., Birk, M. V., van der Spek, E. D., & Hu, J. (2022). The mediating effect of fantasy on engagement in an AR game for learning. Entertainment Computing, 42, 100480.

Chapter 5

Class dismissed.
See you tomorrow!
Jeremy, do you have a minute?
Remember the serious game we played in the class? It didn't quite live up to my expectations..... Some students also complained it did not feel like a game at all......
I am not a game expert. I have heard you know games quite well. So.... what's a game?
Aha!
Well...Playing a game is like...
You enjoy it just for the sake of enjoying.
You can freely explore.
experience novel stories
have the feeling of control over things and it is safe to fail

5.1. Introduction

Over the past years, there has been a trend toward virtual teaching because virtual teaching mitigates temporal and geographical barriers (Molnar et al., 2019). Teachers and parents have recently raised concerns about virtual learning: due to a lack of immersion, children are found to be less motivated and more easily distracted, especially when engaging in remote learning (Garbe et al., 2020; Martín et al., 2021; Rötkönen et al., 2019). To improve motivation, introducing playfulness into virtual learning has been another trend in recent decades (Wilkinson, 2016). Game-based learning, a form of serious games considered a plausible solution for "motivational inadequacies," has gained research attention regarding its promising effect on cognitive learning outcomes (Wouters et al., 2009). However, how to design serious games to be motivating is still an open research question (Wouters et al., 2013).

Games create a so-called "magic circle," an alternate bubble of reality where the players adapt a lusory mindset and engage with the game world by suspending disbelief (Huizinga, 2020). Although game-based learning is more attractive to children than traditional textbooks, some serious games fail to live up to their motivational potential, for instance, because they are considered less sophisticated or immersive than entertainment games and have generic storylines (Sanford et al., 2015). Consequently, the players of these serious games may not enter the "magic circle" and adopt a lusory mindset in the first place, therefore leading to lower motivation (Dondlinger, 2007). A critical catalyst for forming a pervasive and persuasive "magic circle" is the separation from real life (Huizinga, 2020). Malone describes elements that evoke mental images, physical objects, or social situations that are not actually there, as fantasy in games (Malone, 1981).

This separation from real life is especially pertinent in Augmented Reality (AR), which blends the real and game world and thereby creates a liminal interface where the player has to shift between telic, paratelic, and paraludic domains (Nieuwdorp, 2005). The shift from a telic state to a paratelic state, i.e., from a task-oriented to a play-oriented mindset, is a transition from extrinsic towards intrinsic motivation (Barr et al., 1993). Transgressing from the paratelic state through a paraludic interface into the game world comes through adapting the game rules or fiction and constructing meaning in this fictional reality (Nieuwdorp, 2005). In other words, to stop using an educational game as a tool for learning and to start playing requires stepping into the magic circle by adapting a playful (paratelic) mindset and immersing yourself in the game world. AR has been shown to improve immersive experiences by expanding the magic circle's boundaries (Montola, 2005) and enhancing players' experience. In addition, perhaps as a consequence of the enhanced experience, young generations, who grow up playing with digital technology, have a stronger preference for AR game-based learning than more conventional modes of education (Radu, 2014). Since evidence for the positive effect of Augmented Reality on virtual learning has been found, how to maximize the educational affordance of technologies like AR has been a research focus (Wu et al., 2013).

With the positive effect of AR fantasy on player identification and motivation, we're asking this question with the temporal framework in mind: how does fantasy draw children in, mediate enjoyment during gameplay, and affects learning outcomes? In this chapter, we seek to gain a better understanding of the relationship between fantasy and the enjoyment of serious AR games. Players' willingness to adapt and ascribe meaning to the rules of the game world (i.e., to step into the magic circle) is, among others, contingent on the ability of the player to surrender themselves pleasurably to an imaginative world (Paras, 2005). Consequently, the game's fantasy and the player's abilities and preferences could interact with the enjoyment of the game. The challenge of adapting contemporary technologies and relating learning content to a fantasy narrative falls on designers' and researchers' shoulders. Developing compelling design strategies for game-based learning requires an understanding of how the fantasy environments shape users' mental state and how their mental activity affects the game experience, i.e., how their mental activities influence perceived enjoyable, immersive, and autonomous experiences.

To investigate player experience in AR, we created one condition situated in a fantasy setting and the other condition in a real-life setting within the AR game MathMythosAR2 we built. However, designing fantasy game elements does not guarantee that fantasy engages every user in the same way. Therefore, we incorporated the Fantasy State Scale (FSS) (Choi et al., 2013) to gauge players' mental fantasy states. We conducted a study with primary school students and collected their self-reported fantasy state, player experience, and motivation. We measured enjoyment using the enjoyment subscale of the Intrinsic Motivation Inventory (IMI) (McAuley et al., 1989) and measured presence and autonomy using the corresponding subscales of the Player Experience of Need Satisfaction (PENS) (Rigby & Ryan, 2007) questionnaire. By comparing two narrative conditions, we investigated the influence of different in-game fantasy settings on users' fantasy states, the player experience of need satisfaction, and intrinsic motivation.

We performed analyses of variance and mediated regression analyses to answer three main research questions: (1) How do two AR fantasy settings (fantasy/real-life) in games influence the overall experience? (2) What are the mediation effects of fantasy states on the relationship between fantasy settings and enjoyment? (3) What are the mediation effects of need satisfaction on the relationship between players' fantasy states and motivation?

Contextualizing our findings from a quasi-experimental investigation of player experience, we discuss three major findings and their respective design implications. Our research contributes insight into the effects of fantasy in game design. We conclude with a theoretical model for serious game designers who aim to implement fantastical settings in AR-based learning games.

5.2. Related Work

Chapters 1, 2, and 3 have briefly introduced the key concepts related to AR game-based learning, fantasy, and players' experience, including autonomy, presence, and enjoyment. In this section, we will discuss in detail why we explore our research questions through fantasy states and why player engagement is explored through enjoyment, autonomy, and presence.

5.2.1. The Invisible and Ambiguous Fantasy

As described in Chapter 2, fantasy, defined as fictitious, fantastic, or unreal states represented in artifacts or mental activities, exists as environmental characteristics of games and imaginary mental images evoked by fantasy contexts. Choi and colleagues (2013) refer to media-induced imaginary mental images as fantasy states, which are invisible and intangible. Since fantasy states are invisible and people vary in their fantasy proneness and orientation, which refers to their tendency to fantasize and the types of fantasy they appreciate, it is challenging to guarantee that utilizing certain fantasy elements will evoke fantasy states. Therefore, we introduce the scale of fantasy states to measure players' fantasy states from aspects of identification, imagination, analogy, and satisfaction. These four aspects include players' minds identifying with the game world, imagining unreal events, relating to real-life situations, and satisfaction with the game world (Choi et al., 2013).

5.2.2. Enjoyable Player Experience

Research suggests that there is a relationship between fantasy and game enjoyment. The link between fantasy and intrinsic motivation has been researched for a long time, with fantasy in digital games being viewed as the primary source of intrinsic motivation (Malone & Lepper, 1987). Since enhancing interest in learning through play is a goal and unsolved challenge for serious games, research attention has moved to investigate whether fantasy experiences evoke enjoyment. Immersion, the feeling of "being part of and absorbed by the story" (Ryan et al., 2006), is regarded as one of the critical principles of pleasure (Douglas & Hargadon, 2000). Fantasy elements in digital games can create a "magic circle" where players step in, highly immersed with a "suspension of disbelief" (Huizinga, 2020). The blend of play and learn, and the blend of reality and the virtual, consequently lead players to shift between telic, paratelic, and paraludic domains (Nieuwdorp, 2005). Players experience a transition from (telic) using educational tools through (paratelic) immersing in a playful mindset to (paraludic interface) accepting the rule of fantasy and constructing meaning inside the mixed fantasy reality.

Players' autonomy, meaning their willingness and sense of volition to participate in a game, is a vital indicator of whether players perceive the design as playful. In Deterding's (2016) research, users remarked that if they felt low autonomy while playing games, it no longer felt like playing the game but performing goal-directed work activities. This indicates that the player did not move from the telic to the paratelic mindset. Therefore, perceived autonomy during gameplay can be an important indicator of whether the game is approached like a game and not a learning tool. Ryan and colleagues (2006) found that compelling narratives, the visual setting, and in-game control could impact degrees of presence in games. On the other hand, fantasy contributing as interest-enhancing embellishments in serious games shows the potential to create autonomy-supportive game-based learning contexts (Reeve et al., 2002).

5.3. Design of MathMythosAR2

We left most aspects of the fantasy design decisions the same as in MathMythosAR1 (Chapter 4), such as the portrayal of fantasy employed, aesthetic design, the technology used, and methods of endogenous integration. We chose Rubin, the magician from MathMythosAR1, as the main protagonist and expanded on the stories in the fantasy edition of MathMythosAR2. As the research focuses on fantasy narratives this time, we extended the play mechanics with an augmented interactive storybook (Figure 5.1).

Innovation	Portrayal	Warlock
Elements	Mechanics	Cards with Storybooks
	Story	Magic Items/ Events
	Aesthetic	Carton/ Magic Sound Effect
	Technology	Augmented Reality
Genre	Story	Narratology
Adaption	Instruction	Endogenous Fantasy

Figure 5.1 The design choices made in the MathMythosAR2 under the guidance of the classification of fantasy

5.3.1. Design Strategies

MathMythosAR is a series of AR games designed with Unity and Vuforia to encourage children to learn and practice mathematical calculations outside the traditional classroom context. Particularly, Vuforia supports the virtual button function, which enables participants to trigger a button in the real world by visually obstructing the pre-defined image target from the camera (Rötkönen et al., 2019). The 3D models and particle effects used in the design of the game were purchased through the Unity asset store or third-party websites. We generated most 2D image targets using Adobe Photoshop. We created MathMythosAR1 in the form of an AR card game to investigate the influence of fantasy on avatar identification. In MathMythosAR1, the background story of each character was only presented by words on cards, while in MathMythosAR2, we extended the narratives into books with pictures that AR devices can scan for a more interactive experience. Using MathMythosAR2, we explored the relationship between the game's fantasy settings, players' fantasy state, player experience, and motivation. Using Schwartz's (2006) definition of fantasy and realism, we designed two versions of the diegetic world: a fantasy setting that involves magic and monsters (Figure 5.2) and a real-life setting (Figure 5.3) that involves school activities and shopping. Users play the role of Rubin, the magician, in the fantasy setting or Robin, a student, in the real-life setting. The fantasy version is designed to take players to a monster-fighting fictitious world where they may escape the boredom of repeated mathematics practice. The real-life version is then intended to bring individuals to delightful times of festival celebration and preparation in their regular life.

5.3.2. The Gameplay of MathMythosAR2

Children are introduced to math magic in the fantasy setting, a magic power inside magic stones with different power values. The magic power is triggered by summing up the power of two stones. Playing the role of Rubin, children are first introduced to math magic by their magic teacher Steven and subsequently join in defeating monsters that destroy the local town's peacefulness. In this version, calculating the total sum of gems with different power levels will trigger a magic effect, i.e., math magic.

Figure 5.2. The fantasy version of MathMythosAR2 (the numbers represent the game scene's sequence)

In the real-life setting, playing as Robin, players acquire math knowledge from their math teacher Steven, who calculates the total price of fruits. In this version, students calculate the sum of the grocery costs using math knowledge. Then Steven will guide players to go shopping for festival supplies, where children practice their calculation abilities, summing up the shopping expenses to receive festival items.

Both versions retain the same mechanics and apply the same interactions in their respective storylines. The player's journey was designed to incrementally increase the complexity, following flow theory (Nakamura & Csikszentmihalyi, 2009). Children will first be guided to scan the pattern to open the main character's eyes (Figure 5.2, game chapter 1), then navigated to respond to the teacher (Figure 5.2, game chapter 2), Steven, using a virtual button. In the fantasy setting, Steven will ask players to add up magic power using mathematical calculations and then hit the virtual button (Figure 5.2, game chapter 3). In the real-life setting, the teacher, Steven, will ask players to summate the groceries' total price (Figure 5.3, game chapter 3). After that, players will engage in the game's main tasks, i.e., beat up monsters in the fantasy condition (Figure 5.2, game chapter 4 –5) or prepare for the class party in the real-life condition (Figure 5.3, game chapter 4 –5) using cards they have received and knowledge they have learned on the previous pages.

Figure 5.3. The real-life version of MathMythosAR2 (the numbers represent the game scene's sequence)

5.4. Experiment Design

5.4.1. Measurement

The Player Experience of Need Satisfaction (PENS) scale (Rigby & Ryan, 2007) and the Intrinsic Motivation Inventory (IMI) (McAuley et al., 1989) were employed to measure player experience in this research. Because the IMI and PENS include various dimensions with numerous questions, and children lose patience while answering too many questions (Scott, 2000), we excluded competence, relatedness, and intuitive control, from PENS and effort, tension, and competence, from IMI. We selected the autonomy and presence subscales from PENS because these scales provide the strongest indication of the player being engrossed by fantasy. All questions from the Fantasy State Scale (Choi et al., 2013) were included to measure children's mental states of fantasy expressed in identification, imagination, analogy, and satisfaction.

However, PENS and IMI are not explicitly targeted at children. Previous work suggests that some children have difficulties understanding abstract concepts, depending on their cognitive development and language ability (Scott, 2000). Li and colleagues (2019) found that children often give overly positive or negative answers because they struggle to express their feelings or understand emotions through written words. Some children also found the "neutral" option hard to understand. Therefore, Li and colleagues (2019) developed a 4-point animated smiley scale for the PENS and IMI questionnaires (Figure 5.4). In our work, we adapted their animated scale and simplified sentences that we deemed to be too complicated for children to understand. To ensure the accuracy and readability of the translated questionnaire for children, five design researchers and two primary school language teachers reviewed our version of the questionnaire.

Figure 5.4. The 4-points animated smiley scale questionnaire was based on PENS and IMI. Participants received the Chinese version (English text was added in red for English readers)

5.4.2. Participants and Procedure

The study was conducted in a classroom in an after-school tutoring institution in Qingdao, Shandong Province, China (Figure 5.5). 31 Children were invited to participate in the study (of whom 18 self-identified as male and 13 as female), with an average age of 9 (seven years old = 1, eight years old = 9, nine years old = 8, ten years old = 9, eleven years old = 4).

Two Huawei Mate 30 cellphones running Android, two Lenovo ThinkBook computers with Windows 10, and two storybooks (the fantasy and the real-life version) were set up on the gameplay table. Additionally, we set up a GoPro Hero 9 to record behavioral data. Informed consent was obtained before the experiment from both parents and children. Demographic data was collected via a questionnaire—participants were encouraged to use nicknames to keep their demographic information anonymous. Ethical approval was obtained from the Eindhoven University of Technology's Ethical Review Board with the approval number ERB2020ID165.

The procedure of the study started with a tutorial to explain the interactions. We prepared the tutorial with only text and a blank sphere to allow children to get used to interactions such as image target tracking and virtual button holding in AR. After finishing the tutorial, they were invited to play either the fantasy or the real-life version of MathMythosAR2. After playing one version, they were asked to fill in the questionnaire and repeat the procedure with the other version. The versions were offered in a counterbalanced manner to mitigate sequence effects. All questions in the questionnaire were presented in a random sequence.

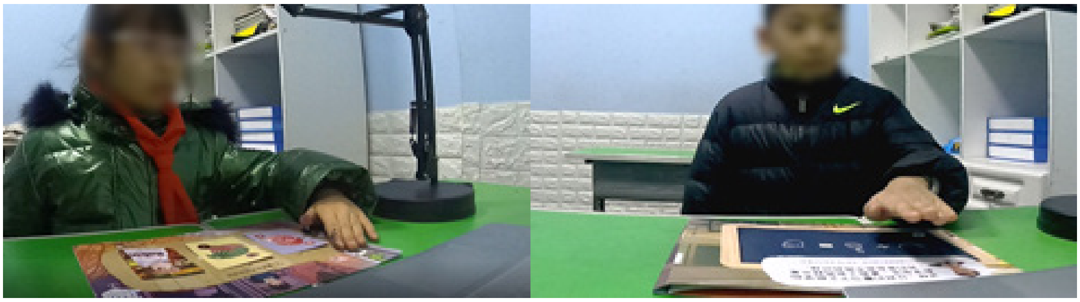


Figure 5.5. Children interact with the storybook using virtual buttons and target tracking.

5.4.3. Reliability

Cronbach's alpha of most questionnaires is within an acceptable range (0.6-0.8), except fantasy satisfaction = 0.5, real-life satisfaction = 0.6, and real-life enjoyment = 0.5. Removing reversed items, Cronbach's alpha increases: fantasy enjoyment = 0.8, real-life enjoyment = 0.7; fantasy presence = 0.8, and real-life presence = 0.8. The interpretation of reversed items was likely challenging for our participants, considering their age (8-12) (Li et al., 2019). Therefore, we exclude fantasy satisfaction in all further analyses and remove reversed items when calculating mean values.

5.5. Results

5.5.1. Normality

Since our sample size (N = 31) is near the boundary where data tends toward a normal distribution in accordance with the central limit theorem, which demands sample sizes greater than 30 or 40 (Ghasemi & Zahediasl, 2012), we computed a normality test.

The results indicate non-normality for all the data collected ($p < 0.05$). Therefore, non-parametric statistics have been applied in the analyses of comparisons and correlations. For the within-group comparison, the Wilcoxon S-R test was conducted. For between-group tests like gender differences, the Mann-Whitney U test was applied.

5.5.2. Fantasy Narrative vs. Real-life Narrative

To answer RQ1: "How do two AR fantasy settings (fantasy /real-life) in games influence the general experience?" we conducted a comparison between fantasy and real-life conditions. A Wilcoxon Signed-Ranks test indicated that the imagination brought on by the fantasy version (mean rank = 11.06) of MathMythosAR2 is significantly higher than in the real-life version (mean rank = 7.33), $Z = -3.12$, $p = 0.002$. The experience of presence in the fantasy version (mean rank = 9.15) is significantly stronger than in the real-life version (mean rank = 8.50), $Z = -2.00$, $p = 0.042$. The identification score in the fantasy version (mean rank = 9.08) is higher than in the real-life version (mean rank = 8.75), $Z = -2.00$, $p = 0.046$. No significant difference is found in the two versions' autonomy, enjoyment, analogy, and satisfaction scores. In general, players perceive higher presence, fantasy states of imagination, and identification when playing the fantasy version of the game (Table 5.1).

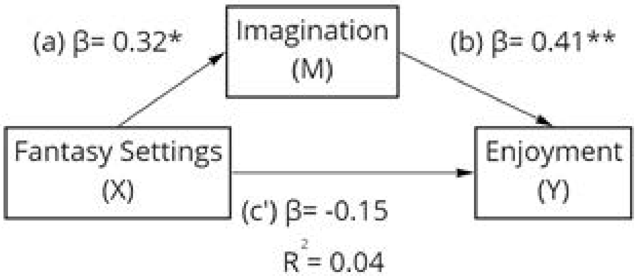
Table 5.1. Descriptive statistics of identification, analogy, imagination (FSS), autonomy, presence (PENS), and enjoyment (IMI) in fantasy narrative and real-life narrative conditions.

	Identification	Analogy	Imagination	Autonomy	Presence	Enjoyment
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Fantasy	3.65 (0.45)	3.43 (0.6)	3.48 (0.58)	3.66 (0.44)	3.50 (0.35)	3.63 (0.49)
Real-life	3.44 (0.63)	3.46 (0.59)	3.16 (0.60)	3.52 (0.58)	3.42 (0.45)	3.63 (0.44)

5.5.3. Mediation

We performed a mediation analyses to investigate RQ2: "What are the mediation effects of fantasy states on the relationship between fantasy settings and enjoyment?". Mediation is a complex regression procedure. A simple mediation model explains how the independent variable X influences the dependent variable Y by mediating variable M (Field, 2017; Hayes, 2017). The path from X to Y (c') is called the direct effect. The pathway from X to Y through M (ab) is called the indirect effect. The total effect is the sum of the direct and indirect effects. In this research, we use the bootstrap method with 5000 samples. As bootstrap is a distribution-free method, it applies to non-normally distributed data (Ng & Lin, 2016). If the bootstrapped confidence interval does not straddle 0, the statistically significant indirect effect is validated, and the mediation model is significant

(Field, 2017; Hayes, 2017). The result is presented in the diagram indicating the mediational relationship and the beta weight on each path. The total effect's R square is reported below the diagram. (Birk et al., 2015)



1 *p<.05; **p<.01.

Figure 5.6. The mediation model uses imagination as the mediator (M), and enjoyment as the outcome (Y), controlling gender

Table 5.2. The effect, standard error, upper and lower limits of 95% confidence intervals of Bootstrapping (5000 samples) results for enjoyment, mediated by imagination

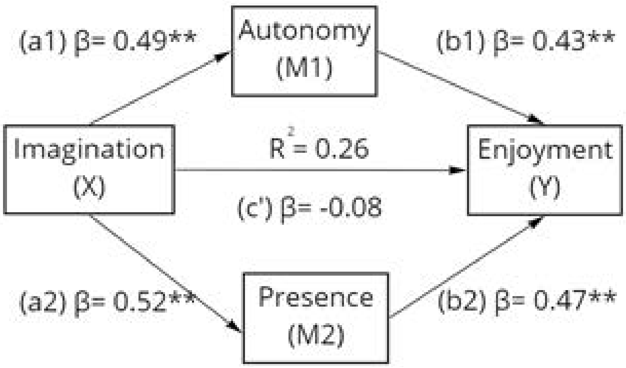
	Effect	SE	BootLLCI	BootULCI
Indirect Effect	0.13	0.075	0.24	0.33
Direct Effect	-0.15	0.11	-0.36	0.07
Total Effect	-0.02	0.12	-0.25	0.22

Figure 5.6 and Table 5.2 show the mediated regression with setting as the predictor (X), imagination as the mediator (M), and enjoyment as the outcome (Y).

Imagination as the mediator brings significant indirect effects to enjoyment (their bootstrapped confidence intervals exclude zero). There is no significant direct effect between X and Y in the model (their bootstrapped confidence intervals include zero). This mediation is valid because current mediation practice no longer requires a precondition of the relationship between X and Y (Hayes, 2017). When the relationship between X and Y entirely accounts for M, it is often interpreted as a full (complete) mediation.

The direct effect value of the enjoyment model indicates there is a negative but not statistically significant direct effect of the game's narrative setting. Mediated by imagination, the indirect effect leading to enjoyment becomes significantly positive. The opposite signs before the value of the model's direct and indirect effects make these three models inconsistent mediations (Blalock, 1969; MacKinnon et al., 2007). The resulting total effect is insignificant because the total effect is the sum of direct and indirect effects. In this case, the mediation model

can be accepted (Baron & Kenny, 1986).
After identifying imagination as the key in the relation between conditions and enjoyment, we were curious to see if player experience plays a role in the relationship between imagination and enjoyment. Therefore, we present a mediation analyses (Figure5.7, Table. 5.3) to answer RQ3—"What are the mediation effects of the player experience of need satisfaction on the relationship between fantasy states and motivation?"



1 *p<.05; **p<.01.
Figure 5.7. The Mediation model uses imagination as the Predictor (X), autonomy (M1), and presence (M2) as the mediators, and enjoyment as the outcome (Y), controlling for gender

Table 5.3. The effect, standard error, upper and lower limits of 95% confidence intervals of Bootstrapping (5000 samples) results for enjoyment, mediated by imagination

	Effect	SE	BootLLCI	BootULCI
Indirect Effect (Total)	0.45	0.12	0.23	0.69
Indirect Effect (Presence)	0.24	0.10	0.07	0.48
Indirect Effect (Autonomy)	0.21	0.07	0.09	0.36
Direct Effect	-0.08	0.11	-0.28	0.12
Total Effect	0. 37	0.12	0.20	0.55

Figure 5.7 and Table 5.3 indicate a significant mediation effect while setting autonomy and presence aspects of players' need satisfaction as mediators between the relationship of imagination and enjoyment.

5.6. Discussion

We present two mediation models to investigate the relationships between fantasy states (analogy, imagination, identification), player experience (autonomy, presence), intrinsic motivation (enjoyment), and the two conditions (real-life and fantasy). The models demonstrated that imagination acts as a mediator between fantasy settings and enjoyment; autonomy and presence act as mediators between imagination and enjoyment. This section interprets the findings and explores answers to the research questions, laying the groundwork for synthesizing design strategies for employing AR fantasy in game-based learning.

5.6.1. How do different AR fantasy settings in games influence the general experience?

The Wilcoxon Signed-Ranks test shows players perceived significantly stronger imagination, presence, and identification in the fantasy narratives. The result of higher imagination scores under a fantasy narrative meets our expectations. This result suggests that designing a fantasy game world with events that deviate from real-world settings can trigger players' imagination in serious gameplay. Participants' presence and identification scores are significantly higher in the fantasy context and could be attributed to both the effect of fantasy (Malone & Lepper, 1987) and AR (Wu et al., 2013). In alignment with previous research, fantasy avatars and stories provide imaginary characters that allow players to identify themselves with, fulfilling their emotional needs (Choi et al., 2013). This result suggests an integration of AR and fantasy can maximize both affordances and enhance players' immersive experience more than a real-life setting in game-based learning.

5.6.2. What are the mediation effects of imagination and identification on the relationship between fantasy settings and enjoyment?

We found differences in scores of imagination and identification but no difference in enjoyment between conditions, which leads us to explore any mediated effect between the game's fantasy settings and the player's enjoyment. The results show that only imagination mediated the relationship between game conditions and enjoyment. Although previous research suggests that identification is central to motivation (Birk et al., 2016), our result indicates that the richness of the imaginative fantasy scenario adds to the experience. Our result suggests that designing for imagination advances experience beyond analogy and identification. Examples can be found in commercial games, e.g., even if players do not identify with fictional characters like Geralt of Rivia from "The Witcher" or Link from "The Legend of Zelda," these games can still provide joyful and immersive environments that stimulate their fantasy.

5.6.3. What are the mediation effects of need satisfaction on the relationship between fantasy states and motivation?

We found autonomy and presence as two aspects of need satisfaction mediating between fantasy and motivation. Autonomy's mediating role in the model emphasizes imagination with fantasy enabling players to approach AR game-based learning more as gameplay rather than a learning tool. Our findings imply that even though the game interaction remains unchanged, game storylines that elicit greater imagination can help players feel more autonomous, allowing them to enjoy AR game-based learning more. Related back to Ryan and colleagues 's (2006) finding that intuitive control increases users' autonomy, users' autonomy, in turn, predicts their enjoyment of games. We recommend designing fantasy environments with open thinking, choice, options, and opportunities that stimulate imagination in game-based learning.

Additionally, the experience of feeling present in the fantasy in game-based learning is also a fundamental bridge to motivational learning. AR technology combines an imaginary world with the real world, creating a feeling of presence and being placed within a mixed reality (Tobar-Muñoz et al., 2017). Employing fantasy that stimulates players' imagination in AR creates an immersive experience that makes learning more enjoyable and motivating to players. Stapleton and colleagues (2003) define the immersive effect of fantasy and AR as a Mixed Fantasy Continuum. Following Stapleton, our findings support that imagination is the key to motivational gameplay. We assume that because fantasy enables players to experience more presence, fantasy-enhanced game-based learning will be experienced as more enjoyable.

5.6.4. Individual Preference for Fantasy

We noticed gender differences in our study: participants identifying as male scored significantly higher in autonomy $t(29)=2.56$, $p=0.02$, identification $t(18.95)2.77=$, $p=0.01$, and analogy $t(29)=2.29$, $p=0.03$, but only in the fantasy condition. While we aimed to eliminate gender effects by designing gender-ambiguous character conditions (keep in mind that Robin and Rubin are not gendered in Chinese), children might still have perceived the role of Rubin in the fantasy setting as more boyish than Robin in the real-life setting. Another explanation could be that boys are more frequently exposed to fantasy game contexts than girls (Greenberg et al., 2010). Boys seem to perceive such types of fantasy as familiar, which might make it easier for boys to enter a paratelic (playful) mindset and subsequently rate their perceived autonomy higher. Children's preference for fantasy settings in games is often regarded as a choice predicated on their fantasy proneness (Merckelbach et al., 2001) and fantasy orientation (Barber et al., 2013).

5.6.5. General Descriptive Data

The general descriptive data (Table 5.1) shows that children enjoy playing with both settings of MathMythosAR2. Their high level of presence shows that Augmented Reality can foster enjoyment. Their elevated autonomy and enjoyment scores across both conditions suggest that the AR game is being regarded as a play activity capable of successfully engaging children in math learning. Although a pretest version without AR is not applied as a comparison group in our research, we find in previous work that virtual environments like AR can increase users' presence (Milgram et al., 1995). Since AR's novelty can be a vital factor here, for those who have never experienced AR, comparing fantasy and real-life settings in our game may be less impactful than the technology itself.

5.7. Limitation and Future Work

There are a few limitations to the experimental setup. Children, in general, give overly optimistic results, potentially because children find understanding neutral emotions challenging and tend to give extreme answers (Li et al., 2019). Additionally, some children may respond to meet what they think is the experimenter's expectation to achieve recognition from adults (Anderson et al., 1976). Although we apply an animated scale to reduce children's burden on understanding the questionnaire, they still appear to have difficulty understanding reversed questions. A pre-instruction of the Likert scale and reversed questions for child participants might be needed for young participants in future research. We provide a magic school life and a real-life school life of narrative contexts in our designed game. More types of fantasy remain to be explored.

The purpose of our study was to investigate the interplay of autonomy and presence and their relationship with fantasy states and enjoyment. Therefore, exploring other associations, such as the influence of competence on fantasy experience and enjoyment, would require a different focus in the study design and data collection, e.g., through investigating a competitive game.

There are more profound and complex implications to be explored in future work. The learning outcomes were not our prime focus in this research, but the effect of AR fantasy on learning, e.g., cognitive skills and working memory, is worthy of exploration. There are three promising directions for our future research: (1) the after-play effect of AR fantasy in game-based learning; (2) the application of narrative choice and fantasy customization in AR serious games; and (3) the educational benefits of fantasy and imagination.

5.8. Conclusion

Our work aims to understand the influence of fantasy elements on children's serious gameplay experience through MathMythosAR2. We found that fantasy contexts stimulate a significantly higher imagination, presence, and identification in children. Their imagination plays an essential role in bridging the fantasy context to enjoyable AR game-based learning experiences. An AR fantasy context creates an AR fantasy where imagination is a crucial bridge to transgress the liminal interface between the real world and the game world, between playing and learning. It is also notable that children's autonomy and presence are critical mediators between their imagination and enjoyment. Based on these findings, the following suggestions are concluded from the previous discussion for serious game designers to consider when designing for children in a classroom setting: 1) the design of fantasy elements in an AR game should stimulate players' abilities to imagine; 2) the design integration of fantasy should stimulate creating imaginary realms over how players identify with the game; 3) providing a fantasy context with openness and creativity, immersion, and AR fantasy can enable players to enjoy game-based learning through imagination towards fantasy; and finally, 4) according to various individual preference, fantasy characters and storylines can be tailored to specific gender groupings or personal tastes.

This page intentionally left blank

Study 3*

The effect of fantasy on learning and recall of declarative knowledge in AR game-based learning

*This Chapter is partially based on Zuo, T., Spek, E. D., Birk, M. V., & Hu, J. (2021, November). An introduction to chemikami ar. In International Conference on Entertainment Computing (pp. 521-526). Springer, Cham;
The effect of fantasy on learning and recall of declarative knowledge in AR game-based learning (review pending.)

Chapter 6


Hey Jeremy. What took you so long?
Nothing important. Ms Jan asked a few questions about games.
Oh really, I thought Jan had some problems with your chemistry exam result.
Ugh... About chemistry. I did fail the exam....
F
PERIODIC TABLE OF ELEMENTS
You know, I pulled an all-nighter for this test...Maybe I just have a hopelessly poor memory
No, you do not. You can remember tons of heroes in the game you keep talking about...
Dota 2?
Yeah, you are right. I know all the 123 heroes including their builds, skills, background stories and lines.
That many?

With increasing research attention on the application of Augmented Reality (AR) and Game elements in education, fantasy elements as imaginary, fictional game features have been shown to improve learners' motivation and are critical to engaging and immersive experiences in AR game-based learning. With its affordance of enriching real-life education with virtual effects, AR game-based learning has shown its potential to improve recall performance in previous research. However, educators and researchers have concerns regarding the effect of employing fantasy game elements in AR game-based learning, suggesting learning with such elements will add cognitive load for children leading to a lower recall. To explore the effect of AR and fantasy in game-based learning for recalling declarative knowledge, we conducted an experiment involving 98 child participants and 26 adult participants from the Netherlands and China, using our own designed AR game- ChemiKami AR. We used a mixed ANOVA to identify the effect of fantasy and AR on knowledge recall. This study showed that using AR fantasy in game-based learning can improve recall of declarative knowledge and increase learning effectiveness in classroom learning contexts for children. We offer insights and guidelines for designing AR and fantasy experiences that enhance declarative knowledge recall for target groups with different ages, learning capacities, and cultural backgrounds.

6.1. Introduction

Augmented reality (AR) for learning promises to improve the recall of information because of AR's potential to enhance narrative experiences (Lim & Lim, 2020) and enrich the visual qualities of interactions (Sotiriou & Bogner, 2008), which leads to better recall (Vincenzi et al., 2003). The recall of declarative knowledge, knowledge of rules that learners can verbalize and apply, is an essential indicator of effective learning (Van Abswoude et al., 2019). The effect of AR-based learning has, for example, been investigated on recalling historical information (Lim & Lim, 2020), spatial navigation (Kaufmann et al., 2005), and rehearsal tasks in academic recall (Chen Chen et al., 2019).

The presentation mode of AR content ranges from practical enrichment of physical contexts, such as text overlays or placement of virtual objects in physical environments (Yuen et al., 2011), to fantastical scenarios featuring virtual factors and colorful scenarios of live interaction with digital representations and their environments. The range of presentation types raises the question: which presentation can encourage learners to recall more?

Educators show concerns that fantasy and playfulness in learning might be irrelevant, diverting too much attention (Rosenfeld et al., 1982), adding too much cognitive load for children (Ang et al., 2007), and, as a result, rendering AR learning ineffective (Lee, 2015). However, children may appreciate fantasy, unreal and fictitious settings such as magical stories in game-based learning because fantasy avatars may correspond to their wishful identification (Klimmt et al., 2010; van Looy et al., 2010), and fantasy narratives may allow them to immerse themselves in learning in contrast to working through a learning tool (van der Spek et al., 2014).

While the use of AR to improve knowledge recall for children seems a promising area of research, educators' concerns are justified and require careful investigation, considering that research has not provided conclusive evidence addressing the effect of using AR and fantasy to enhance the effect of declarative knowledge learning and recall. Previous work has shown that the game genre in game-based learning determines the learning effect (Clarke et al., 2015; Garris et al., 2002; Ladley, 2010; Novak, 2012). Working memory, a cognitive process of storing and operating information temporarily, involves the system that processes visual-spatial, sound, and episodic information (Baddeley & Hitch, 1974). Working memory is one of the determining factors of effective learning (Jarvis & Gathercole, 2003). The application of AR is promising for a more effective recall of information by elaborating to-be-learned material that enables multi-modal sensory, including visual, verbal, proprioceptive, and tactile memory (Vincenzi et al., 2003).

To gain better insights into the effect of fantasy-enhanced AR on the effect of learning and recall, we designed ChemiKami AR—a card-based AR game to help beginners memorize chemical elements. To investigate the effect of fantasy in AR game-based learning on learning and recall of chemical elements, we conducted experiments with 124 participants from three locations, Jan van Brabant College in Helmond, the Netherlands, International School Eindhoven, in the Netherlands, and Changzhou in China. All participants played the game in AR and Non-AR, while we varied the setting (fantasy, real-life) of recalling chemic elements between subjects.

Our research aims to support designers with practical guidelines for incorporating AR and fantasy in game-based learning and inspire learners and educators with contemporary instructional approaches to achieve their learning goals.

6.2. Related Work

6.2.1. AR for Education: Benefits and Challenges

The application of Augmented Reality (AR), a technology that blends the virtual with the physical, in education has been shown to improve learning motivation and engagement (Pellas et al., 2019) and create a more immersive and pervasive gaming experience (Klopfer & Yoon, 2005). AR provides context-aware learning situations in real environments (T. Liu, 2009). It allows participants to perceive complicated spatial connections and the unobservable in real-life settings to comprehend better abstract ideas (Arvanitis et al., 2009) and can potentially improve recall by facilitating the integration of information (Vincenzi et al., 2003). Despite the educational advantages of AR, designers should be aware of technical and pedagogical challenges while designing AR for education (Wu et al., 2013). According to Squire & Jan (2007) 's study, when adequate instruction or guidance for gameplay is absent, students' comprehension of information flow towards devices and the natural world is challenging. When learners have to process too much information from both worlds, facing new technology and unfamiliar settings and tasks simultaneously, the mix of real-world problems and virtual fantasy may be confusing (Dunleavy et al., 2009).

6.2.2. Fantasy in Game-Based Learning

Although designing AR game-based learning faces several challenges, it is promising if game-based learning can stimulate children's inherent need for fun and satisfaction, which enables their intrinsic motivation to learn (Li et al., 2019). Fantasy as a game element represents narrative, visual, or interactive styles that do not exist in the real world (Malone, 1981; Zuo et al., 2019). Endogenous fantasy, the integration of educational content into fantasy integrally and continuously, can intrinsically motivate learners (Malone & Lepper, 1987). Research by Stapleton and colleagues (2002) shows that mixed reality technology like AR and VR can facilitate the suspension of disbelief and engage participants in a rich fantasy experience. They constructed a mixed fantasy continuum for compelling entertainment experiences with mixed reality and fantasy (Figure 6.2).

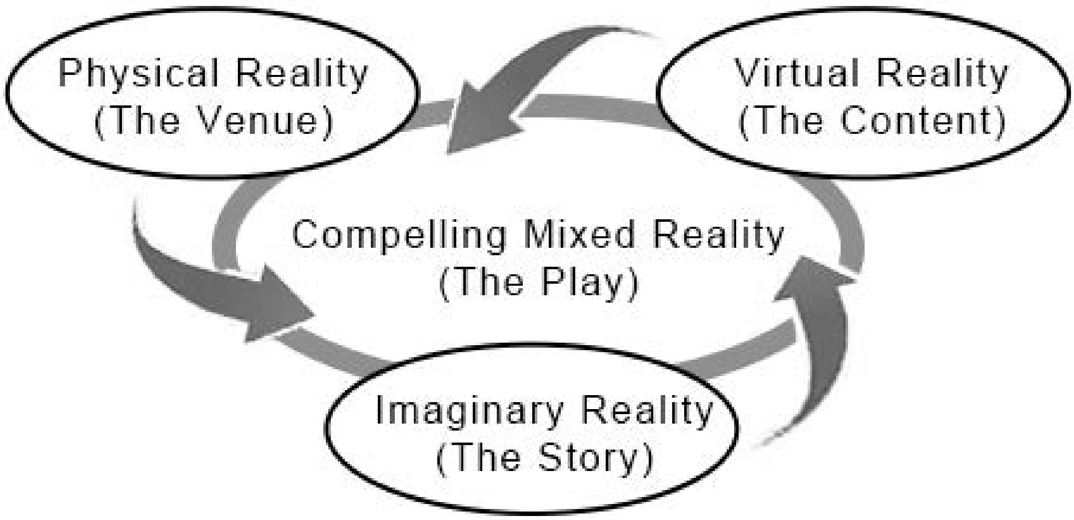


Figure 6.2: Mixed-fantasy continuum (Stapleton et al., 2002)

Figure 6.1: The animation "Cells at work!" (left) (Cells at Work Official Website, 2022) and "Once Upon a Time…. Life" (right) (Once Upon a Time...Life Official Website, 2022) that employs anthropomorphism toward cells and organs in human bodies

Anthropomorphism is one way of intrinsically (or endogenously) integrating fantasy (Malone & Lepper, 1987). Anthropomorphism, introducing non-human entities with human traits, has been shown to enhance people's memory of events (Baker et al., 2018). Anthropomorphism in literature enables young readers to identify with the character, opening a portal for them to enter the enjoyable world of fantasy (Kellogg et al., 1975). Animation for education also frequently takes the feature of anthropomorphism. For example, "Cells at Work!" and "Once Upon a Time... Life" are two animations that describe human body systems and defensive mechanisms via the stories of various characters that represent different cells or organs in human bodies (Figure 6.1).

However, as previously stated, designers and educators face the challenge of giving appropriate and suitable guidance for users to approach AR games that facilitate effective learning. Participants need easy-to-use and easy-to-understand interaction contexts with blended virtual fantasy and real-world scenarios. Designers should understand if incorporating fantasy content with AR in learning benefits learning effects or not. Declarative knowledge recall throughout the learning process is an essential indicator of effective learning.

6.2.3. The Role of Working Memory in Education

Working memory refers to a cognitive process of storing and operating information temporarily (Baddeley & Hitch, 1974). In working memory, the storage of declarative knowledge, such as conceptual, propositional, or descriptive knowledge, serves as the foundation of the learning process (Ten Berge & Van Hezewijk, 1999). An Individual's working memory capacity, the ability to hold information, is relatively constant, usually ranging from 3 to 5 items (Nelson, 2010). With such capacity unchanged, extra information around the essential data to be stored can help individuals compress and memorize information more effectively (Brady et al., 2009). In other words, well-designed contexts where learners encode and retrieve information can benefit learners with more recall by putting in the same amount of effort. For example, with the effect of positional specificity, learners can improve their performance of recall. Positional specificity is the recognition of specific spatial or visual patterns associated with which the information was first presented. Besides visuals, other sensational effects could also facilitate the function of working memory.

Baddeley & Hitch (1974) developed a multicomponent working memory model consisting of the phonological loop, visuospatial sketchpad, and episodic buffer. The phonological loop, which refers to the temporary storage of sound, is a rehearsal process that is constantly refreshing to prevent its decay (Baddeley & Hitch, 2019). The visuospatial sketchpad stores the image and spatial information. Research suggests that high-imageability words are easier to remember than abstract words (Baddeley & Lewis, 2017). The episodic buffer temporarily stores source information coded into a coherent episodic representation (Baddeley, 2000) (Figure 6.3).

The procedure of information integration can also be facilitated through AR. Previous research suggests participants are more effective at recall because AR enables multi-modal sensory elaboration, including visual, visuospatial, verbal proprioceptive, and tactile memory (Vincenzi et al., 2003). With the potential association between the multi-modal sensory elaboration enabled by AR and the working memory's multicomponent, we are curious about the representation we can design with AR. We wanted to investigate whether AR fantasy in game-based learning can improve declarative knowledge recall.

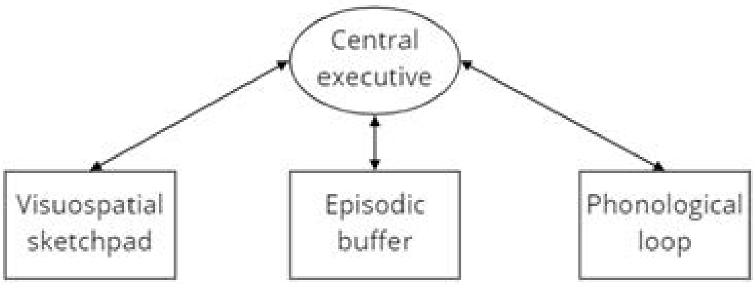


Figure 6.3: The multicomponent working memory model (Baddeley, 2000)

To explore the effect of fantasy in AR game-based learning on declarative knowledge learning and recall, we conducted a quasi-experiment where we compared three conditions: AR real-life content, AR fantasy content, and a non-AR version as the baseline. We are interested in four research questions:

•RQ1. Is AR with fantasy more effective at improving recall than AR with real-life content?
•RQ2. How do participants perform with AR in comparison to their recall without AR?
•RQ3. After playing with AR, will the recall of the augmented content be activated by content on cards?
•RQ4. Do age groups, genders, and locations associate with any difference in the recall?

To answer the research questions, we designed an AR-based learning game, ChemiKami AR, and implemented the experiment settings around the game.

6.3. Design of ChemiKami AR

Innovation	Portrayal	Warlock
Elements	Mechanics	Card Game
	Story	Magic Items/ Events
	Aesthetic	Carton/ Magic Sound Effect
	Technology	Augmented Reality
Genre	Story	Narratology
Adaption	Instruction	Endogenous Fantasy

Figure 6.4: The design choice made in ChemiKami AR with corresponding fantasy classification (fantasy in artifacts).

ChemiKami AR is an Augmented Reality card game for children to learn chemical elements, developed using Unity 3D 2020.2.7F1 and the Vuforia Engine 9.7. With the support of Unity 3D and the Vuforia Engine, the app ChemiKami AR pre-installed on the phone can present a 3D overlay on the screen when a specific pattern is recognized through scanning via the phone's camera. We developed the game with more 3D interactive animations when two specific cards are scanned, using Unity 3D with C#. All the 3D models were created using Blender 2.83LTS and Vroid Studio v0.12. Adobe Photoshop and Illustrator were used to design 2D image targets for cards. There were two languages available: English and Chinese. An English teacher checked the phrasing in both languages. In addition, two designers have the gameplay interaction checked. A chemistry expert and a physical science expert also reviewed the game content.

We refer to the "classification of fantasy in serious games" discussed in Chapter 2 to make game design choices. In alignment with the previous studies, we employed the portrayal of innovation and retained elements of fantasy and strategies of an application similar to the previous design. Driven by the research focus of investigating the recall of declarative knowledge, we focus on designing different types of fantasy avatars (Figure 6.4). The game introduces participants to element cards, the cards about chemical elements, and application cards, the cards about elements' applications. Both types of cards can be scanned separately or simultaneously with the phone, displaying an overlay with 3D animations. The application card depicts a real-life circumstance requiring using one of the chemical elements.

In chemistry, an element is a pure substance of identical atoms. Atoms are too small to be seen with our eyes (Craig Freudenrich, 2022). Therefore, students usually know the visual shapes of an element by the compounds or monomers it composes, which come in various forms (Gray, 2012). For example, there are multiple isomers from the element carbon, with numerous looks, including diamonds, graphite, and more (Pierson, 2012). The uncertainty of elements' visual representations confuses beginners because there is no visual representation they can refer to when encoding information in their memory process. The absence of representative visual, audio, or story that helps beginners' memorization makes it valuable to design a fantasy avatar representing each chemical element. For example, we designed a character that represents the element Fluorine (Figure 6.5, left). We are curious whether fantasy can aid in learning and recalling chemical elements and their applications. We designed a real-life setting for the control group, in which elements are represented by one of the shapes of their monomers. For example, Fluorine's monomers are light yellow liquid at extremely low temperatures (Figure 6.5, middle). The models' shapes and textures in the real-life group are drawn from the book "The Elements: A Visual Exploration of Every Known Atom in the Universe" by Nick Mann and Theodore Gray (2012).

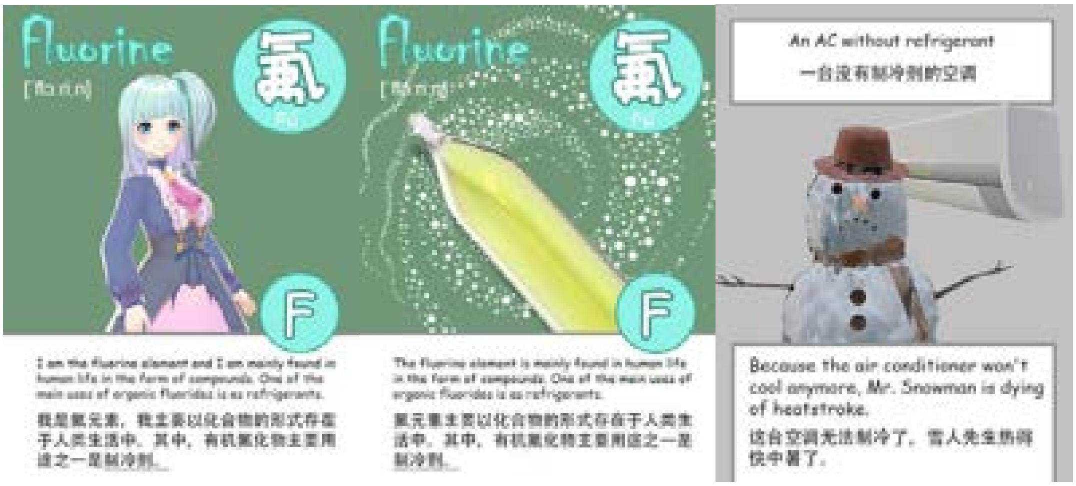


Figure 6.5: The fantasy element card Fluorine (left); The real-life element card Fluorine (middle); The corresponding application card to Fluorine (right).

The interaction of the game in the two conditions is similar. In the fantasy condition, when participants scan an element card, they see an augmented overlay of a 3D avatar that introduces itself as an anthropomorphic embodiment of the chemical element. In the real-life condition, when scanning an element card, participants view a 3D representation of the relevant element's monomer while listening to the element's introduction from a background voice on their phones (Figure 6.6) which is also shown as text on the cards. Participants in either group need to locate the element's associated application from a stack of application cards, e.g., the participant pairs the element Fluorine with its application (Figure 6.7). A correctly paired scanning triggers animation and completion of the tasks on the application card, while wrongly paired cards trigger no effect. In the case of Fluorine (Figure 6.6), the snowman stops melting because the air conditioner is functioning when the refrigerant consisting of the element fluorine is added. There are ten game tasks, which include, for example, helping a flat balloon fly with Helium, helping a dizzy fish with oxygen, and more.

Figure 6.6: Scanning an element card and looking for its application card in the real-life condition

Figure 6.7: Correctly paired scanning of Fluorine and its application in the AR fantasy condition.

We created the game with ten chemical elements to test the maximum number of chemical elements that can be memorized, as people's working memory capacities usually range from 3 to 5 items (Nelson, 2010). We also created a baseline set of non-AR cards with ten different sets of elements and associated applications (Figure 6.8) to test learners' recall of traditional learning materials without AR and fantasy. Since the baseline was set up to emulate the traditional instruction context, we designed real-life photographs similar to figures from chemistry textbooks. The task stays the same in the baseline setting: identifying a corresponding correct pair for each element card. Participants can see the correct answer from the slides to identify if they are correct.

Figure 6.8: Card pairing in the non-AR baseline condition.

6.4. The Experiment Settings

Table 6.1: The experiment settings

	Between subject factor	
Within-subject factor	AR Fantasy	AR Ordinary
	Baseline	Baseline

To study the effect of the fantasy setting [Fantasy, Real-life] and the interface setting [AR, Non-AR] (Table 1) on recall, participants played either a fantasy-enriched card game or a real-life card game, then did a knowledge test containing ten elements involved in the game. They were also invited to engage in a non-AR baseline version and finish a relevant knowledge test. The ten chemical elements used in the fantasy version were identical to those in the real-life version. Chemical elements in the within-subject interface setting [AR, Non-AR] comprised two different sets of 10 chemical elements to avoid memory effects (Field, 2017) affecting our results. The sequence effect was also mitigated through a counter-balanced gameplay sequence of the AR games and baseline. The randomization of questions that appeared in the knowledge test is also achieved through Tencent Questionnaire.

6.4.1. Participants and Procedures

A total of 124 participants participated in the experiment. Ninety-eight participants were children between 13 and 15 years old in our target age range, the appropriate age for students to start learning chemistry. Twenty-six participants were adults (between 18 to 84), with an average age of 45, who were not our main targets but could give extra insights into the effect on adolescents and adults. Adult data collection was not intended initially, but many parents of adolescent participants showed an interest in the card game and offered to participate. As a result, we obtained supplemental data from adults around middle age, which can be pilot research to further investigate designing fantasy for participants of different ages. This study was undertaken in two countries, the Netherlands and China, to see if cultural differences affect learning with AR and fantasy.

Our study in the Netherlands was conducted as a class activity for children at two different schools—the International School Eindhoven (ISE) and the Jan van Brabant college (JVB). ISE is an international school where we invited international students (N=66, 32 self-identified as female, 34 as male) from 4 classes with an average age of 13. JVB is a local school where we invited students (N=12, 9 of whom self-identified as female, 3 as male) at an average age of 14. Students from both schools had just started learning chemistry.

A second part of the study was conducted in Changzhou, China, with 20 children (average age = 13; 7 self-identified as female, 13 as male). We also conducted the study with 26 adults in Changzhou (average age 45; 19 self-identified as female, 7 as male). We allocated around half of the participants from each location to play the fantasy setting and the baseline interface and the other half to play AR real-life setting and the baseline interface. Due to the local COVID-19 policy in China, it is impossible to carry out the research as a class activity, with data collection covering a full classroom of participants at a time. The experiment was done individually in Changzhou, with data collected from one participant at a time. The consent of participants and their guardians was acquired in advance. The Eindhoven University of Technology ethics review board reviewed and approved the research procedure (ERB2020ID165).

Figure 6.9: The experiment set up in Changzhou (left), JVB (middle), and ISE (right)

We prepared 10 Samsung Galaxy S8 phones with Android systems for the study at JVB and ISE. Participants first marked the name of elements they already knew from a questionnaire and then started the gameplay. Participants received a set of cards and a phone (if needed) for each round of play and listened to an instruction on two types of cards and the steps of play. Each participant had 10 mins to play the set of the game they were assigned to. After 10 minutes, experiment assistants collected the participants' cards and devices. Then they asked participants to do the knowledge tests to answer ten single-choice questions, as mentioned in the measurement section, within 5 mins. We encouraged participants to use nicknames while collecting their demographic data to keep the data anonymous. Blanks were to be filled out to collect gender information. We labeled answers like woman, female, and girl as female and conducted the same coding for males for statistical convenience. Additionally, all participants were encouraged to leave comments about the version they played.

The study in Changzhou was conducted one by one. Due to local COVID-19 policy restrictions, we could not access local schools to organize similar class activities as in the Netherlands. All participants' data were gathered in separate rooms at their homes. We used the same android phone, Xiaomi Mix2, and the same sets of cards for every participant. All experiment steps and gameplay time limitations remained consistent with those applied as class activities in the Netherlands (Figure 6.9). Although we tried to control environmental variables, there were differences between a classroom setting and a private room setting. Therefore, we will reflect on the locations' differences and their potential effect in the later discussion.

6.4.2. Measurements

We prepared three sets of knowledge tests that assess participants' learning effectiveness. Since individuals were assigned to either AR fantasy or AR real-life conditions, each participant filled in only two sets of questions (one condition and one baseline). Each set contained ten single-choice questions regarding the ten elements they learned from the version they had just played.

To answer RQ3, "After playing with AR, will the recall of the augmented content be activated by content on cards?" We embedded the images they had seen from the element cards in the knowledge test questions. Each participant was randomly assigned five questions with pictures and the other five questions with only text. We compared results between the text questions and the picture questions to address RQ3. Examples of the text (Figure 6.10) and picture (Fantasy: Figure 6.11, Real-life: Figure 6.12) questions are presented below. A participant got one point for each correct response to a question and zero points for each wrong answer.

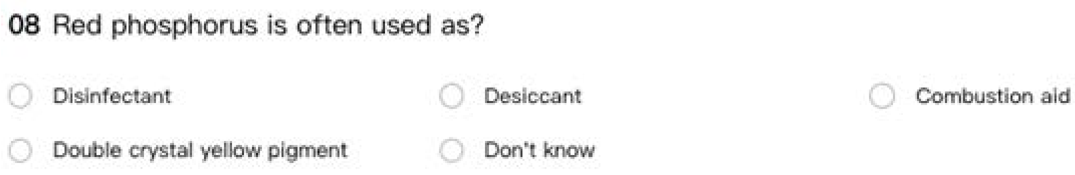


Figure 6.10. The text question about the element Phosphorus (which remains the same in the fantasy and the real-life condition)

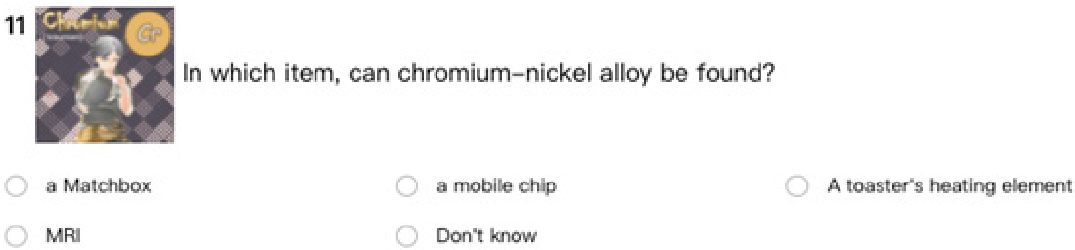


Figure 6.11. The picture question about the element Chromium (in the fantasy condition)

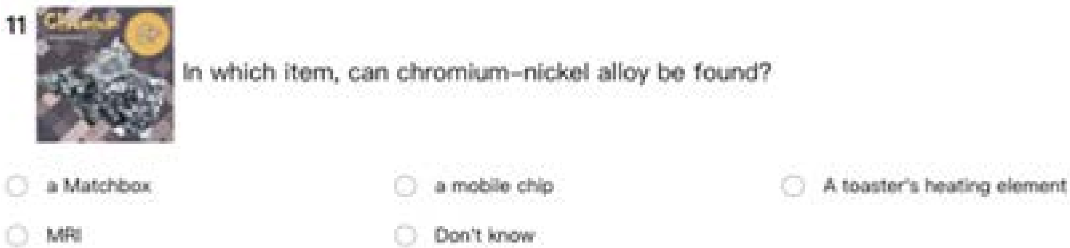


Figure 6.12. The picture question about the element Chromium (in the Real-life condition)

6.4.3. Data Analyses

We processed our data using SPSS25. Considering our target user groups were chemistry beginning learners, we excluded the data collected from the adult participants at the initial steps of answering RQ1, RQ2, and RQ3. Because we collected data from children at three different locations, we compared the knowledge about chemical elements prior to the study. Adults' recall data was only added to the analyses to compare age groups when addressing RQ4.

6.5. Results

To answer RQ1 and RQ2, we conducted a mixed ANOVA to test the difference in knowledge tests results, using the fantasy setting "Fantasy or Real-life" as the between-subject factor, the interface setting "AR or Baseline" as the within-subject factors, and the total scores and number (s) of known element(s) as the dependent factors.

Table 6.2: Descriptive data

DV	Interface	Fantasy Setting	Mean	Std. Deviation	N
Previous Knowledge	AR	Fantasy	4.04	2.369	53
		Real-life	4.31	2.391	45
		Total	4.16	2.371	98
	Baseline	Fantasy	4.19	2.466	53
		Real-life	4.04	2.383	45
		Total	4.12	2.417	98
Knowledge Test	AR	Fantasy	7.53	1.576	53
		Real-life	6.4	2.104	45
		Total	7.01	1.913	98
	Baseline	Fantasy	7.15	2.143	53
		Real-life	6.02	2.718	45
		Total	6.63	2.476	98

Table 6.3: Mixed two-way ANOVA with the fantasy setting (Fantasy/ Real-life) as between subject, the interface setting (AR /Non-AR) as the within-subject variable

DV	Source	SS	F	P
Prior Knowledge	Interface Setting	0.163	0.196	0.659
	Fantasy Setting	0.203	0.019	0.891
	Interface Setting * Fantasy Setting	2.122	2.553	0.113
Knowledge Test	Interface Setting	6.939	2.865	0.094
	Fantasy Setting	**61.988***	**9.082**	**0.003**
	Interface Setting * Fantasy Setting	2.14E-06	0	0.999

*DV= Dependent Variable, SS=Sum of Squares, *p<0.05

6.5.1. RQ1. Is AR with fantasy more effective at improving recall than AR with real-life content?

As indicated in Table 6.3, there was a significant main effect of the Fantasy setting “Fantasy or Real-life,” $F(1,96) = 9.08$, $p = 0.003$, $\eta p2=0.086$ on the knowledge test scores. The scores for the knowledge test in AR fantasy (M = 7.53, SD = 1.58, N = 53) and AR real-life (M = 6.4, SD = 2.10, N = 45) conditions were significantly different. These findings imply that the fantasy setting in AR game-based learning influences recall. Specifically, our findings indicate that AR fantasy is more successful in improving recall than the design with AR real-life elements. There was no significant effect from within-groups or between-group factors on the scores of prior knowledge tests, suggesting children participants had similar prior knowledge of chemical elements in different groups.

6.5.2. RQ2.How do participants perform with AR in comparison to their recall without AR?

As indicated in Table 6.3, the mixed-ANOVA showed a non-significant effect for the main effect of the Interface Setting ($p= 0.094$). No interaction effect ($p=0.999$) was found in the mixed two-way ANOVA test when analyzing with our target group ($N = 98$). The result suggested no difference in the effect of learning and recalling declarative knowledge between AR games and baseline.

6.5.3. RQ3. After playing with AR, will the recall of the augmented content be activated by content on cards?

To identify whether AR has an effect on activating the recall of the augmented content when participants see the card image alone, we compared participants' performance with picture questions to their performance with test questions in each game. The results indicated that with AR fantasy, participants scored better on image questions ($M = 4.06$, $SD = 0.989$) than on text questions ($M = 3.64$, $SD = 1.002$) ($t(52) = 2.59$, $p=0.012$), implying that AR fantasy potentially affected the recognition of memory. No such effect was found in AR real-life group. However, we observed that participants who participated in the real-life baseline group scored higher with image questions ($M = 3.36$, $SD = 1.50$) than answering test questions ($M = 2.82$, $SD = 1.50$); $t(44) = 2.67$, $p = 0.011$, suggesting real-life picture without AR can also help recall.

6.5.4. RQ4.Do age groups, genders, and locations associate with any difference in the recall?

Since this study was conducted across regions and with different age groups, we examined if the results varied according to participants' ages, genders, and cultural backgrounds. We included adults' data and extended the mixed ANOVA model originally constructed the interface setting with "AR or Baseline" as the within-subject component and the fantasy setting with "Fantasy or Real-life" as the between-subject factor, incorporating additional between-subject variables, including age groups, genders, and locations. The results suggested there was a significant effect of location, $F(2, 116) = 11.05$, $p = 0.000$, $\eta p2= 0.160$, a significant interaction effect of "Fantasy or Real-life" * "AR or Baseline" * location, $F(2, 116) = 3.21$, $p = 0.044$, $\eta p2=0.052$.

We found no significant effect by gender and age groups. However, we spotted a significant effect of the within-subject factor, the interface "AR or Baseline," $F(1, 116) = 10.51$, $p = 0.002$, $\eta p2=0.083$, suggesting that participants from all ages with

AR recall more than with their baseline, which was insignificant when analyzing children's data only. There was also a significant interaction effect of "Fantasy or Real-life" * "AR or Baseline" $F(1, 116) = 4.56$, $p = 0.035$, $\eta p2 = 0.038$. The between-subject factor "Fantasy or Real-life," which was significant in children's data, becomes insignificant when including adults' data.

To further investigate the effect of adults' on our study results, we applied Bonferroni-corrected pairwise comparisons. The result suggests that adults scored significantly higher with fantasy AR than with non-AR baseline (p=0.01). The results show no statistically significant differences between adults' recall with real-life AR and non-AR baseline and no statistically significant differences between their recall with fantasy AR and real-life AR.

Table 6.4: Descriptive data from different locations in the form of M (SD)

		ISE	JVB	Changzhou
Fantasy	AR	7.54 (1.72)	6.20 (1.10)	8.00 (1.00)
	Baseline	7.14 (1.93)	3.60 (1.67)	8.54 (1.05)
	n	35	5	13
Real-life	AR	6.23 (2.13)	5.43 (0.54)	8.14 (2.19)
	Baseline	5.68 (2.59)	5.71 (3.20)	7.86 (2.41)
	n	31	7	7

To further compare children's recall between different locations, we conducted a Bonferroni-adjusted pairwise comparison, excluding adults' data in the comparison. Pairwise comparisons suggested that participants from Changzhou scored significantly higher than participants from JVB in almost all cases (Fantasy condition, AR: p = 0.054, baseline: p = 0.000; Real-life condition, AR: p = 0.005). Additionally, in the Real-life condition, participants from Changzhou scored significantly higher than participants from ISE (AR: p = 0.011, baseline: p = 0.020). Participants from ISE scored significantly higher than participants from JVB in the baseline (p = 0.001).

In terms of the effect of our design on participants' recall, we found that JVB participants performed much better in AR fantasy than their baseline (p = 0.008). Participants from ISE scored significantly higher with AR fantasy than with AR Real-life (p = 0.003) (Fig 6.13).

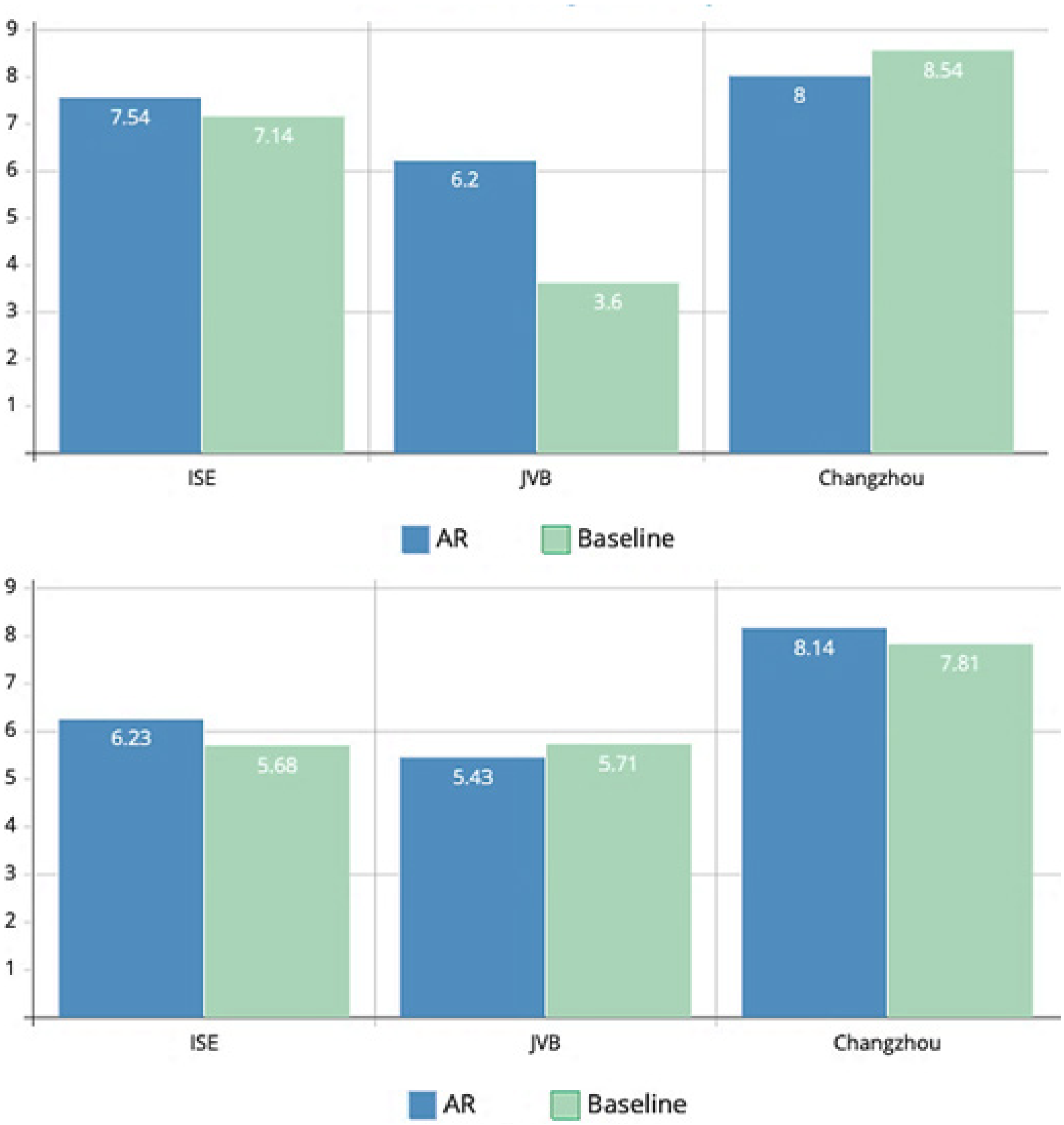


Figure 6.13. Children participants' mean scores in the fantasy condition from three different locations. (Above) Participants' mean scores in the Real-life condition from three different locations. (Below)

6.6. Discussions

6.6.1. Result Summary

We examined the influence of AR and fantasy on learners' recall of declarative knowledge in this study. We gained the following insights:

- For children, design using fantasy with AR was more effective in enhancing recall than designing AR with real-life contents of the learning material.
- Children did not demonstrate a substantial difference in recall between AR and baseline conditions.

- We discovered that adding photos as supplementary information improved children's recall in baseline and the AR fantasy condition. Potentially the recall of the augmented content was activated by content on cards after playing with AR
- We found adults perform differently from children. Adults' recall was affected by the use of AR. With AR, adults scored better. Children's recall performance was determined by whether the AR game featured fantasy or real life. Children performed better when exposed to fantasy in AR game-based learning.

- Children in Changzhou performed well in all cases. Their recall was not influenced by our design. ISE students learned more effectively in AR with fantasy representations than in real-life materials. JVB students gained significant improvement over baselines after playing the AR fantasy version.

In general, AR and fantasy game components can aid descriptive knowledge recall. However, the influence of AR and fantasy on recall depends on how individuals encode information, which varies by age group and cultural background.

6.6.2. Result Interpretation

We try to explain our findings by analyzing the influence of AR fantasy on game-based learning and how it supports the cognitive process of recall. We also try to explain the difference between age groups and locations through further analyses of different user groups.

There are a few explanations about why young participants performed better with AR fantasy than with AR real-life. In our AR fantasy version, we used anthropomorphism, turning the chemical elements and their application into human forms and magical scenarios. The anthropomorphic fantasy version may connect an abstract concept to a visualized role, with a plausible story and identifiable sounds that AR strengthen. Additionally, AR fantasy brings stronger immersive and autonomous participants' experiences through imagination (Zuo et al., 2022). Engaging imagination in learning can positively affect memorization recall (Egan, 1989), which is further enhanced by AR fantasy content, activating a vivid memory (Huang & Tseng, 2015).

Another reason could be the motivational effect of fantasy. The AR fantasy version features avatars and settings with magic and supernatural elements, bringing a more enjoyable game-based learning experience, especially for young participants (J. Habgood & Ainsworth, 2011). According to Hoffman & Schraw's (2009) work, motivational beliefs may enhance learning effectiveness as working memory demands grow. Additionally, previous research indicates that working memory functions as a mediator between children's anxiety and academic achievement (Owens et al., 2008), implying that effective learning is about memorization with a joyful learning experience. AR Fantasy provides contexts that engage participants in a relaxing and enjoyable atmosphere, which is beneficial for reducing anxiety and frustration during a heavy memorization process, leading to better academic performance.

In our case, AR attaches stories, visual representation, and sound to physical objects (Frohlich & Murphy, 2000), the cards. The recall of attached virtual information is theoretically feasible by activating the position-specific effect when participants are exposed to the initial location or objects where information is presented. Our finding indicates that young participants scored significantly higher with picture questions than text questions with AR fantasy. In contrast, there was no such difference with AR real life. This finding suggests AR fantasy may be better at triggering a position-specific effect that inspires participants' imaginations and recall of the virtual contents from the physical objects than AR real-life. However, we also found participants in their baseline scored higher with the picture question than with the text questions. The finding indicates that questions accompanied by images offer extra information for memory recognition, which may also influence participants' recall in the AR versions. To evaluate if AR fantasy enables a stronger recall, we need to collect more targeted data relating to the encoding and retrieving of information during their memory process.

We find that performance of recall varied by age group. Young participants who grow up with digital technologies and gameplay are more accommodating to the AR application (Li et al., 2019). Therefore, the novelty influence of AR game-based learning on recall doesn't influence them as much as it does on adults. It is also worth mentioning that students spend their days learning in classrooms and are frequently required to memorize textbook content for exams, which may suggest that their baseline recall is already quite high. The positive effect of AR is relatively not strong in terms of improvement from students' baseline. The adults in our situation, mainly in their middle ages, had been absent from the classroom and test assessments for an extended period. It is reasonable that their memorizing techniques and test-taking skills have declined, having a lower baseline recall, which offered more space for AR to have an effect.

Through the result that no main effect of fantasy was found among adults' learning and recall, we found connections to previous research regarding fantasy settings for different age groups. Earlier studies suggest that fantastical aspects are a substantial motivator for younger generations but do not effectively drive senior participants (Greenberg et al., 2010). However, the pairwise comparison demonstrates only in the AR fantasy condition did the adults enhance their recall from baseline. Such results might suggest that AR fantasy still has a positive effect on recall. It is possible that the fantasy genre used in our design, which was intended to assist young participants, did not correspond to the genres favored by the majority of adults. Adults also like fantasy in films, books, and games. The design of fantasy should be tailored to their interests in order to improve recall.

We also find that recall varied by location. Participants at ISE are international students, and they study chemistry in English. They possess sufficient learning capacities, and the fantasy version improves their motivation and fosters a vibrant classroom environment that encourages them to learn more. The English version of chemistry is more challenging for native Dutch participants at JVB. Under such circumstances, AR has a stronger influence. We noticed that participants from Changzhou, China, who performed significantly better than participants from the other two locations, showed no difference between game versions. Despite many of them leaving feedback, claiming they like the fantasy version or the idea of learning with AR games, their recall performance is not influenced by the factors of AR or fantasy. This phenomenon may be partly explained by the method used to collect data from Changzhou participants, which is one-by-one, resulting in participants' greater focus and recall in each case. Another reason may be, as Biemans & van Mil (2008) found in their research on the learning styles of Dutch and Chinese students, that Chinese students have a stronger test-directed orientation when learning. This orientation is related to Vermunt's reproduction-directed learning style (Vermunt & Donche, 2017). Such a learning style includes memorizing and rehearsing key information the learner selected from the learning material (Vermunt, 1996), possibly leading to an excellent performance in related tests regardless of conditions. However, this does not indicate that such learners do not appreciate fantasy contexts or the implementation of novel technologies like AR in learning. On the contrary, fantasy and AR would create more alternative learning strategies or motivators for learners than test-oriented learning styles (Sapounidis & Demetriadis, 2013).

6.7. Design Guidelines

We suggest several design guidelines applicable to AR fantasy in game-based learning by evaluating the research outcomes. We discover that applying fantasy enhances recall more than using real-life settings in an AR learning environment, implying that well-designed fantasy may transform redundant information into a facilitator for processing information. We can draw a few insights into how to construct fantasy effectively from our study.

Anthropomorphism with a visualized concept, narrative representations, and audio feedback creates plausible and unique virtual fantasy contexts for memorization processes. Likewise, we recommend recognizable AR fantasy representations connecting to these three aspects. Since AR fantasy settings can aid in recalling the virtual information while perceiving the physical content, learning experiences can be designed to switch between playing with physical materials with augmented layers and playing without augmented layers to engage the participants' imagination throughout their memory process. Fantasy play may increase students' motivation to study and may result in more effective learning. For designers, it is vital to understand the target user groups' fantasy orientation (Barber et al., 2013) and the forms of fantasy they appreciate.

Noticing that participants appreciate fantasy differently by age group and location, we recommend that designers adjust the application of AR and types of fantasy for various target groups. For example, designers could apply AR technology to adults with playful content according to their preferences. The integration of AR and fantasy should also be adjusted according to the target groups' capabilities and learning styles. We suggest applying AR to deepen understanding of the concept when the content to be memorized is too complicated for the learners. If the learning of abstract knowledge influence students' motivation, AR fantasy can be employed to encourage students to learn autonomously and improve their performance on recall. For students with reproduction-directed learning styles, the application of AR and fantasy should focus on inspiring them further in terms of knowledge application and creativity.

6.8. Limitations and Future Work

There are several limitations in our design of the study. We experimented and collected data differently in different locations, depending on the local COVID-19 policies. Some phenomena might also be attributed to data collecting methods in which data from Changzhou were mostly gathered individually. Participants sitting together in a classroom and participating in the experiment simultaneously could have different engagements, which might have had an impact on the different outcomes. Additionally, adults' data were only collected in Changzhou. Although adults are not our research focus, a further collection of data from other locations would provide more solid results on the influence of age. It was indicated that the recall of the virtual content is activated by content on cards after playing with AR. A concrete conclusion regarding this, however, requires further investigation.

Furthermore, real-world learning environments and the demands put on students' memory are often more complicated than our experiment settings. Additional long-term research may help us understand how AR and fantasy benefit students in a range of diverse contexts. Our results, taken along with earlier research, show a possible pathway for recall enhancement triggered by AR fantasy through increased motivation. It is a potential direction to continue research on the relationship between motivation and recall in future work.

6.9. Conclusion

This study provides evidence that using AR fantasy in game-based learning can increase recall of declarative knowledge and increase learning effectiveness for children. We believe that AR fantasy can activate the recall of virtual overlays from physical objects. On the other hand, adults react differently from children, who demonstrate an improvement in recall with AR regardless of whether fantastical or real-life components are used. We also find there is a difference between students' recall performance with AR fantasy caused by different locations and cultural backgrounds.

ChemiKami AR benefits both learners by providing an engaging and effective game-based learning experience. The empirical results on the influence of fantasy and AR on the recall may drive more exploratory research to exploit the potential of AR and game-based learning. We suggest several design guidelines for developing AR learning apps and employing fantasy in game-based learning. We hope this research helps designers to employ fantasy game elements in learning. Hopefully, this work can inspire more designers to create attractive game-based learning experiences that can compete with entertainment games and effective game-based learning experiences that engage learners with enjoyable, meaningful learning experiences.

Augmented Reality (AR) Game-based learning has gotten increased attention in recent years. Within game-based learning, fantasy is a vital feature that can turn learning content for children into engaging and immersive experiences. However, situating learning in an AR fantasy context so that learning becomes engaging should also fit pedagogical contexts such as instructor scaffolding and diverse subject matter features. Therefore, understanding how to design effective AR fantasy in game-based learning requires exploring its potential in different educational scenarios for different disciplines. We present a combined study with two AR games, MathMythosAR2, designed to stimulate mathematics learning, and FancyBookAR, designed for English as second-language learning. For each game, we created a fantasy narrative and a real-life narrative. We investigated player engagement and teacher scaffolding through qualitative and quantitative analyses. Our findings suggest design guidelines and practical solutions for situating learning in AR fantasy in the context of game-based classroom instruction.

This page intentionally left blank

Study 4*

Situating learning in AR fantasy, design considerations for AR game-based learning for children

*This chapter is partially based on Zuo, T., Jiang, J, Van der Spek, E. D., Birk, M., & Hu, J. (2022). Situating Learning in AR Fantasy, Design Considerations for AR Game-Based Learning for Children. Electronics, 11(15), 2331.

Chapter 7


This game is so cool!
Maths is fun!
Expectation
My screen freezes..
What does it mean?
Incoming
It's not a game at all
No Fortnite!!
Totally.
Reality

7.1. Introduction

Blending game features with instruction, game-based learning enables participants to engage in learning with a fun and immersive experience without focusing on the learning challenge (Fotaris et al., 2017b). Games provide complex interactivity in virtual worlds that support learning by experience. To transfer the knowledge learned from the virtual world to practical situations in the real world, learners and teachers need a collaborative learning environment in the classrooms (Pitair, 2003). However, when learners engage fully with the virtual environments in learning games, they find it difficult to communicate with teachers in a classroom (Tenório et al., 2018). Such situations may be improved by contemporary technology.

Augmented Reality (AR), a technology integrating virtual graphics, 3d models, animations, and sound effects with physical materials or spaces, enables users to engage with real-world objects and virtual interactive overlays simultaneously (Radu, 2014; Taufiq et al., 2021). AR creates a digital context where nonetheless learners' contact with reality is maintained, and communication in a classroom is facilitated through physical interaction (Tenório et al., 2018). With digital game features and physical situations, AR game-based learning allows games to be integrated into classrooms and subsequently provide engaging, situated learning. The core of situated learning is to intrinsically link the knowledge to be learned to physical and cultural contexts where learning occurs (Lave & Wenger, 1991). AR provides contexts that allow users to sense real-world situations and adapt digital instruction with them (Dunleavy et al., 2009).
AR game-based learning has been used to playfully augment serious contexts and thereby present instructional content in an engaging manner and has received increased attention in recent years (Chih Hung Chen, 2020; Li et al., 2017; Pellas et al., 2019). Research on AR game-based learning incorporates computer science, pedagogy, and experience design (Pellas et al., 2019). Researchers need to simultaneously consider the current situations in learning, technological affordances, and resulting user experiences. One approach to better leverage technological possibilities, enrich educational contexts, and improve player experiences, is by incorporating gaming features such as avatar customization (Birk et al., 2016), fantasy (Charsky, 2010), and goal-setting (Alessi & Trollip, 2001) into AR learning. One of the game elements that can provide motive-specific affective incentives (Job & Brandstätter, 2009) is fantasy, i.e., unreal and fictional settings that deviate from everyday life (Malone, 1980; Zuo et al., 2019). Fantasy can positively affect game-based learning, increasing players' engagement, especially for children who are not self-motivated to study (J. A. Connolly & Doyle, 1984; Parker & Lepper, 1992; Zuo et al., 2020).

The way in which fantasy should be incorporated in learning contexts has sparked academic interest in recent years (Lee, 2015; van der Spek et al., 2014). To move beyond the entertainment requirements of fantasy, we need to consider pedagogical requirements when incorporating fantasy elements into game-based learning applications. An appropriate learning environment features authentic contexts that allow for the natural complexity of the real world (Brown et al., 1989), coaching and scaffolding during the initial steps (Belland, 2014), and articulation to enable explicit expression of tacit knowledge (Eraut, 2000), creating spaces for exploration of participants (Richard, 2010). In order to understand how to design a game-based learning experience that situates learning in AR fantasy, engages learners, and adheres to pedagogical principles, structured research is needed. Research that investigates the classroom context and the way fantasy and different subject matters may interact with it.

To investigate situating learning in AR fantasy and game-based learning for different learning contexts, we present two studies with two of our AR games: MathMythosAR2, a game for mathematic learning and practicing, and FancyBookAR, a game for English as second language learning and practicing. We prepared two narratives for each game: a fantasy version and a real-life version. By comparing the fantasy and real-life versions, we explore the effect of fantasy on engagement and scaffolding and the design considerations for designing AR game-based learning with fantasy or real-life contexts. By contrasting the effect of AR fantasy with the different subject matter, we develop strategies for adjusting fantasy structures to the specific qualities of the subject matter in the classroom.

This study benefits the pedagogy domains by offering inspiring practice and practical solutions for the needs of situating learning in technologically-rich contexts with a game-based learning experience. It connects learning situations with immersive technology with a novel, immersive and enjoyable experience that meets the needs of 21st century learning. We offer innovative solutions that connect participants and teachers with an engaging learning experience and strategies for scaffolding learning with AR fantasy. This research also contributes to design research by offering innovative game design and practical design strategies for designing with AR fantasy, bringing the future of immersive technology closer to our lives.

7.2. Literature Review

7.2.1. Augmented Reality in Game-Based Learning

Augmented Reality (AR) is a technology that enhances real-world environments with an interactive virtual overlay that engages the user’s visual, auditory, and haptic senses (Hughes et al., 2005). Perceptually AR enhances the actual environment, leading to immersive experiences (Klopfer & Yoon, 2005). AR promises to engender a better play-learn experience by 1) visualizing knowledge and concepts from alternative perspectives, for example, by bringing invisible and abstract concepts to life (Fotaris et al., 2017a), 2) facilitating social interactions with tangible and virtual materials, regardless of geography or time restrictions (Li et al., 2020), and 3) by bridging formal and informal learning by eliminating barriers between virtual and physical worlds (Dunleavy & Dede, 2014; Rodrígues & Bidarra, 2014). To incorporate these AR characteristics into game-based learning, designers should first understand how game aspects can be designed with AR and their implications in educational contexts.

7.2.2. The Magic Circle and Motivational Effect of AR Fantasy

As a term that describes fictional, imaginative, or unreal contexts, fantasy exists in games featuring narratives, interactions, and settings that deviate from the real world (Malone & Lepper, 1987; Zuo et al., 2019). Playful experiences with fantasy game elements can invite users into an immersive world called the "magic circle (Huizinga, 2014)," with a temporal and spatial boundary separating users from the real world. Such boundaries are blurred by AR technology, where players simultaneously enter the virtual world, sensing the physical world (Montola, 2005). AR Fantasy can create a circle that Stapleton and colleagues (2003) refer to as a "mixed fantasy continuum," which creates compelling venues and content prototypes to engage the audience's imagination. Certain imaginary mental activities involving creating new realities or relating to existing ones are what Choi and colleagues (2003) defined as imagination and analogy states of fantasy. These mental states are key to a convincing mixed-fantasy experience that allows participants to step into the magic circle with a "suspension of disbelief" (Montola, 2005). To identify whether fantasy elements build a convincing magic circle, we need to understand players' fantasy states while analyzing their engagement (Heater, 1992).

Table 7.1: Indicators of emotional, behavioral, and cognitive engagement.

Dimension	Positive Indicators	Negative Indicators
Emotional Engagement	Thrilled, Curious, Express values and Feelings, Focused, Interested, Enthusiastic, Happy.	Anxiety, Bored
Behavioral Engagement	Confident, Preference for Challenges, Extra Effort, Expressing the Value.	Frustration for Failure
Cognitive Engagement	Extra activity, Comprehension of Knowledge, Attention, Active Participation.	Forced to Play, Not Following Rules, Confused

Engagement is a process of getting involved and connected (Doherty & Doherty, 2018). Based on research on factors that reflect different aspects of learning engagement (Bouta & Retalis, 2013; Filsecker & Kerres, 2014; Lee & Shute, 2010), we summarize a table of indicators for engagement in Table 7.1. The indicators include emotional, behavioral, and cognitive aspects of engagement and can be used to identify the effect of integrating AR fantasy on engagement through qualitative methods.

Players' emotional engagement comes from the pleasure of immersion (Doherty & Doherty, 2018), which fantasy elements can facilitate (Zuo et al., 2022). Players' cognitive engagement reflects "one's effort to put into self-regulated learning, involving a process of making sure oneself comprehends the game content." (Sedano et al., 2013). Previous research indicates that players can be more motivated in fantasy contexts but find it challenging to integrate the newly learned information with their prior knowledge (van der Spek et al., 2014). Therefore, it is still an open question whether incorporating fantasy in AR game-based learning may result in users' sufficient understanding, leading to positive behavioral and cognitive engagement.

In addition to qualitative methods of measuring engagement, we collect participants' self-reported enjoyment parts of intrinsic motivation through the Intrinsic Motivation Inventory (IMI) in this study. Malone and colleagues connect endogenous fantasy with intrinsic motivation, in which learners are driven by qualities such as enjoyment and self-fulfillment (Malone & Lepper, 1987). Endogenous fantasy in game-based learning can let participants engage with affective incentives (Job & Brandstätter, 2009) without focusing on the learning goals (Mozelius, 2014).

7.2.3. Pedagogical Principles for Integrating Fantasy in AR Game-Based Learning

Fantasy and Situated Learning

Situated learning refers to learning practical applications through communication and interaction with environments (Lave & Wenger, 1991). Immersive technologies like AR potentially provide various contexts and alternative perspectives to support situated learning. However, some questions remain about incorporating AR fantasy in game-based learning. Guidelines of situated learning often suggest designers embed contexts for authentic learning, where participants explore, discuss and construct concepts of real-world issues they can relate to (Council et al., 1999). Authentic learning refers to activities that involve learning by solving issues, studying cases, and practicing situations that are similar to those encountered in real-life situations (Lombardi & Oblinger, 2007). Some scholars perceive authentic contexts as the opposite of fantasy, suggesting that only real-life contexts can draw learners to engage instead of passively receiving (Ladley, 2010). However, tracing back to the criteria of authentic learning, we find the essential is to learn grounded knowledge in fields instead of memorizing abstract knowledge (Newmann et al., 1995). Fantasy circumstances can positively engage learners and facilitate integration of knowledge in applied domains. The key is whether a convincing and immersive magic circle around an accessible and grounded learning context is constructed.

Scaffolding and the Role of Teachers

Balancing learners' motivation and comprehension in an immersive game-based learning magic circle requires careful design by game designers and proper guidance from teachers. The role of teachers in situated game-based learning differs from a traditional tutoring context. In traditional education, teachers guide participants through scaffolding, which means offering temporal support to complete learning targets (van de Pol et al., 2010). Scaffolding includes many approaches, such as modelling, posing questions, answering questions and more, in one-to-one, small groups, and whole-class communication. Game-based learning in a classroom can bring about additional challenges to students, which in turn require more scaffolding on top of the scaffolding in traditional contexts. For example, challenges for students that require additional scaffolding might include technological difficulties, structuring game tasks, adapting complexity, forming explicit strategies, time management, behavioral regulation, emotional control and more (Sun et al., 2021).

Despite these challenges, in a game-based learning context, participants can also be guided by instructional content with natural progressions of the game's storyline (Wouters & van Oostendorp, 2016). Participants who are fully immersed in the environment might require a less direct explanation from teachers (Young, 1993). Certain circumstances, allowing teachers to hand over controls of the learning context to participants, encourage autonomous learning by participants (Garrett et al., 2015). However, it also challenges teachers to assist participants and focus their attention on the learning without interfering with their autonomy (Wouters & van Oostendorp, 2016) and their determination to interact based on their interests and values (Ryan et al., 2006). AR, as a technology, engages participants with the virtual world while also maintaining a portion of their attention in the real-life classroom (Yuen et al., 2011). AR allows participants to seamlessly move between virtual and real-world interactive exploration, creating spaces to insert teachers' roles.

Incorporating the role of teachers necessitates a detailed assessment of how students perform in different educational contexts. Pivec And colleagues (2003) summarize a criterion for different degrees of problem-solving skills of tasks, based on Vygotsky's (1978) work: (1) tasks can be accomplished alone by a student; (2) tasks that can be completed with the assistance of others; and (3) tasks that cannot be performed even with the assistance of others. A further in-depth assessment of participants' task completion using this criterion, in combination

with their autonomy analyses, can help situate teachers' roles in scaffolding in specific contexts.
Based on the above literature review, we outlined three research questions about situating learning with AR fantasy in games:

RQ1: Does fantasy or real-life narratives in AR game-based learning in the classroom provide a more engaging and immersive experience for participants?
RQ2: What is the teachers' role in scaffolding fantasy construction and learning?
RQ3: How to situate learning in AR fantasy in games to improve participants' engagement, experience, and the teachers' scaffolding?

To answer these research questions, we introduce our design, MathMythosAR2, and FancyBookAR, two storybook-based AR games focusing on learning mathematics and English, respectively. According to our findings through experiments and data analyses, we try to find answers to these questions.

7.3. Game Design

Innovation	Portrayal	Warlock
Elements	Mechanics	Cards with Storybooks
	Story	Magic Items/ Events
	Aesthetic	Carton/ Magic Sound Effect
	Technology	Augmented Reality
Genre	Story	Narratology
Adaption	Instruction	Endogenous Fantasy

Innovation	Portrayal	Catperson
Elements	Mechanics	Cards with Storybooks
	Story	Magic Items/ Events/ Creature
	Aesthetic	Carton/ Magic Sound Effect
	Technology	Augmented Reality
Genre	Story	Narratology
Adaption	Instruction	Endogenous Fantasy

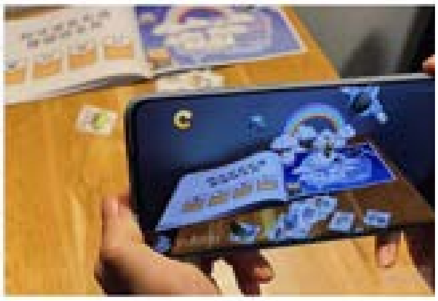


Figure 7.1: The design choice made in MathMythosAR2 (above) and FancybookAR (below) with corresponding fantasy classification (fantasy in artifacts)

Both FancyBookAR and MathmythosAR2 were designed with Unity and Vuforia. We employed the "classification of fantasy in serious games" discussed in Chapter 2 to guide us when making design choices (Zuo et al., 2019). The fantastical categories used in FancyBookAR are comparable to those found in MathMythosAR2, employing a similar portrayal of innovation—magic and elements of fantasy. MathMythosAR2 focused on learning and practising addition and subtraction, while FancyBookAR focuses on learning and practicing English vocabulary and sentence construction. The same game mechanics, such as cards, storybooks, and phone interactions, were used for instruction and gameplay. Narrative genres of fantasy were applied in both games (Figure 7.1). To understand the difference in players' experiences under fantasy and real-life scenarios, we provided two narrative versions for each game: the fantasy and the real-life versions. We designed these games for one-to-one scaffolding, meaning teachers can assist students with explicit explanations, question prompting and answering related to the subject knowledge and the game. Additionally, both games provide direct feedback to players' answers each time, with positive feedback when the answer is correct and further explanation of the related subject knowledge when the answer is wrong.

7.3.1. MathMythosAR2

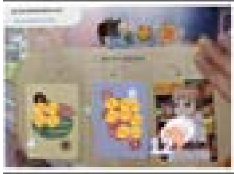
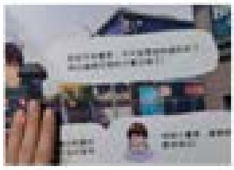
MathMythosAR2 is an AR game that encourages children to learn and practice arithmetic addition techniques of mathematics. There are seven chapters in each game version. Participants are first introduced to its narrative by scanning the pattern in the storybook. Then they use a virtual button by covering a specific pattern on the storybook with a hand to react to dialogue between NPC (Non-Player Characters). Then participants will be introduced to the addition technique. Participants need to hold the virtual button and trigger the randomly generated numbers (randomization of correct answers+-3), releasing when the right numbers are displayed. Participants receive cards with values to embark on the final practice, scan the cards with values, and sum up their total values. In the fantasy version, participants play a role of a magician. Participants learn "math magic" to save a village from evil. Participants complete the game task by making choices about the magic narratives and completing calculation exercises situated in the math magic fantasy. Key narratives and options in each chapter are presented with screenshots in Table 7.2.

The "real-life" version (Table 7.3) of MathMythosAR2 retains the same narrative framework and gameplay mechanics. However, the participants play a role of a normal everyday life student, Robin. The main tasks are summing up total prices and shopping for the class party. Key narratives and options are presented in Table7.2.

Table 7.2: The fantasy version of the game MathMythosAR2

Chapter Screenshots	Key Narratives	Options
	Wake up! Rubin! Wake up!	N/A
	Hey Rubin, why are you sleeping here? The class is off.	1. Who are you? 2. Hi, Mr. Steven. I have some questions about math magic.
	There are two kinds of magic power with stones: single-digit and two-digit. (The screenshot shows how the NPC reacts to wrong answers)	Choices available are between the correct answer ±3.
	Brunwich was a beautiful town in the east. An invasion of evil magic shattered the peaceful area. Residents are in trouble, and only we can help them.	N/A
	It's a monster! Innocent people are turned into monsters by evil sorcery! To save them, we must use math magic to break the spell! Are you ready?	1. Wait! What was that again? I'm not ready 2. Yes! I'm ready!
	Every time you sum up the magic power on the two magic stones will break a level of the evil spell. (one time of single-digit addition, two times of two-digit addition)	Choices available are between the correct answer ±3.
	Oh, you save my life! Thank you, young magician!	1. What??? You are a human? 2. I'm glad you are back! Is everything ok?

Table 7.3: The real-life version of the game MathMythosAR2

Chapter screenshots	Key Narratives	Options
	Wake up! Robin! Wake up!	N/A
	Hey Robin, why are you sleeping here? The class is off.	1. Who are you? 2. Hi, Mr. Steven. I have some math questions.
	There are two kinds of fruit prices on the board, the single-digit number and the two-digit number.	Choices available are between the correct answer ±3.
	I heard you are organizing the class party for the new year and some materials are missing. I can help you buy them.	N/A
	Let's shop for party snacks. I will give you some coupons. When shopping, please use the addition techniques you just learned. Are you ready?	1. Wait! What was that again? I'm not ready 2. Yes! I'm ready!
	What's the total price of the coupons? (one time of single-digit addition, two times of two-digit addition)	Choices available are between the correct answer ±3.
	The cashier machine is broken. I'm sorry for the inconvenience. Thank you for your assistance with the calculation.	1. I would not have come to your store if I had known that. 2. No problem, I am willing to help. It's just simple mathematics.

7.3.2. FancyBookAR

FancyBook is an AR game that encourages children to learn English words and form sentences using these words. There are five chapters in the game. In each chapter, participants will first receive vocabulary cards and a storybook with incomplete sentences that need words to fill in the blanks. To complete the sentences, participants need to understand the meaning of the words on each card and the possible context wherein they fit. A correctly constructed sentence with the cards will trigger the completion of a game scene. As a result of completing the tasks on the current scene, participants activate the animation of the characters and complete the stories. There are two versions of narrative in FancyBookAR, a fantasy version and a real-life version.

In the fantasy narrative version, participants play a role of a magician, the cat person. Participants need to complete the story by choosing the options set in a fantasy genre. Key narratives and options are presented with screenshots in Table 7.4.

The “real-life” version (Table 7.5) of FancyBookAR retains the same narrative framework and gameplay mechanics. However, the cat person is clothed in a regular outfit and lives in its own normal home this time. The narratives and options are set close to real-life situations (Table 7.5).

Table 7.4: The fantasy version of the game FancyBookAR

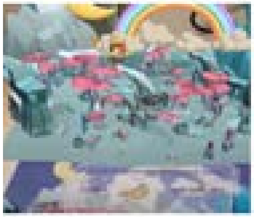
Chapter screenshots	Key Narratives	Options
	It's too dark. I use the _ to light up the sky.	1. magic stick 2. star bottle 3. open 4. turn on
	The star is too messy! I use __ to clean the ground.	1. a robot 2. a magic book 3. a trash-eating monster
	I need to provide food and drinks. I take _ from the sky.	1. a moon croissant 2. rainbow drink 3. a cotton candy
	I _ a _ to pick up my friend.	1. ride 2. drive 3. dragon 4. cloud 5. spaceship
	I play with my friend in a _.	1. mushroom trampoline park 2. candy park 3. magic forest

Table 7.5: The real-life version of the game FancyBookAR

Chapter screenshots	Key Narratives	Options
	It's too dark! I__ the __.	1. turn on 2. open 3. window 4. light
	The room is so messy! I use __ to clean the __.	1. a broom 2. a vacuum 3. a rag 4. bed 5. ground 6. table
	I need to provide food and drink. I buy __ in the supermarket.	1. chocolate 2. milk 3. a mango 4. a hamburger
	I __ to pick up my friend.	1. ride a scooter 2. take a bus 3. skateboard
	It's playtime! I _with my friend.	1. dance 2. watch TV

7.4. The Experimental Design

Using the two games described above, each having two narrative versions, we performed an experiment with game versions (FancyBookAR vs. MathMythosAR2) as the between-subject factor and the narrative versions (real-life vs. fantasy) as the within-subject factor. We compared the mathematics and language learning games that AR fantasy incorporated to explore ways and patterns of using AR fantasy to achieve increased engagement with two distinct learning subjects. We compared the fantasy and real-life versions to see the effect of fantasy on players' engagement and experience. We answered the research questions using the findings of the qualitative and quantitative analyses, investigating the phenomena and causes with reference to previous work.

7.4.1. Participants and Procedure

This study involved 62 (male=30, female=32) participants from two different locations in China. Thirty-one participants from Qingdao, Shandong province, with an average age of 9.2, ranging from 7 to 11 years old, were invited to play the game MathMythosAR2. Thirty-one participants from Hefei Anhui province, with an average age of 10.6, ranging from 8 to 14 years old, were invited to play the game FancyBookAR. Participants played two versions of the narrative for both games: fantasy and real-life versions. Both versions were offered in a counterbalanced order to mitigate possible sequence effects. The assistant invited each participant to a preset room with a Huawei android phone, a Lenovo ThinkPad laptop, and sets of cards together with storybooks. Additionally, we set up a GoPro Hero9 camera to record the procedure.

Before the gameplay started, an assistant introduced the general gameplay to participants using a blank version with only text and 3D sphere models, letting participants get used to scanning image targets and holding virtual buttons. The participants would then be asked to play one of the versions by the assistant, who also served as an instructor and gave help if participants asked. After completing the version, the participant would be asked to complete a questionnaire before going to the other version and completing another questionnaire. Besides IMI, PENS, and FSS, the questionnaire also collected their demographic information, including their self-identified gender and age. We asked them to fill in their nicknames instead of real names to maintain the data anonymously. Informed consent was achieved by participants, the school teachers, and the participants' guardians. The procedure, game contents, and questionnaire were approved by the Eindhoven University of Technology ethical review board with the approval number ERB2020ID165.

7.4.2. Measurement

To answer RQ1, we collected the participants' self-reported immersion through the immersion section of the Player Experience of Need Satisfaction Questionnaire (PENS) (Rigby & Ryan, 2007, Johnson et al., 2018). To identify their engagement during gameplay, we invited two experts to analyze the gameplay videos and code the participants' engagement using the indicators (Table 7.1). Experts were also invited to code using words outside of the pool of indicators if they needed to highlight any context-specific phenomenon about engagement. To answer RQ2, we identified participants' understanding and the teacher's scaffolding through video analyses of how they completed the tasks. Tasks that were well understood and completed by participants alone were marked as "independent." Tasks that participants completed with the teacher's assistance were marked as "with assistance." Tasks that participants did not complete, even with help from the teachers, were marked "uncompleted." Questions participants raised when seeking help were also recorded.

To further investigate participants' fantasy states during the learning process, we collected their self-reported data of imagination and analogy using the fantasy state scale (FSS). We used the autonomy and enjoyment sections from the PENS questionnaire and the Intrinsic Motivation Inventory (IMI) to collect their self-reported data on autonomy and enjoyment. Since FSS, IMI and PENS were not designed specifically for children, and previous studies suggest some children have difficulty understanding "neutral" and double negative sentences (Scott, 2000), we used a 4-point animated smiley scale developed by Li, Van Der Spek, Hu, & Feijs (2019) (Figure 7.2) for the questions in PENS, IMI and FSS.

Figure 7.2: The 4-point animated smiley scale developed by Li and colleagues (2019)

7.4.3. Data Analyses

Two experts coded the participants' types of engagement and comprehension and teacher's assistance using MAXQDA 2020. There were 10 video recordings from 10 participants for each narrative version of each game, for a total of 40 video clips. Experts engaged in closed coding by marking the video's timeline using a pre-defined pool of keywords we determined regarding engagement types (Table 7.1) and task performance (independent, with assistance, uncompleted). In addition, the experts were allowed to open code salient events themselves. To further understand the qualitative data experts coded, we used an affinity diagram (Plain, 2007) to organize the keywords of user engagement in a structure containing game versions, narrative versions, and engagement types. Based on the areas of confusion when users wanted assistance, we drew up representative user journey maps that included participants' engagement and teachers' scaffolding.

7.4.4. Reliability Test

The Cronbach's alpha values for data collected in Hefei using FancyBookAR are generally at an acceptable level (0.7~0.8). However, data from Qingdao using MathMythosAR2 has a low alpha for the presence (0.6) and enjoyment section (0.5). After deleting the reversed question, we found an increase in the value, with enjoyment= 0.7 and presence=0.8. Given that children participants from Qingdao had a slightly lower average age than those from Anhui, young participants around this age (M=9.2) with their understanding of reversibility still developing (Piaget et al., 1947) may find it difficult to answer reversed questions. The mean scores for enjoyment and presence sections in the Qingdao group are reported without the reversed question.

7.5. Results

7.5.1. Participants' Self-Reported Experience and Engagement

We analyzed the participants' presence, imagination, analogy, enjoyment, and autonomy data using SPSS. We performed a within-between mixed-factor analyses of variance (ANOVA), setting the game versions (MathMythosAR2 or FancyBookAR) as the between-subject factor and the game version (fantasy or real-life) as the within-subject factor. Tables 6-9 show the results, with significant outcomes highlighted in bold.

Table 7.7: The mean and standard deviation values of different sections, presented as M (SD)

		Autonomy	Presence	Enjoyment	Imagination	Analogy
MathMythosAR2	Fantasy	3.66 (0.44)	3.65 (0.37)	3.67 (0.48)	3.48 (0.58)	3.43 (0.61)
	real-life	3.52 (0.58)	3.54 (0.49)	3.69 (0.45)	3.16 (0.60)	3.46 (0.59)
FancyBookAR	Fantasy	3.17 (0.72)	2.92 (0.79)	3.29 (0.71)	3.12 (0.67)	2.85 (0.98)
	real-life	3.26 (0.81)	3.04 (0.72)	3.47 (0.59)	2.70 (0.77)	3.20 (0.78)

Table 7.6: Mixed two-way ANOVA with the game versions (MathMythosAR2/ FancyBookAR) as between subject, the narrative versions (fantasy /real-life) as within-subject variable

DV	Source	SS	F	P
Autonomy	**Game versions**	**4.27**	**6.92**	**0.01**
	Narrative versions	0.02	0.10	0.76
	Interaction	0.40	1.68	0.20
Presence	**Game versions**	**11.65**	**17.56**	**0.00**
	Narrative versions	0.00	0.00	1.00
	Interaction	**0.42**	**4.37**	**0.04**
Enjoyment	**Game versions**	**2.73**	**5.01**	**0.03**
	Narrative versions	0.30	3.10	0.08
	Interaction	0.21	2.16	0.15
Imagination	**Game versions**	**5.29**	**7.81**	**0.01**
	Narrative versions	**4.19**	**22.25**	**0.00**
	Interaction	0.06	0.34	0.56
Analogy	**Game versions**	**5.45**	**6.35**	**0.01**
	Narrative versions	**1.16**	**4.04**	**0.05**
	Interaction	0.81	2.80	0.10

DV= Dependent variable, SS= sum of squares, F= value on the F distribution, Variables of Significance: P ≤ 0.05.

Table 7.8: Pairwise comparisons Fantasy VS Real-life, Bonferroni adjusted

Measure	Domain	Mean Difference	Std. Error	Sig.b
Autonomy	MathMythosAR2	.140	.123	.260
	FancyBookAR	-.086	.123	.487
Presence	MathMythosAR2	.117	.079	.145
	FancyBookAR	-.117	.079	.145
Enjoyment	MathMythosAR2	-.016	.079	.839
	FancyBookAR	**-.181***	**.079**	**.026**
Imagination	**MathMythosAR2**	**.323***	**.110**	**.005**
	FancyBookAR	**.413***	**.110**	**.000**
Analogy	MathMythosAR2	-.032	.136	.814
	FancyBookAR	**-.355***	**.136**	**.012**

Table 7.9: Pairwise comparisons MathMythosAR2 VS FancybookAR, Bonferroni adjusted

Measure	Narrative versions	Mean Difference	Std. Error	Sig.b
Autonomy	**Fantasy**	**.484***	**.152**	**.002**
	Real-life	.258	.179	.154
Presence	**Fantasy**	**.730***	**.157**	**.000**
	Real-life	**.496***	**.157**	**.002**
Enjoyment	**Fantasy**	**.379***	**.154**	**.016**
	Real-life	.215	.133	.113
Imagination	**Fantasy**	**.368***	**.159**	**.024**
	Real-life	**.458***	**.175**	**.011**
Analogy	**Fantasy**	**.581***	**.208**	**.007**
	Real-life	.258	.175	.146

7.5.2. Participants' Engagement Through Video Analyses by Experts

We created an affinity map of engagement patterns (Figure 7.3) for each game and story version by synthesizing the most frequently used keywords for player engagement. We discovered that the fantasy versions of both games engaged participants with more positive emotions than the real-life versions. Part of this finding contradicts what we discovered in their self-reported data, in which participants reported more enjoyment with the real-life version of FancyBookAR. Such discrepancies show that participants' attitudes towards fantasy in FancyBookAR changed at the beginning when being observed and at the end when being reported. Despite their positive emotional connection with the fantasy versions, many participants demonstrated negative cognitive engagement, such as confusion about the context, whereas they were more confident about playing the real-life version and demonstrated positive emotional engagement, such as "focused."

Regarding specific game versions, some participants had a negative emotional and behavioral engagement in the real-life narrative of the game MathMythosAR2, including "bored" and "anxious." Those who perceived boredom especially showed reluctance to stay and complete the game tasks but demonstrated greater positive emotion and active engagement with the same game's fantasy narrative.

Participants who played both versions of FancyBook AR showed positive emotional engagement, like focused and enthusiastic engagement in the real-life version, as well as emotions of enjoyment and interest when engaging in the fantasy version. When participants encountered unfamiliar words and phrases in the fantasy version, they expressed signs of confusion and frustration when repeated attempts failed. In the real-life version, participants spoke out more frequently about the meaning of the sentence in their native language when completing the tasks, being more confident about the result.

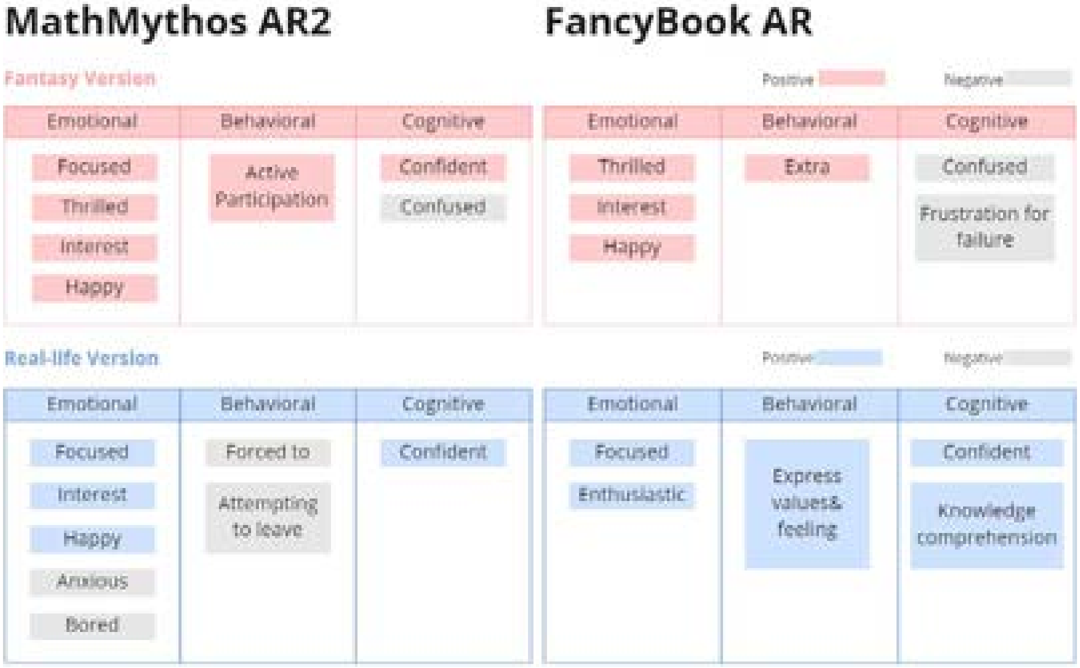


Figure 7.3: The affinity map of engagement by game versions and narrative versions (with colored tags representing positive signs and gray tags representing negative signs)

7.5.3. Participants' Comprehension and the Teacher's Assistance Through Video Analyses by Experts.

The timelines resulting from the expert analyses are displayed in Figure 7.4 and Figure 7.5 in the form of a user journey map, where ten horizontal lines represent ten samples in the video analyses of each game's narrative. Based on the game scenes, we also highlighted the negative and positive engagement moments described in Figure 7.3. We investigated the teachers' assistance and participants' engagement to assess participants' comprehension and the role of teachers with different game versions and narrative versions.

7.5.3.1. MathMythosAR2: commonalities between the two narrative versions

We discovered that when participants were exposed to new interactions, they required assistance most of the time. As a result, the teacher introduced the interactions to participants at the start of the whole game (Chapters 1 and 2). For chapters with complex interactions, such as Chapters 3 and 4, the teacher also needed to guide participants to use virtual buttons at the first stage of interaction. Instructions for interaction on the screen, presented as animated arrows and bubble feedback to emphasize the interactable elements, and a pedagogical agent to offer interaction tips. However, participants still preferred to ask their teacher in person. Some participants misunderstood the instructional arrow as a touch button on the phone rather than a virtual button on the physical book. Certain situations required the teacher to point out the right way of interaction in person. This might suggest that the virtual button we applied in the game MathMythosAR2 was not accessible and easy to use for most participants, which eventually added more cognitive load to participants when learning math.

We created a pedagogical agent in both narratives, a teacher named Steven. Interestingly, our experiment assistant, the real-life teacher, often read the lines of Steven. Although we did not inform the instructor to do so in advance, it might be because the character is not dubbed, and the teacher wanted to provide participants with a better comprehension of the narrative and a more immersive gaming experience. Parts of the reasons could also be that the teacher in real life inserted himself into the role of the teacher in the game. This phenomenon suggests that teachers' instructions can also facilitate story interpretation. Designing a role for teachers can make it easier for teachers to insert themselves into the fantasy and provide scaffolding. Further investigation is needed into how design also influences teachers' identification and engagement.

Apart from acting as a facilitator of storytelling and giving gameplay instructions, the teacher also provided help with explaining the rules of mathematical operations when participants couldn't come up with the correct answer. Moreover, experts noted differences in instruction by narrative versions.

7.5.3.2 MathMythosAR2: differences between two narrative versions

In the fantasy version, when participants had difficulty adding two-digit numbers together, the teacher helped them break the numbers down into single-digit addition to recall the addition they had already memorized. It is possible that this differentially affected the participants' fantasy experience of the game since a school teacher helping participants with math questions is part of the real-life narrative of MathMythosAR2, whereas in the fantasy narrative, it is a magic teacher, and a school teacher intervening could take participants out of the experience. The experiment showed that reported presence was higher in the fantasy condition, so if the phenomenon we observed above had an effect on participants' presence, it was not very strong.

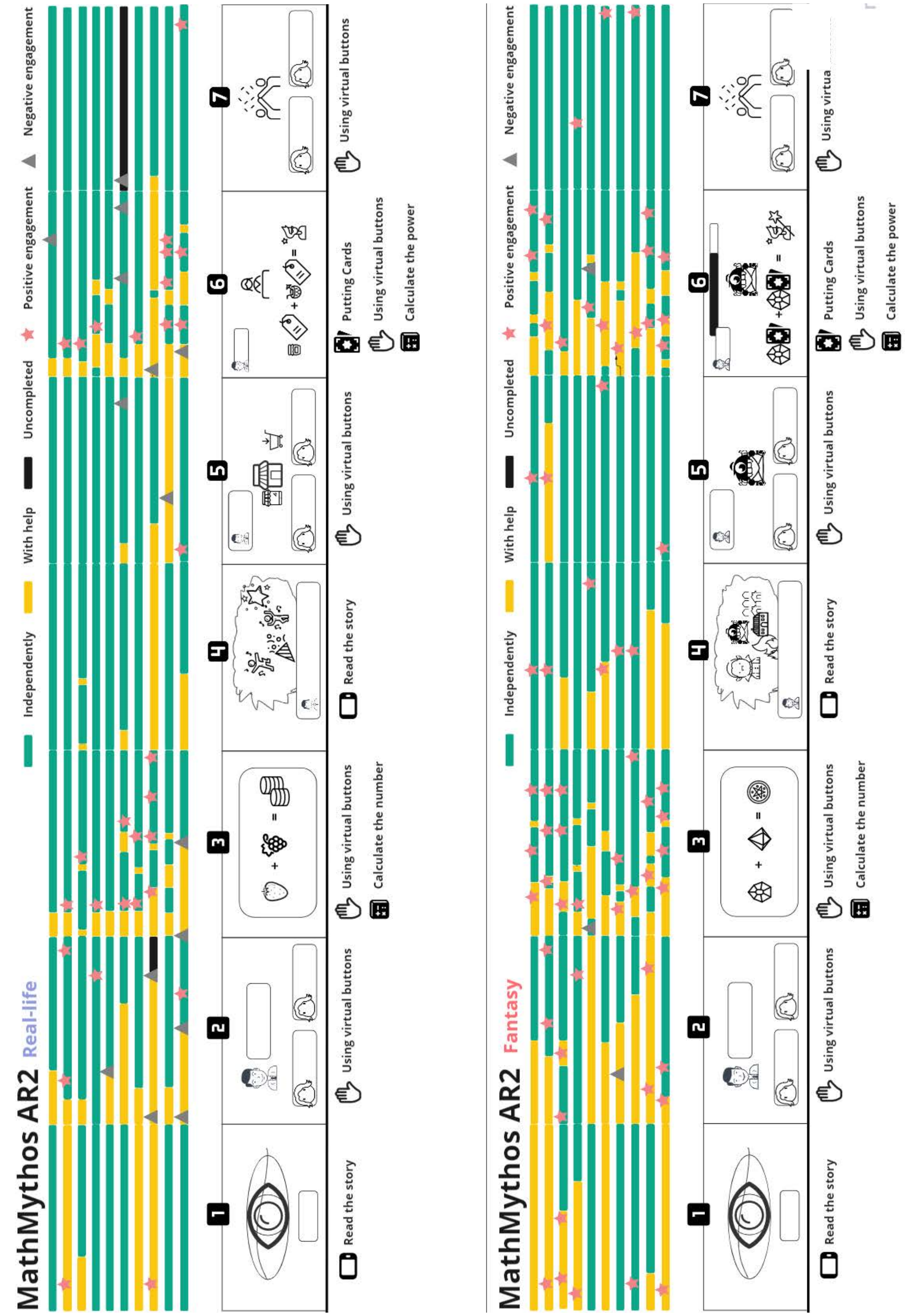


Figure 7.4: User journey maps of MathMythosAR2 with the real-life version (left) and the fantasy version (right)

In both narratives, we used pink magic (fantasy) and gold coins (real-life) to represent 2-digit numbers, blue magic (fantasy), and silver coins (real-life) to represent 1-digit numbers. When completing tasks independently, participants did not refer to two concepts in their calculations but often recalled in a low voice the mathematical operations they had learned before. We also found differences in teachers' roles of instruction on storytelling and gameplay. With the real-life versions, participants listened carefully to the teacher's introduction to the interaction first and then tried it out with the teacher's guidance. With the fantasy version, participants showed more tendency to try the game first instead of waiting for instruction. However, it was still frequent that their initial attempts failed, requiring scaffolding from teachers. With the fantasy version, the teacher spent more time helping participants understand the narrative than with the real-life version.

In addition to signs of engagement mentioned previously in Figure 7.3, another possible sign of positive engagement marked by experts was that participants in the fantasy condition tended to hold the cards they received in Chapter 3. In the same chapter of the real-life versions, all participants put cards aside. Only a few participants showed signs of disengagement with the fantasy narrative, confused about the fantasy narrative and interactions with the virtual buttons at the beginning of the gameplay. Most participants showed positive engagement with or without assistance in the fantasy narrative. In contrast, most positive engagements occurred when participants finished the task independently in the real-life version. However, more participants showed anxiety at the beginning of the gameplay in the real-life version, whereas others expressed boredom at later stages where most tasks were repetitive practice.

7.5.3.3. FancyBookAR: commonalities between the two narrative versions

With both versions, participants needed assistance understanding the meanings of words and sentences. Their understanding of the game narrative and the learning content highly depended on their prior knowledge and the tutoring from teachers. Teachers sometimes checked whether participants properly understood the sentence they constructed, as some participants just picked random cards to activate the animation effect without fully understanding the sentence. Therefore, the teacher and participants interacted more frequently, but the communication states varied depending on the narrative versions.

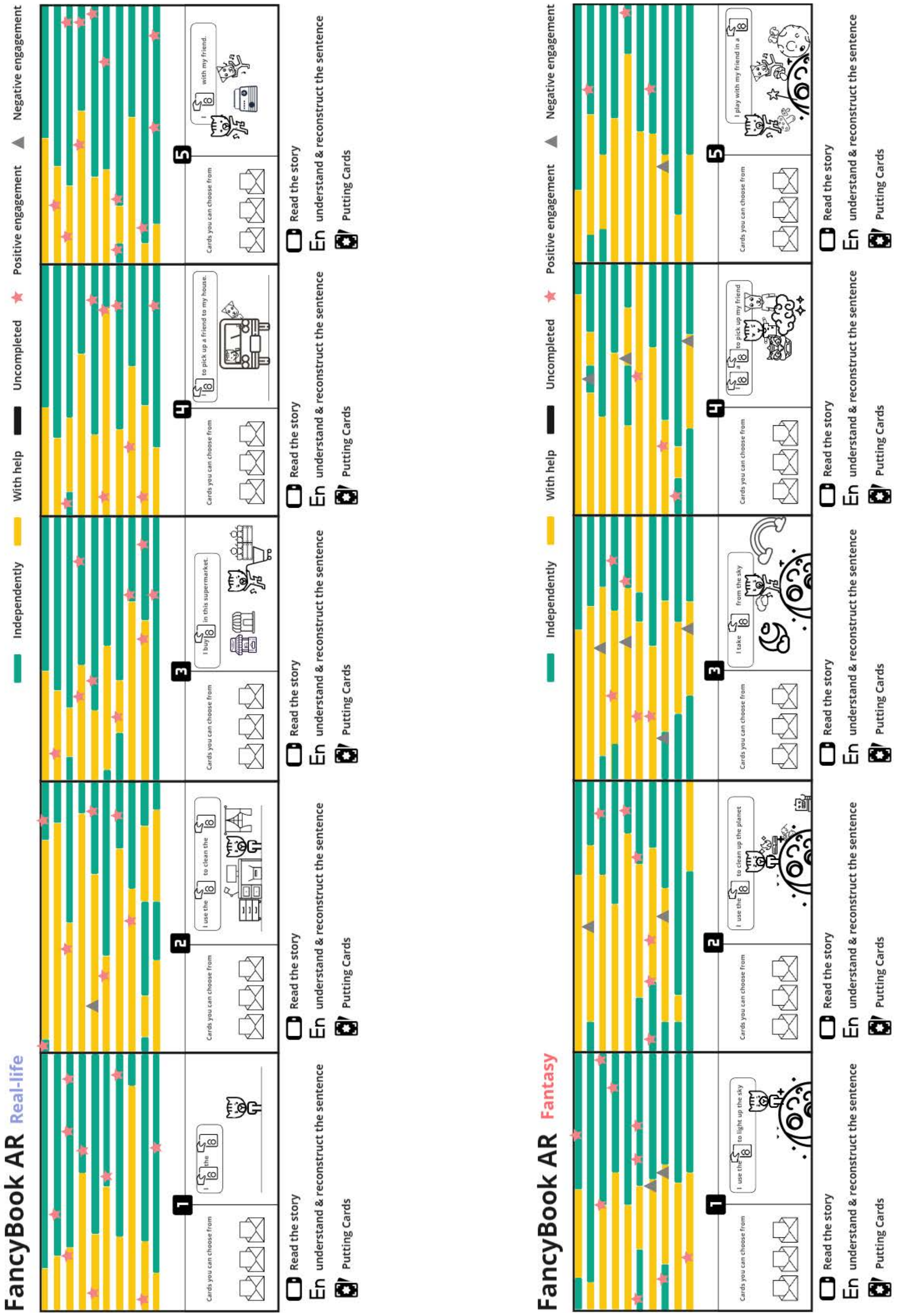


Figure 7.5: User journey maps of FancyBookAR with the real-life version (left) and the fantasy version (right)

7.5.3.4 FancyBookAR: Differences between two narratives versions

More participants read along with the sentence and showed more initiative to tell the teacher the corresponding Chinese translation with the real-life narrative. With this version, participants were more active in asking questions, showing confidence in understanding words related to the context. Whereas with the fantasy version, the meaning and application of words like “trash-eating monster” and “magic stick” were alien to the participants. They showed signs of confusion and prolonged hesitation even after teachers translated these words into Chinese.

7.6. Discussion

7.6.1. Does fantasy or real-life narrative in AR game-based learning in the classroom provide a more engaging and immersive experience for participants?

In general, the fantasy narrative leads to stronger mental states of imagination, while the real-life narrative leads to stronger analogy. Learning English with the game FancyBookAR, participants perceived significantly higher enjoyment and immersion in the real-life version than in the fantasy version. Combining their self-reported enjoyment and autonomy (Table 7.8) with patterns of engagement (Figure 7.3), we found fantasy in FancyBookAR led to less enjoyment and negative cognitive engagement for participants. Despite participants having stronger aroused emotional engagement at the beginning of the gameplay with the fantasy narrative of FancyBook AR, their confusion with the fantasy narrative setting eventually negatively influenced their play experience. This also explains the conflicting results: participants perceived more aroused emotional engagement at the beginning with the fantasy FancyBookAR, but they self-reported they enjoyed the fantasy version less than the real-life version after the gameplay.

Participants learning mathematics with the game MathMythosAR2 reported slightly but statistically insignificant higher enjoyment and presence with fantasy narratives. Their engagement pattern suggests more positive emotional engagement in the fantasy narrative. Although the fantasy narrative caused confusion, it didn’t influence participants’ enjoyable and immersive experiences. Participants showed signs of negative engagement like boredom, anxiety, and being forced to play with the real-life narrative. Despite the results, it is inadequate to interpret the data as fantasy settings may favorably engage participants in Math learning and adversely engage participants in second-language learning. Instead, we wish to understand these occurrences via the lens of participants’ experiences with fantasy and the features of different learning subjects.

7.6.1.1. Contextual reasons for differences in players’ experience and engagement

The learning of English for students is topic-based and taught via subject matter material, which is a key difference between mathematics learning and second language acquisition (Gaffield-Vile, 1996). With FancyBookAR, the subject matter learners simultaneously acquired the narrative content and linguistic knowledge of English. The unfamiliarity of the content influenced learners' language comprehension and vice versa. The fantasy narrative of FancyBookAR contains more subject-specific contexts than the real-life narrative, which is regarded as an application of existing language proficiency in new contexts (Vollmer, 2009). However, unproficiency with fantasy-oriented terms hindered the application of knowledge, leading to a poor understanding of the narrative. Such a situation might refer to what O'Malley and Chamot (1990) described as foreign language anxiety and content-related anxiety, causing negative engagement, such as feelings of frustration. Similarly, pervasive and immersive games often need "reinterpretation of meaning conventions" (Nieuwdorp, 2005). Participants might have failed to achieve a suspension of disbelief if they failed to make the meaning out of the fantasy narrative when learning a second language.

The situation changed in MathMythosAR2 since solving mathematical problems like calculation can be tackled independently of story comprehension with abstract thinking methods (Atkinson et al., 1965). The phenomenon we found that participants murmured the mathematical formulae during the gameplay also partly reflected a natural separation of narrative understanding and mathematical operation when completing mathematical game tasks. The narrative theme in this game is close to the "mathematical theme" concept, which creates contexts for participants to apply their mathematical knowledge. Such extrinsically tied narrative to the learning content is not a fixed body of knowledge (Steffe et al., 2013). Therefore, confusion occurred among some participants with math learning in the fantasy narrative, but this did not seem to influence their enjoyable, immersive experience and overall engagement. Conversely, not understanding the words impacted the understanding of the story in the FancyBookAR. When participants are satisfied with meaning interpretation and construction (Nieuwdorp, 2005), they achieve a suspension of disbelief, feeling more immersed and engaged with their emotional response (Egan, 1994).

Analogy and imagination for comprehension and engagement

Our study found that the fantasy narrative triggered higher states of imagination, and the real-life narrative activated stronger analogy states. Analogy helps learners make sense of phenomena, while imagination is often regarded as the prerequisite to engaging in education in most domains (Egan, 1989). Furthermore, imagination connecting the real world to the virtual world in a Mixed Reality experience is a driving force in make-believe and creating an immersive experience (Zuo et al., 2022). Both mental states are fundamental in AR game-based learning for different stages of play. A potential point is the challenge may have an inverse effect on the imagination. Learners need to connect to prior knowledge when making sense of things (van der Spek et al., 2014). If the game is too challenging, participants are more comfortable with things they can relate to their prior experience. Therefore, how much participants are open to fantasy could depend on how confused they are not while playing.

7.6.2. What is the teachers' role in scaffolding fantasy construction and learning?

An important way of resolving participants' confusion is through teachers' scaffolding. Teachers' scaffolding in game-based learning mainly focuses on three areas in the gameplay: interaction, narrative, and knowledge.

7.6.2.1. Interaction

Children participants are familiar with digital interactions like screen touch and physical interactions like turning pages. The interaction with the augmented physical world, which requires eyes on the digital layer and hands on the physical layer, is unfamiliar, therefore, sometimes challenging for participants, especially at the beginning. Although we designed animated arrows and related instructions to highlight important areas and ways of interaction, we noticed that the teacher's instructions in the real world are still more effective than the virtual instructional content, especially for complex interactions. For example, with the game MathMythosAR2, teachers used verbal instructions and gestures to help some participants understand that triggering a virtual button is done by covering a pattern with the palm of their hand rather than clicking with their fingers. As the interaction in MathMythosAR2 is more complicated and various than FancyBookAR, we found teachers spent more effort instructing participants on how to interact. Despite the necessity of scaffolding at the beginning, too much direct intervention in the middle of the game can interrupt participants' immersion and flow experience (Barzilai & Blau, 2014). This aspect led us to consider the necessity of designing complex interactions such as virtual buttons. A more straightforward and consistent approach to interacting, like scanning cards in FancyBookAR, is effort-saving for teachers and helps participants concentrate on the main task.

7.6.2.2. Narrative

We found that the teachers' role in facilitating participants' understanding of the narrative differed between the two games. Using MathMythosAR2 for mathematics learning, participants had more questions regarding the fantasy narrative. But they also showed more initiative to try things out first, regardless of whether the narrative was correctly interpreted or not. The teacher normally assisted participants in gaining a better understanding of the narrative by describing the stories in simpler words when participants asked related questions. They sometimes inserted themselves into the pedagogical agent, teacher Steven, reading or retelling his lines. This phenomenon might be due to the similarity between the teachers' and the pedagogical agent's roles in guiding participants and focusing their attention. To reduce the feelings of being interrupted and provide a smoother play experience for the participants, we can design a pedagogical agent to function as an easy self-insert for the teacher.

Teachers' scaffolding for participants' narrative comprehension when learning English with FancyBookAR was more complicated because the narrative was intrinsically related to the language learning content. Teachers were more careful when interpreting narratives. Rather than just telling participants what the story was, they frequently encouraged participants to discuss their understanding first or waited for them to ask questions. Such ways of scaffolding connect to strategies for second-language learning.

7.6.2.3. Knowledge

Common language-learning strategies in real-world contexts are implicit knowledge acquisition and explicit knowledge learning. Implicit knowledge acquisition represents unconscious acquisition through exposure to a second language context. In contrast, explicit knowledge learning consists of a conscious introduction and instruction of the rules of languages (O'malley et al., 1990). FancyBookAR aims to engage second-language English learners in playful games without necessarily focusing on the learning contents, creating contexts for implicit knowledge acquisition. Research suggests explicit knowledge learning can facilitate implicit knowledge acquisition. The lack of explanation for unfamiliar words and explicit introduction to grammar makes self-directed learning challenging for participants with FancyBookAR. Teachers, therefore, played a role in introducing the learning contents explicitly and directing participants' attention to key learning points. Due to the unfamiliar vocabulary and its unusual application in fictional contexts, learning with a fantasy narrative required even more explicit explanations from teachers. The above phenomena reflected a need to introduce new knowledge to participants with the FancyBookAR. A device-based or a teacher-led introduction regarding the meaning, pronunciation, and application of unfamiliar vocabulary and grammar is required to facilitate the learning procedure.

With both narratives of MathMythosAR2, teachers spent little time instructing participants with learning content directly. Since children of this age were already proficient in arithmetic operations, and the narrative is not a necessary component of arithmetic knowledge, participants' incomplete understanding of the external narrative did not directly affect their ability to perform operations. Most cases requiring scaffolding are when participants make repeated calculation errors. While instructing participants, teachers often address arithmetic concepts outside of the narrative framework.

It is also noticeable that the teacher needed to explain the narrative and interaction partly because both games can be designed better. For example, for MathMythosAR2, more intuitive instruction should be offered for interaction with a virtual button. For FancyBookAR, the narrative design should consider children's familiarity with different types of stories or narration methods to accommodate better understanding. There is also a need to consider participants' different levels of academic performance when designing the games. Research suggests effective instruction for low achievers requires a context that facilitates teachers' explicit instructions and students' idea-sharing (Pfister et al., 2015). A feasible solution to create a context that facilitates certain teacher-student interactions is to design storyline branches and a separate scene that allow teachers to conduct explicit instruction for those who repeatedly make mistakes. Further strategies for addressing certain issues while situating learning in AR fantasy of game-based learning will be discussed in response to RQ3.

7.6.3. How to Situate Learning with AR Fantasy in Games to Improve Participants' Engagement, Experience, and the Teachers' Scaffolding?

Although endogenous fantasy is often regarded as an essential way of improving participants' engagement, situating learning in AR fantasy of game-based learning doesn't necessarily require turning every learning goal into a fantasy representation and integrating each part endogenously. In combination with our result, we suggest designers first consider whether the narrative is tied to the learning goals. When a narrative is not necessarily a fixed body of the learning content, designers can consider incorporating fantasy as portraying abstract concepts for narrative-independent knowledge to activate the participants' imagination, further enhancing participants' motivation and immersion, especially in repetitive practices. In situations such as second-language learning, when the narrative serves as the fixed body of the learning contents, designers first should examine whether the additional cognitive burden imposed by the fantasy narrative would impede or facilitate participants' comprehension of the knowledge. Design should consider activating users' analogy with real-life narrative, facilitating understanding where fantasy can be applied as a next step after participants have established a good understanding of explicit knowledge. Designers can partly integrate learning content with fantasy to leverage endogenous fantasy's positive effects. Designers can create fantasy and real-life mixed settings, e.g., an alien visitor settles down to regular life on Earth, allowing participants to understand the learning context that is intrinsically linked to the stories with imagination and interest.

We summarize several strategies for situating learning in AR fantasy of game-based learning to further support teachers' scaffolding on gameplay interaction, narrative, and knowledge understanding: 1) Regarding interaction, we suggest designing games with simple and consistent ways of interaction. Complex AR interaction, for the first time, needs real-world instruction. 2) When digital instruction is ineffective regardless of the game's storyline, we suggest designers consider reducing complicated interaction and giving teachers a role in the story. It's feasible to design a pedagogical agent that enables instructors to take on the role of a scaffolder. 3) To assist teachers in scaffolding new knowledge introduction and provide more instructions to low-achieving learners, we advise designing introduction scenes using real-world settings to activate analogy and offer supplementary instruction scenes for explicit explanations.

7.7. Conclusion

We answered three research questions regarding situating learning in AR fantasy of game-based learning through experiments and analyses with qualitative and quantitative data. We discovered that fantasy narratives increase participants' engagement in mathematics learning while disengaging participants in second-language learning. They perceive stronger immersion with AR fantasy for mathematics learning than with AR fantasy for second-language learning. Fantasy narrative activates participants' imagination, while real-life narrative enables their minds to analogy. We found the basis of developing affective incentives to fantasy is related to participants' comprehension of the contexts. They are more open to imagination and fantasy when there is less challenge in learning. We found that teachers' scaffolding mainly focuses on complicated interaction in AR with MathMythosAR2 for learning Math. With FancyBookAR for learning English, teachers' scaffolding mainly focuses on narrative interpretation and knowledge explanation. We further contextualized and explained the phenomena we found and suggested several guidelines for situating learning in the AR fantasy of game-based learning. 1) When the narrative is not intrinsically tied to the learning goal, design can employ fantasy narrative to represent abstract concepts, activating affective incentives to immerse and engage participants more, especially in repetitive practice. 2) When the story is intrinsically tied to knowledge to be learned, we recommend starting with real-life narratives that engage the user's analogy mind to aid interpretation, then progressing to fantasy narratives as the next level of play. 3) We also recommend mixing fantasy and real-life settings to achieve positive effects of imagination and analogy mental states in the actual design. 4) We recommend a design with simple AR interaction like card tracking, which is effort-saving for teachers and task-concentrating for participants. 5) It's feasible to design a pedagogical agent that enables teachers to seamlessly take on the role of scaffolding at any time. 6) Design should also prioritize analogy activation when constructing scenes for de-vice-based or teacher-led presentations of new information for beginners, as well as clear explanations for low-achieving learners.

7.8. Limitations

We could not invite participants from different regions to the same laboratory due to the local covid-19 policy restrictions. Influence from different lab settings was not balanced out in our research. The two games differ in the specific play steps and details due to the different learning methods of the two subjects, which we did not eliminate as an effect on the experimental results. We could not eliminate the chance that quantitative research with children might involve over-scored situations and fail to represent their thinking effectively. We could only give more comprehensive perspectives by adding qualitative analyses. For experimental purposes, we only set magic story narratives as the fantasy condition and school-home life narratives as the real-life condition. In actual game design, fantasy covers a wider range of categories, and its application is often integrated with real-life conditions, which requires further exploration and research.

This page intentionally left blank

Conclusion

Conclusion, Contribution, Limitations, and Future Work

Chapter 8

8.1. Introduction

AR game-based learning, creating a virtual and real-world blended "magic circle" (Huizinga 2014), invites participants to engage in learning with a lusory attitude, an attitude of overcoming unnecessary challenges (Michalos, 1981). Augmented Reality (AR) enhances tangible interaction in a classroom (Taufiq et al., 2021), while player experience and motivation to learn can be further improved through game-based learning (Pertierra et al., 2017). However, poorly designed learning games render negative player experiences, including limited control, frequent interruptive instructional content, and unappealing narratives (Sanford et al., 2015). These negative experiences will eventually prevent participants from stepping into the magic circle. A separation from everyday life, e.g., fantasy in games, is promising to construct a persuasive and pervasive magic circle (Huizinga, 2020).

According to previous work, fantasy, AR, and game-based learning are promising factors that potentially improve participants' motivation and experience, enable efficient learning, and facilitate smooth scaffolding and situated learning if designed properly. There is a need for research on design strategies for integrating fantasy game elements with learning content that leverage AR's technology affordance to enable educational effectiveness in the participants' game-based learning journey.

In this thesis, we started by exploring the constitution of fantasy in serious games, identifying a classification of fantasy available for design and research. We conducted four studies following a four-phase player journey including 1) before playing, i.e., attraction to gameplay and starting to play; 2) during gameplay, i.e., when players immerse themselves in play; 3) after gameplay, i.e., when players recall knowledge of gameplay; and 4) the social context of gameplay, i.e., when applying gameplay in a classroom. For each study, we introduced our designed games, referring to the classification of fantasy in serious games, which is constructed in Chapter 2. We apply quasi-experiment and qualitative analyses methods to explore four aspects of the game-based learning journey:

1. How can fantasy attract/invite children to a game?
2. How can fantasy support engagement during gameplay?
3. How can fantasy support learning after gameplay?
4. How do fantasy games for learning fit in a classroom environment?

This chapter summarizes answers to each study's research questions that had been discussed in previous chapters. With responses to each research question, we reflect on our research and design choices and how they influenced the subsequent research and design choices. We address design issues arising at four nodes in a game-based learning journey, providing designers and academics with design guidelines. Lastly, we discuss the contribution, limitations, and future directions.

8.2. Summary of the Results

8.2.1. Summary of Results Chapter2, Answer to RQ1: What constitutes fantasy in serious games?

Fantasy, describing fanciful situations or ideas that differ from reality, has two major aspects: [mental activities] and [artifacts]. The mental activities of fantasy represent people's internalization of unusual and unreal external objective stimuli.

Research in mental activities related to fantasy focuses on several directions. Fantasy orientation describes the types of fantastical worlds in which one tends to think and play (Bunce & Woolley, 2021b). Fantasy proneness identifies one's willingness to engage in imaginary activities (Merckelbach et al., 2001). Mental states of fantasy include imaginary or analogical thoughts as well as identification with and satisfaction from outside contexts. The player experience of fantasy includes the emotional, immersive and satisfactory experience aspects of fantasy (Choi et al., 2013).

Fantasy artifacts represent fantasy contexts, elements, and themes that are constructed by humans. We classified the focus and directions within this broad area into several subcategories. The main directions of innovation in fantasy artifacts include aspects like creative fantasy, i.e., a ground-breaking creation of novel fantasy, and the portrayal of fantasy, i.e., restructuring or reinvention of existing ideas (Lee, 2015). There are elements of games that can integrate fantasy, including play mechanics, stories, aesthetics, and technology (Schell, 2014). Fantasy can furthermore be classified into different genres. However, genres continuously blend different fantasy depictions and schemas and are subsequently too rich to be covered by a classification. We highlight only a few types and categorize them into narratological and ludological viewpoints on game design. A narratological approach to fantasy includes avatars such as aliens, dragons, ninjas, and robots; stories such as cyberpunk, magic, horror, and alternate history; narrative methods such as nonlinear, ring-shaped, retro; visual rendering styles such as cartoon, pixel, gothic. A ludological approach to fantasy includes alternative gameplay viewpoints such as third-person, top view, and side-scrolling; player modes such as asynchronous multiplayer and Player-Versus-Environment; novel rules such as time manipulation, action, adventure, Role-Playing Game, and more.

With various types of fantasy, integrating games with instructional content requires a delicate design. Design strategies for employing fantasy in serious games mostly focus on two ways of integration: endogenous fantasy and exogenous fantasy, that is, meaningfully integrating the learning content with the fantasy or using the fantasy to motivate the learning of unintegrated learning content.

8.2.2. Reflection on Our Research Related to Findings in Chapter 2

Creating the fantasy classification helped us survey the state of art and identify avenues for design interventions. We found that previous research regarding fantasy mainly focused on the aspects of mental activities, while the existing applications and practices focused on ways to create and apply different kinds of fantasy in games. The intersection of these two areas was still unexplored regarding how fantasy game elements affect players' mental activities and how mental activities subsequently influence learning activities.

8.2.3. Reflection on Our Design Choices Related to Findings in Chapter 2

The "artifacts of fantasy" we constructed through the review in Chapter 2 guided our design research in four studies. Considering the need to employ fantasy in a learning context, we chose the portrayal of fantasy, that is, a recreation of fantasy based on existing work, which brings fewer cognitive challenges to learners. In this research, we found various aspects of fantasy elements that we can design for game-based learning. Given that this research project is not unlimited in time and is exploratory in nature, we decided not to go through every fantasy genre and every type of fantasy game element. Considering the potential connection to previous research on thematic-fantasy play, we, therefore, decided to focus on the narratology genre of fantasy and explore its motivational effects during learning activities.

Therefore, we chose fantasy avatars and stories from the narratology genre of fantasy as the subject of our design research. We employed the fantasy story type of "magic," a representative theme of "high fantasy" (Sullivan, 2018), in the design of four different games. Subsequently, we investigated how a magical fantasy setting compared to a real-life setting of the same game design.

8.2.4. Chapter 4, Answer to RQ2: How can fantasy and similarity influence player identification and motivation?

To answer this research question, we designed avatar aspects of fantasy in AR game-based learning. Through a literature review, we found avatar identification is a key concept to players' motivation. Therefore, we addressed two related sub-questions:

RQ2.1: Do players have distinct avatar identifications (similarity and wishful identification) for a fantasy or a real-life avatar setting, for a similar or a dissimilar avatar setting?

We found Players perceived more similarity identification toward similar (humanoid) avatars than dissimilar (animaloid) avatars. Whether the avatar was fantastical or not did not influence players' similarity identification. However, players did score higher on wishful identification with fantasy avatars compared with real-life avatars and with similar (humanoid) avatars compared with animaloid avatars.

RQ2.2 How does participants' avatar identification affect motivation when playing with different fantasy and similarity game settings?
Our finding suggested participants enjoyed game-based learning more in the fantasy settings, which in turn encouraged more wishful and similarity identification. This finding demonstrates that fantasy avatars possibly enable an enjoyable experience by altering self-perception, providing pretend play, and having imaginative wishes fulfilled.

We also found that humanoid avatars activated players' motivation through similarity identification. It is possible that a more similar humanoid avatar would create less self-discrepancy, making it easier for players to insert themselves into the role.

8.2.5. Reflection on Our Research Related to Findings in Chapter 4
The results of our quasi-experiment suggest that fantasy avatar settings and self-similar avatar settings can foster players' motivation through avatar identification. Although the findings relating identification to enjoyment in study 1 are correlations and not causation, this could partly explain why some serious games with animal characters fail to attract young players, as the avatar may not provide sufficient identification to stimulate enjoyment.

These findings on avatar design guided our exploration of fantasy-driven narrative design in future work. In this research, we found that including fantasy elements in the design did not ensure that every player was in a fantasy state of mind, as each player approached various game features with a unique attitude. It is thus critical to incorporate a measure of players' fantasy states to further understand players' attitudes toward different fantasy game elements in future research. Additionally, in this study presented in Chapter4, we discovered the potential of player experiences, such as player identification, that are impacted by fantasy design and affect learning. This finding encouraged us to explore more aspects of player experience with fantasy in AR game-based learning.

8.2.6. Reflection on Our Design Choices Related to Findings in Chapter 4
In this study presented in Chapter 4, we identified avatar similarity and avatar fantasy as two independent factors that affect players' identification and

enjoyment. Players appreciate fantasy settings. Humanoid avatars are likely to be more effective at generating the motivating effect associated with similarity identification. As a result, we've decided to use human avatars as the primary characters in our next game design and study. In this work, we found participants showed interest in giving their own explanation of the animation and developing a narrative with the animation. It is promising to explore incorporating fantasy narratives into augmented reality (AR) game-based learning in the next study. Therefore, we expanded the current card game by creating books with narratives in fantasy settings, which require more time for engagement and complicated interaction than a simple card game. As the game mechanism grew more complicated, we incorporated interaction guidelines and used flow theory (Nakamura & Csikszentmihalyi, 2009) to increase the game's difficulty as the story unfolds progressively.

8.2.7. Chapter 5, Answer to RQ3: What's the mediating effect of fantasy on engagement in an AR game for learning?

With the positive effect of AR fantasy on player identification and motivation, we're asking this question with the temporal framework in mind: how does fantasy draw children in, mediate enjoyment during gameplay, and affects learning outcomes? To understand the relationship between fantasy narratives, fantasy states, player experience, and motivation, we divided the primary research question into sub-questions in study 2. Firstly, we wanted to understand players' experiences in two conditions, a fantasy setting with stories of magic and a real-life setting with stories of school life.

RQ3.1 How do two AR fantasy narratives (fantasy/real-life) in games influence the general experience?

Payers perceived significantly stronger imagination, presence, and identification with fantasy narratives than with real-life narratives. These findings led us to explore any mediated effect of fantasy states between the game's fantasy settings and the player's enjoyment. Therefore, we investigated the following sub-research question.

RQ3.2 What are the mediation effects of fantasy states on the relationship between fantasy settings and enjoyment?

The results showed that only imagination states of fantasy mediated the relationship between game conditions and enjoyment. After identifying imagination as an important mediator in the relationship between conditions and enjoyment, we were curious to see if player experiences would play a role in the relationship between imagination and enjoyment. Therefore, we investigated the following sub-research question.

RQ3.3 What are the mediation effects of need satisfaction on the relationship between players' fantasy states and motivation?
We found a significant mediation effect when setting autonomy and presence aspects of players' need satisfaction as mediators between imagination and enjoyment.

8.2.8. Reflection on Our Research Related to Findings in Chapter 5
This research confirmed the key role of imagination as a mediator between fantasy narrative and motivational play. Bringing enjoyable imagination requires designers to immerse players in an AR game-based learning context where learning is perceived as similar to playing a game instead of a learning activity. After viewing the motivational effect of fantasy from a player experience perspective, we were curious to evaluate the impact of employing fantasy in AR game-based learning from a learning outcome perspective. We conducted studies with Chinese students. We are also curious if there were any effects caused by cultural differences. Therefore, we have decided to include international students in our next move to offer more comprehensive perspectives of learning situations in different cultures.

8.2.9. Reflection on Our Design Choices Related to Findings in Chapter 5
This study confirmed the positive effect of fantasy narratives on engaging learners. What remains to be explored is how does the effect of learning with AR fantasy. Meanwhile, after two research studies on mathematics learning, we found a promising effect of AR fantasy on mathematics learning. However, it is uncertain if such a positive effect would remain the same in other learning domains with abstract concepts requiring representation. Therefore, we decided to design for learning chemistry, a subject containing both conceptual and practical knowledge. We want to explore how AR fantasy influences players' recall of declarative knowledge.

8.2.10. Chapter 6, Answer to RQ4: How does the incorporation of fantasy in AR game-based learning influence learning and recall of declarative knowledge?
Through a review of related work, we found working memory is a key to effective learning (Jarvis & Gathercole, 2003). Therefore, we planned to evaluate if fantasy in AR game-based learning will benefit knowledge retrieval throughout the memory process. We conducted a quasi-experiment, setting the [AR or Non-AR baseline] as the within-subject factor and [fantasy or ordinary] as the between-subject factor. We explored the learning effect of AR fantasy in game-based learning by answering four sub-research questions:

RQ4.1: Is AR with fantasy more effective at improving recall than AR with real-life content?

For children participants, design using fantasy settings on the augmented layer was more effective at enhancing recall than designing AR with real-life settings.

RQ4.2: How do participants perform with AR in comparison to their recall without AR?
Teenagers did not demonstrate a substantial difference in performance between AR and baseline.

RQ4.3: After playing with AR, will the recall of the augmented content be activated by content on cards?
We discovered that adding photos as supplementary information improved students' recollection in one baseline group and the AR fantasy group. There was potentially some lasting effect of AR fantasy on enhancing recall.

RQ4.4 Do age groups, genders, and locations associate with any difference in the recall?
We found that adults performed differently from teenagers. Adults' performance was influenced by whether AR was used. With AR, adults score better. Teenagers' recalls were determined by whether the game featured fantasy or real-life settings, with teens doing better when exposed to AR fantasy content.

Teenagers in Changzhou generally recall better than other participants and performed well in all cases. ISE students learned more effectively in AR with fantasy representations than with ordinary materials. JVB students gained significant improvement over baselines after playing the AR fantasy version.

8.2.11. Reflection on Our Research Related to Findings in Chapter 6

This study responded to the concerns about the learning effectiveness of employing fantasy in AR game-based learning. We discovered that using AR fantasy in game-based learning could increase teens' recall of declarative knowledge, increasing learning effectiveness in traditional learning contexts. We found that AR fantasy could potentially leave players with a lasting impression of virtual overlays on physical objects, resulting in teenagers' improved recall.

This study introduced players with international backgrounds, assisting us in developing appropriate design techniques for incorporating fantasy into AR game-based learning that facilitates recall of declarative knowledge. We found adults reacted differently from teenagers, who demonstrated an improvement in performance with AR regardless of whether fantastical or real-life settings were used. We also found a difference between students' performance with AR and fantasy caused by different learning contexts and cultural backgrounds.

Given the positive learning effect and motivational effect of AR we found in this and the previous work, we want to explore how AR fantasy can be situated in a classroom. Furthermore, to generalize design strategies that suit different learning subjects, students' engagement, and teachers' scaffolding, we want to explore and compare different learning subjects and identify how AR fantasy works in language learning compared to mathematics learning. Through this, we want to develop design strategies that are adaptive to various learning features and participants' needs.

From the aspects of research methods, we found that qualitatively investigating study questions were required in future work because some children did not completely comprehend the scales and reversed questions and may have given overly positive responses out of consideration for kindness.

8.2.12. Reflection on Our Design Choices Related to Findings in Chapter 6

To this point, our ideas have been researched on the process of individual learners playing the game by themselves. Communication and interaction between teachers and students, on the other hand, are critical in classroom contexts. It is yet unknown how the fantasy scenario influences students' learning and teachers' instruction. We were curious about the key design aspects of incorporating fantasy into AR serious games for classroom situations and different learning subjects. To investigate this, we subsequently chose our previous storybook form by creating an AR serious game combining cards and storytelling elements. Additionally, we designed a storybook together with cards for second language acquisition to compare it to the previously designed MathMythosAR2 for mathematics instruction, examining the influence of augmented reality and fantasy on various disciplines.

8.2.13. Chapter 7, Answer to RQ5: How does AR fantasy in game-based learning need to be designed to fit in the classroom context?

With qualitative and quantitative studies, we examined player engagement and teachers' scaffolding in fantasy and non-fantasy environments across two learning disciplines to answer RQ5.1 and RQ5.2. We developed strategies for situating learning in AR fantasy of serious games based on our findings, responding to RQ5.3.

RQ5.1: Does fantasy or real-life narrative in AR game-based learning in the classroom provide a more engaging and immersive experience for participants?
A stronger imagination mental state was found with the fantasy than with the real-life version, while a stronger analogy mental state was found with the real-life than with the fantasy version. We found participants had a higher emotional engagement with both games' fantasy versions. However, participants had a

negative engagement, like confusion and frustration for failure with the fantasy version of FancyBookAR. We discovered that fantasy narratives increased students' engagement in mathematics learning while disengaging students in second-language learning. Children's self-reported enjoyment is significantly higher with the real-life version than with the fantasy version in FancyBookAR. We found an interaction effect in immersion, suggesting children perceive stronger immersion with the fantasy than with the real-life version in the game MathMythosAR2, while the situations reverse in the game FancyBookAR.

RQ5.2: What is the teachers' role in scaffolding fantasy construction and learning?
We discovered that teachers' scaffolding mainly focused on helping students understand complex interactions in AR with MathMythosAR2 for math learning, as AR interaction, such as the virtual button, was still new for participants. With the fantasy version of MathMythosAR2, there was more need for teachers' explanation of the narrative than the real-life version. However, students also showed more initiative to try out first, regardless of whether they fully understood the fantasy narrative. Teachers' scaffolding using FancyBook for English learning was mostly focused on narrative interpretation and knowledge explanation. Participants who had difficulty understanding the narrative also found it challenging to comprehend the knowledge with FancybookAR. Such a situation occurred more frequently with the fantasy version of FancybookAR than with the real-life version.

RQ5.3: How to situate learning with AR fantasy in games to improve participants' engagement, experience, and the teachers' scaffolding?
We extended contextualization and explanation of the observed phenomena with previous research. In accordance with the answers to RQ5.1 and RQ5.2, we further synthesized design strategies of situated learning in game-based learning with AR fantasy:

1. When the narrative is not intrinsically linked to knowledge, design can leverage fantasy stories to represent abstract concepts, triggering affective incentives to increase students' immersion and engagement, especially when doing recurrent practice.
2. When the narrative is intrinsically linked to the knowledge to be learned, we advocate beginning with real-world narratives that engage the user's analogy mental state and assist in interpretation before advancing to fantastical narratives as the next level of play.
3. It is also recommended to integrate fantasy and real-world contexts to maximize the benefits of imagination and analogous mental states in the actual design.
4. Design should incorporate simple AR interactions such as card tracking, which saves teachers time teaching the students how to play and helps students focus on the learning aims.

5. It is possible to create an in-game pedagogical agent that enables teachers to insert themselves into the role of scaffolding at any moment smoothly.
6. Design should also consider prioritizing the activation of analogies while creating scenes for device-based or teacher-led presentations of new knowledge for beginners, as well as providing explicit explanations for low-achieving learners.

8.2.14. Reflection on Our Research Related to Findings in Chapter 7

Through this study, we found that participants' affective incentives to be engaged with the game are related to participants' comprehension of the contexts. The application of fantasy will influence participants' comprehension, especially when the narrative is intrinsically tied to the knowledge to be learned. When there is more challenge in comprehension and learning, children are less open to fantasy, and more scaffolding from teachers is required. The design of fantasy in AR game-based learning should consider both situations of the learning content and teachers' roles.

Besides, we also find a promising direction of combining fantasy and real-life settings together. For comparison purposes in this exploratory research, we defined fantasy and real-life settings distinctively. In future work, more levels of fantasy and a combination of fantasy and real-life is promising for providing engaging environments with challenges suitable for different learning situations.

8.3. Conclusion

Throughout the thesis, we conducted a literature review and four studies investigating the application of fantasy in AR serious games. In study 1 (Chapter 4), we found avatar design with similarities and fantasy can increase children's avatar identification. The correlation between avatar identification and motivation with similar and fantasy avatars indicated a path to invite children to a game. In study 2 (Chapter 5), we identified players' imagination as a mediator between fantasy settings and engagement and player experience as a mediator between imagination and engagement. This finding indicated that players' engagement could be supported by fantasy through improved experience and an increased level of imagination. In study 3 (Chapter 6), we found that fantasy improves children's learning and recall of declarative knowledge. We contend that well-designed fantasy transformed redundant information into a facilitator for recalling declarative knowledge and eventually supported learning after the gameplay. In study 4 (Chapter 7), we discovered participants' engagement with fantasy is affected by the challenges they encountered. When the learning content was intrinsically related to the fantasy narrative, it became challenging for them to learn, and they showed signs of disengagement, requiring more scaffolding from teachers. To fit fantasy into a classroom environment, designers need to consider whether the learning subject is intrinsically related to the narrative, positioning teachers' roles and balancing children's engagement and comprehension.

8.3.1. Design Guideline

According to our findings through four studies, we addressed the four stages of the game-based learning journey mentioned in Chapter 1: 1) before playing; 2) during gameplay; 3) after gameplay; 4) the social context of gameplay. We summarize the strategies of designing with fantasy in AR game-based learning from four studies' findings (Figure 8.1). In the left column, there are four key nodes in a game-based learning journey and key issues to be addressed by the design strategy, respectively. In the middle column are the key factors related to the design solution. The detailed strategies for design with fantasy in AR game-based learning are highlighted in the right column, which was summarized through the exploration of related key factors in four studies.

This diagram of design strategies can serve as a guideline for designers to refer to when employing fantasy in AR game-based learning for players at different stages. Designers can also access the corresponding design strategies based on keywords relevant to their design, such as imagination, working memory, etc.

8.4. Contributions

This research made theoretical, empirical, and artifactual contributions to the design research spectrum of Human-Computer Interaction, specifically in domains of game design, Augmented reality, and game-based learning. We provided theoretical contribution through enriching knowledge about the definition of AR fantasy and its effect on player experience, motivation, learning outcome, and learning situation.

The classification of fantasy we provided through categorizing related theoretical and practical work offers multiple definition perspectives toward clearer concepts of fantasy. The classification includes different aspects of fantasy definitions researchers can refer to for their research and types of fantasy in artifacts designers can design, and types of fantasy in mental activities design can activate. The design strategies we built (Figure 8.1) through the four studies can serve as an update of the classification we constructed previously in the "strategies for the adaption" part of fantasy in artefacts (Table 2.1, Chapter 2.) In future work this classification of fantasy should be updated through case studies and empirical studies. We hope our design strategies can provide guidelines for researchers on related topics of designing with fantasy in game-based learning. It can stimulate more exploratory research to utilize the potential of augmented reality and game-based learning.

Our empirical studies provided an improved understanding of designing with fantasy in AR game-based learning, expanding existing knowledge about the player experience, identification, motivation, situated learning, and working memory to new domains. All the concepts, data, research methodologies, and tools included in this research may serve as further inspiration on both content and procedure levels for other scholars and practitioners. The design strategies derived from the four studies can serve as guidelines and references for designers when addressing their cases. Designers can benefit from the design strategies we provide to meet diverse learners' needs, generate new concepts, balance educational requirements and learners' experiences and create their designs with augmented reality and fantasy.

We present four designs of AR serious games in this research, which function as artifact contributions, including structures, methods, approaches, or designs that disclose new prospects, results, insights, and explorations. Our designs present the general public inspiration to contemplate new possible futures of learning with fantasy, playfulness, and extended reality technologies. We provided examples of design cases addressing the creation of engaging learning settings in classrooms, enabling the technological affordance of AR in education, connecting learners and educators with fun and meaningful learning experiences, and shaping the future of 21st learning.

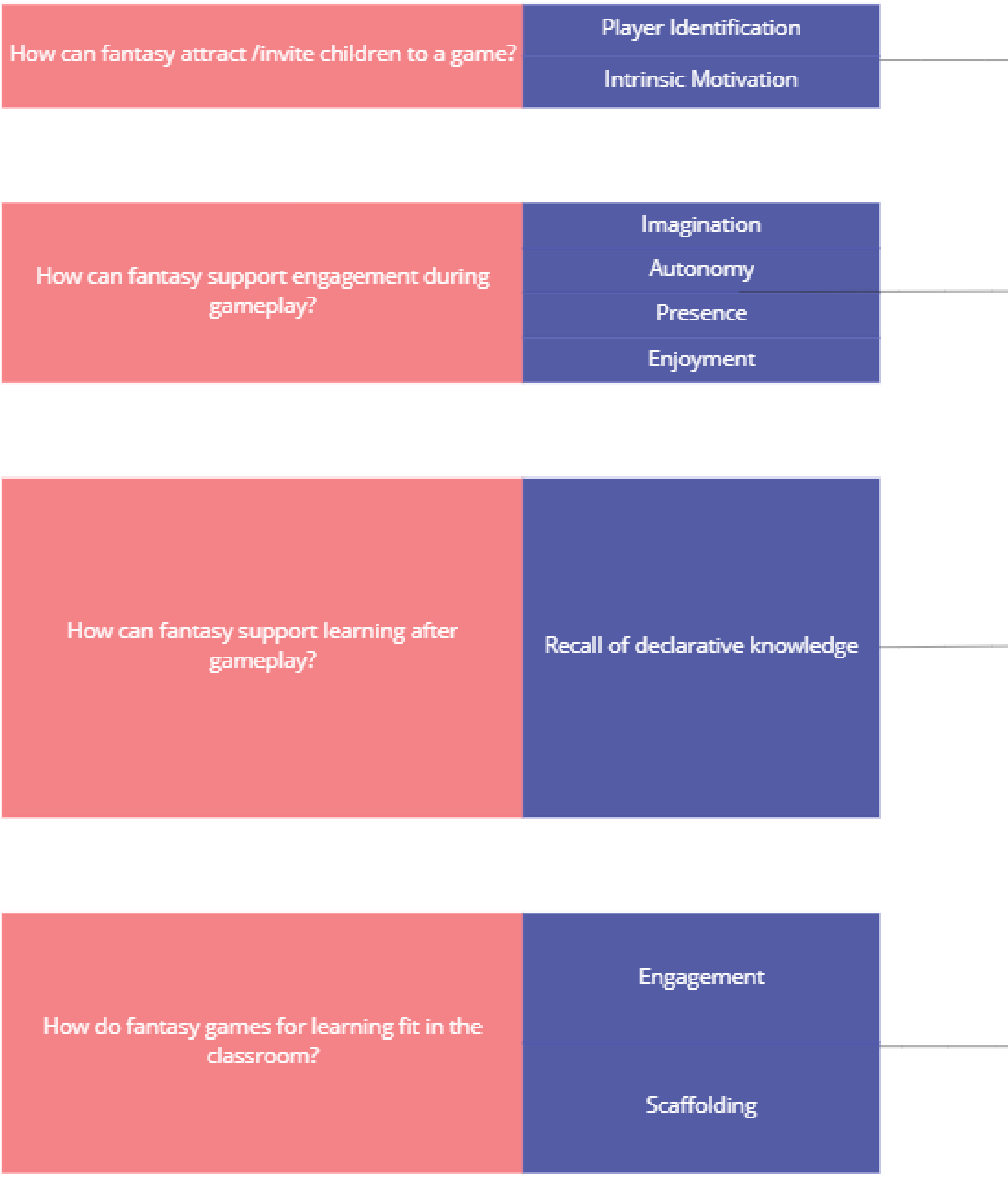


Figure 8.1: Guidelines for designing with fantasy in AR game-based learning

Before

Design with fantasy avatars
Design with player self- similar avatars

During

Activation of imagination is more important than that of identification
Design with openness and creativity, immersion of mixed fantasy
fantasy characters and storylines can be tailored to individual tastes.
Design with fantasy elements that stimulate imagination states of fantasy

After

Design with recognizable AR fantasy representations can enhance recall
Switch between playing physical materials with and without augmented layers to engage the players' imagination.
It is vital to understand target user groups' fantasy orientation, the forms of fantasy users appreciate.
AR is sufficient for adults, while children appreciate AR with fantasy.
Students with enough learning abilities can be motivated to perform better with AR fantasy; For beginners AR is a good start; For students with reproduction-directed learning design can focus on inspiration of creativity.

Environment

Employ fantasy when the narrative is not the fixed body of knowledge
Employ real-life narrative first then move to fantasy, when the narrative is the fixed body of knowledge
design with simple AR interaction
design a pedagogical agent that enables teachers to insert their role of scaffolding
For beginners and low achiever, design of scenes should prioritize analogy activation.

8.5. Limitations and Future Work

8.5.1. About the Target Groups

Due to limited time and effort, we only invited students from China and the Netherlands, which might bring this work with limitations of generalization toward children from different cultural backgrounds. Although we tried to give complementary perspectives through qualitative research, there were some unavoidable challenges with children when doing quantitative research. Some young children tended to give extreme scores and had trouble expressing comprehensive attitudes and understanding neutral attitudes from the scale. Some children may respond in a way that they think meets the experimenter's expectation to achieve recognition from adults. Future research should pay more attention to whether children are expressing their true thoughts and whether they are capable of doing so in the given contexts. Feasible solutions regarding this issue in future work include reducing the identity gap between experimenter and subject, adding some objective questions that they feel safe to judge, giving more open questions, creating a more relaxed atmosphere, etc.

We investigated the application of fantasy in AR learning games for children aged 7~15. Children under 7 years old who are still at a preoperational stage with their cognitive and motor skills development may have difficulty understanding digital interaction (Ferreira et al., 2016). Design for this age range might require different considerations. Therefore, the outcome of this research might not suit this case. We explored adults' performance with AR fantasy in Chapter 6, finding some promising AR aspects in improving their learning efficacy. However, it is still questionable if our proposed design guidelines are suitable for adults, which requires further investigation.

8.5.2. About the Procedure

Aiming to offer more comprehensive perspectives of and explore fantasy in more disciplines and learning contexts, we designed four different games that addressed various learning subjects and research focuses instead of offering different iterations of the same design. However, the design choice we made might lead to an incoherence of experience we gained from one study and applied to the next. A viable path for our next step is to deepen research in a subject by focusing on a single topic and iterating the same game.

Due to varying Covid-19 regulations in the regions where we conducted our experiments, the number of participants differs significantly by location. Participants were recruited and involved in the experiment in a variety of ways: individually and collaboratively, locally or remotely, which might have unexpected effects on our results. As the outbreak fades and rules become more relaxed, we anticipate inviting more volunteers from a broader range of backgrounds and performing experiments in more carefully controlled experimental settings.

8.5.3. About the Topic

Despite the comprehensive coverage we presented in fantasy classification, our research only focused on avatars and narrative aspects of fantasy due to the limited time and technical feasibility. We are currently in the explorative phase of research due to the paucity of research on fantasy in Augmented Reality game-based learning. Therefore in the current phase, we focused on identifying whether fantasy in AR game-based learning had any effect. Different types of fantasy, e.g., sci-fi, steampunk, aliens, and more aspects of fantasy, e.g., interaction types, rules, and viewpoints, are still to be explored.

Meanwhile, the guidelines for designing with fantasy in AR game-based learning that we developed may only be applicable as a reference for several designers and will not apply to every case of learning game design. For example, AR learning games for museums would be completely different situations because participants might approach the game with different mental states and interactive contexts than in a classroom. We defined four phases of a player's journey in the research in this thesis. However, some aspects in each phase may still remain unexplored. For example, how should one design AR learning games for whole-class scaffolding situations? There could also be more phases in the players' journey that we have not explored. For example, the phases where players turn off the game, walk out of the magic circle and listen to teachers' instruction. We hope to further develop and enrich this research through more exploration in this field in our future work.

Reference

* all images in this thesis are drawn by Tengjia Zuo unless otherwise specified.

Abu Talib, M., Bettayeb, A. M., & Omer, R. I. (2021). Analytical study on the impact of technology in higher education during the age of COVID-19: Systematic literature review. Education and Information Technologies, 26(6), 6719–6746. https://doi.org/10.1007/s10639-021-10507-1

Adedokun, O., Henke, J., Parker, L. C., & Burgess, W. (2017). Student Perceptions of a 21st Century Learning Space. Journal of Learning Spaces, 6(1), 1–13.

Alessi, S. M., & Trollip, S. R. (2001). Multimedia for learning: Methods and development. Allyn & Bacon.

Amabile, T. M. (1985). Motivation and Creativity. Effects of Motivational Orientation on Creative Writers. Journal of Personality and Social Psychology, 48(2), 393–399. https://doi.org/10.1037/0022-3514.48.2.393

An, Y. J., & Reigeluth, C. (2011). Creating Technology-Enhanced, Learner-Centered Classrooms: K–12 Teachers' Beliefs, Perceptions, Barriers, and Support Needs. Journal of Digital Learning in Teacher Education, 28(2), 54–62. https://doi.org/10.1080/21532974.2011.10784681

Anderson, R., Manoogian, S. T., & Reznick, J. S. (1976). The undermining and enhancing of intrinsic motivation in preschool children. Journal of Personality and Social Psychology, 34(5), 915.

Ang, C. S., Zaphiris, P., & Mahmood, S. (2007). A model of cognitive loads in massively multiplayer online role playing games. Interacting with Computers, 19(2), 167–179.

Apperley, T. H. (2006). Genre and game studies: Toward a critical approach to video game genres. Simulation and Gaming, 37(1), 6–23. https://doi.org/10.1177/1046878105282278

Arsenault, D. (2009). Video game genre, evolution and innovation. Eludamos. Journal for Computer Game Culture, 3(2), 149–176.

Arvanitis, T. N., Petrou, A., Knight, J. F., Savas, S., Sotiriou, S., Gargalakos, M., & Gialouri, E. (2009). Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities. Personal and Ubiquitous Computing, 13(3), 243–250. https://doi.org/10.1007/s00779-007-0187-7

Asgari, M., & Kaufman, D. (2010). Does fantasy enhance learning in digital games? In Educational Gameplay and Simulation Environments: Case studies and lessons learned (pp. 84–95). IGI Global.

Asgari, M., & Kaufman, D. (2014). Relationships among computer games, fantasy, and learning. https://www.researchgate.net/publication/228703790

Atkinson, R. C., Bower, G. H., & Crothers, E. J. (1965). Introduction to mathematical learning theory.

Azuma, R. T. (1997). A survey of augmented reality. Presence: Teleoperators &

Virtual Environments, 6(4), 355–385.
Baddeley, A. (2000). The episodic buffer: a new component of working memory? Trends in Cognitive Sciences, 4(11), 417–423.
Baddeley, A., & Hitch, G. (1974). Working memory. In Psychology of learning and motivation (Vol. 8, pp. 47–89). Elsevier.
Baddeley, A., & Hitch, G. (2019). The phonological loop as a buffer store: An update. In Cortex (Vol. 112, pp. 91–106). https://doi.org/10.1016/j.cortex.2018.05.015
Baddeley, A., & Lewis, V. (2017). Inner active processes in reading: The inner voice, the inner ear, and the inner eye. In Interactive processes in reading (pp. 107–129). Routledge.
Baker, L. J., Hymel, A. M., & Levin, D. T. (2018). Anthropomorphism and Intentionality Improve Memory for Events. Discourse Processes, 55(3), 241–255. https://doi.org/10.1080/0163853X.2016.1223517
Balfe, M. (2004). Incredible geographies? Orientalism and Genre Fantasy. Social and Cultural Geography, 5(1), 75–90. https://doi.org/10.1080/1464936042000181326
Barber, A. B., Pierucci, J. M., Gilpin, A. T., McInnis, M. A., & O'Brien, C. T. (2013). Fantasy orientation constructs and related executive function development in preschool: Developmental benefits to executive functions by being a fantasy-oriented child. International Journal of Behavioral Development, 38(1), 62–69. https://doi.org/10.1177/0165025413508512
Barbosa Lima, E. (2016). Chronotope in western role-playing video games: an investigation of the generation of narrative meaning through its dialogical relationship with the heroic epic and fantasy. Brunel University London.
Baron, R. M., & Kenny, D. A. (1986). The Moderator-Mediator Variable Distinction in Social Psychological Research. Conceptual, Strategic, and Statistical Considerations. Journal of Personality and Social Psychology, 51(6), 1173–1182. https://doi.org/10.1037/0022-3514.51.6.1173
Barr, S. A., McDermott, M. R., & Evans, P. (1993). Predicting persistence: A study of telic and paratelic frustration. Advances in Reversal Theory, 123–136.
Barzilai, S., & Blau, I. (2014). Scaffolding game-based learning: Impact on learning achievements, perceived learning, and game experiences. Computers and Education, 70, 65–79. https://doi.org/10.1016/j.compedu.2013.08.003
Bateson, G. (1922). a Theory of Play and Fantasy. 149. http://courses.bloodedbythought.org/play/images/7/7e/Bateson%2C_Gregory_A_Theory_of_Play_and_Fantasy.pdf
Belland, B. R. (2014). Scaffolding: Definition, current debates, and future directions. In Handbook of research on educational communications and technology (pp. 505–518). Springer.
Biemans, H., & van Mil, M. (2008). Learning Styles of Chinese and Dutch Students Compared within the Context of Dutch Higher Education in Life Sciences. The Journal of Agricultural Education and Extension, 14(3), 265–278. https://doi.

org/10.1080/13892240802207700
Birk, M. V., Atkins, C., Bowey, J. T., & Mandryk, R. L. (2016). Fostering intrinsic motivation through avatar identification in digital games. Conference on Human Factors in Computing Systems - Proceedings, 2982–2995. https://doi.org/10.1145/2858036.2858062
Birk, M. V., Mandryk, R. L., Miller, M. K., & Gerling, K. M. (2015). How self-esteem shapes our interactions with play technologies. CHI PLAY 2015 - Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play, 35–46. https://doi.org/10.1145/2793107.2793111
Blalock, H. M. (1969). Theory construction: From verbal to mathematical formulations.
Botte, B., Bakkes, S., & Veltkamp, R. (2020). Motivation in Gamification: Constructing a Correlation Between Gamification Achievements and Self-determination Theory. In Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 12517 LNCS. Springer International Publishing. https://doi.org/10.1007/978-3-030-63464-3_15
Bouta, H., & Retalis, S. (2013). Enhancing primary school children collaborative learning experiences in maths via a 3D virtual environment. Education and Information Technologies, 18(4), 571–596. https://doi.org/10.1007/s10639-012-9198-8
Brady, T. F., Konkle, T., & Alvarez, G. A. (2009). Compression in Visual Working Memory: Using Statistical Regularities to Form More Efficient Memory Representations. Journal of Experimental Psychology: General, 138(4), 487–502. https://doi.org/10.1037/a0016797
Brehm, J. W., Miron, A. M., & Miller, K. (2009). Affect as a motivational state. Cognition and Emotion, 23(6), 1069–1089. https://doi.org/10.1080/02699930802323642
Breuer, J. J., & Bente, G. (2010). Why so serious? On the relation of serious games and learning. Eludamos. Journal for Computer Game Culture, 4(1), 7–24. https://doi.org/10.1016/j.biotechadv.2011.08.021.Secreted
Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. Educational Researcher, 18(1), 32–42. https://doi.org/10.3102/0013189X018001032
Bunce, L., & Woolley, J. D. (2021a). Fantasy orientation and creativity in childhood: A closer look. Cognitive Development, 57(November 2020), 100979. https://doi.org/10.1016/j.cogdev.2020.100979
Bunce, L., & Woolley, J. D. (2021b). Fantasy orientation and creativity in childhood: A closer look. Cognitive Development, 57(December 2020), 100979. https://doi.org/10.1016/j.cogdev.2020.100979
Cai, S., Chiang, F.-K., Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of augmented reality-based natural interactive learning in magnetic field instruction. Interactive

Learning Environments, 25(6), 778–791.
Carr, D., Buckingham, D., Burn, A., & Schott, G. (2006). Computer games: Text, narrative and play. Polity.
Cells at work official website. (2022). Aniplex of America. https://cellsatwork-anime.com/
Charsky, D. (2010). From edutainment to serious games: A change in the use of game characteristics. Games and Culture, 5(2), 177–198. https://doi.org/10.1177/1555412009354727
Chen, C. H. (2020). Impacts of augmented reality and a digital game on students' science learning with reflection prompts in multimedia learning. Educational Technology Research and Development, 68(6), 3057–3076. https://doi.org/10.1007/s11423-020-09834-w
Chen, Chen, Zhang, L., Luczak, T., Smith, E., & Burch, R. F. (2019). Using Microsoft HoloLens to improve memory recall in anatomy and physiology: A pilot study to examine the efficacy of using augmented reality in education. Journal of Educational Technology Development and Exchange, 12(1). https://doi.org/10.18785/jetde.1201.02
Chen, ChingHui, Ho, C.-H., & Lin, J.-B. (2015). The Development of an Augmented Reality Game-based Learning Environment. Procedia - Social and Behavioral Sciences, 174, 216–220. https://doi.org/10.1016/j.sbspro.2015.01.649
Choi, B., Huang, J., Jeffrey, A., & Baek, Y. (2013). Development of a scale for fantasy state in digital games. Computers in Human Behavior, 29(5), 1980–1986. https://doi.org/10.1016/j.chb.2013.04.007
Choi, G., & Kim, M. (2018). Battle Royale Game: In Search of a New Game Genre. International Journal of Culture Technology (IJCT), 2(2), 5.
Christoph, K., Dorothée, H., & Peter, V. (2009). The video game experience as "true" identification: A theory of enjoyable alterations of players' self-perception. Communication Theory, 19(4), 351–373. https://doi.org/10.1111/j.1468-2885.2009.01347.x
Clarke, R. I., Lee, J. H., & Clark, N. (2015). Why Video Game Genres Fail. Games and Culture, 12(5), 445–465. https://doi.org/10.1177/1555412015591900
Cohen, J. (2001). Defining Identification: A Theoretical Look at the Identification of Audiences With Media Characters. Mass Communication and Society, 4:3(1), 245–264. https://doi.org/10.1207/S15327825MCS0403_01
Cohen, J., Weimann-Saks, D., & Mazor-Tregerman, M. (2018). Does Character Similarity Increase Identification and Persuasion? Media Psychology, 21(3), 506–528. https://doi.org/10.1080/15213269.2017.1302344
Connolly, J. A., & Doyle, A. B. (1984). Relation of social fantasy play to social competence in preschoolers. Developmental Psychology, 20(5), 797–806. https://doi.org/10.1037/0012-1649.20.5.797
Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious

games. Computers and Education, 59(2), 661–686. https://doi.org/10.1016/j.compedu.2012.03.004
Cordova, D. I., & Lepper, M. R. (1996). Intrinsic Motivation and the Process of Learning : Beneficial Effects of Contextualization , Personalization , and Choice. 88(4), 715–730.
Council, N. R., Suzanne, M., John, D., & James, W. (1999). How people learn: Bridging research and practice (Issue 1). National Academies Press.
Craig Freudenrich, P. D. (2022). Can We See Atoms? https://science.howstuffworks.com/atom10.htm
Davis, M. H. (1983). Measuring Individual Differences in Empathy: Evidence for a Multi- dimensional Approach. Journal of Personality and Social Psychology, 44(1), 113.
de Valk, L., Bekker, T., & Eggen, B. (2015). Designing for social interaction in open-ended play environments. International Journal of Design, 9(1), 107–120.
Deci, E. L., & Ryan, R. M. (2004). Handbook of self-determination research. University Rochester Press.
Deci, E. L., & Ryan, R. M. (2012). Self-determination theory.
Deterding, S. (2016). Contextual autonomy support in video game play: a grounded theory. Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, 3931–3943.
Dillon, R. (2010). On the Way to Fun: an emotion-based approach to successful game design. AK Peters/CRC Press.
Doherty, K., & Doherty, G. (2018). Engagement in HCI. ACM Computing Surveys, 51(5), 1–39. https://doi.org/10.1145/3234149
Dondlinger, M. (2007). Educational Video Game Design: A Review of the Literature. Journal of Applied Educational Technology, 4(1), 21–31.
Douglas, Y., & Hargadon, A. (2000). The Pleasure Principle : Immersion , Engagement , Flow. 153–160.
Dunleavy, M., & Dede, C. (2014). Augmented reality teaching and learning. Handbook of Research on Educational Communications and Technology, 735–745.
Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. Journal of Science Education and Technology, 18(1), 7–22. https://doi.org/10.1007/s10956-008-9119-1
Egan, K. (1989). Memory, imagination, and learning: Connected by the story. Phi Delta Kappan, 70(6), 455–459.
Egan, K. (1994). Young Children's Imagination and Learning: Engaging Children's Emotional Response. Young Children, 49(6), 27–32.
Eraut, M. (2000). Non-formal learning and tacit knowledge in professional work. British Journal of Educational Psychology, 70(1), 113–136.
Erdoğan, V. (2019). Integrating 4C Skills of 21st Century into 4 Language Skills in EFL Classes Vacide Erdoğan. International Journal of Education and Research, 7(11),

113–124. http://www.ijern.com/
Fan, M., Antle, A. N., & Warren, J. L. (2020). Augmented Reality for Early Language Learning: A Systematic Review of Augmented Reality Application Design, Instructional Strategies, and Evaluation Outcomes. Journal of Educational Computing Research, 58(6), 1059–1100. https://doi.org/10.1177/0735633120927489
Fein, G. G. (1981). Pretend play in childhood: An integrative review. Child Development, 1095–1118.
Ferguson, C. J., & Olson, C. K. (2013). Friends, fun, frustration and fantasy: Child motivations for video game play. Motivation and Emotion, 37(1), 154–164. https://doi.org/10.1007/s11031-012-9284-7
Ferreira, S. M., Gouin-Vallerand, C., & Hotte, R. (2016). Game based learning: A case study on designing an educational game for children in developing countries. 2016 8th International Conference on Games and Virtual Worlds for Serious Applications, VS-Games 2016. https://doi.org/10.1109/VS-GAMES.2016.7590350
Field, A. (2017). discovering statistics using spss.
Filsecker, M., & Kerres, M. (2014). Engagement as a Volitional Construct: A Framework for Evidence-Based Research on Educational Games. Simulation and Gaming, 45, 450–470. https://doi.org/10.1177/1046878114553569
Flink, C., Boggiano, A. K., & Barrett, M. (1990). Controlling Teaching Strategies: Undermining Children's Self-Determination and Performance. Journal of Personality and Social Psychology, 59(5), 916–924. https://doi.org/10.1037/0022-3514.59.5.916
Fotaris, P., Pellas, N., Kazanidis, I., & Smith, P. (2017a). A systematic review of augmented reality game-based applications in primary education. Proceedings of the 11th European Conference on Games Based Learning, ECGBL 2017, 181–190.
Fotaris, P., Pellas, N., Kazanidis, I., & Smith, P. (2017b). A systematic review of augmented reality in stem education. In Memorias del xi congreso europeo en aprendizaje basado en el juego graz. https://doi.org/10.25115/eea.v39i1.4280
Frankel, L., & Racine, M. (2010). The Complex Field of Research: for Design, through Design, and about Design. International Conference of the Design Research Society, 1–12. http://www.designresearchsociety.org/docs-procs/DRS2010/PDF/043.pdf
Frasca, G. (2003a). Chapter 10. Simulation versus narrative. The Video Game Theory Reader, 221–235. http://www.phil-fak.uni-duesseldorf.de/fileadmin/Redaktion/Institute/Kultur_und_Medien/Medien_und_Kulturwissenschaft/Dozenten/Szentivanyi/Computerspielanalyse_aus_kulturwissenschaftlicher_Sicht/frasca.pdf
Frasca, G. (2003b). Ludologists Love Stories , Too : Notes From a Debate That Never Took Place. Proceedings of DiGRA 2003,«Level Up, 92–99. http://www.digra.org/dl/display_html?chid=http://www.digra.org/dl/db/05163.01125
Gaffield-Vile, N. (1996). Content-based second language instruction at the tertiary

level. Elt Journal, 50(2), 108–114.
Games, E. (2017). Fortnite. Epic Games.
Garbe, A., ogurlu, U., Logan, N., & Cook, P. (2020). Parents' Experiences with Remote Education during COVID-19 School Closures. American Journal of Qualitative Research, 4(3). https://doi.org/10.29333/ajqr/8471
Garrett, T., The, S., Interaction, C., & Case, A. (2015). Student-Centered and Teacher-Centered Classroom Management : A Case Study of Three Elementary Teachers Student-Centered and Teacher-Centered of Three Classroom Teachers Management : Study Elementary. Journal of Classroom Interaction, 43(1), 34–47. https://www.jstor.org/stable/23869529
Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. Simulation and Gaming, 33(4), 441–467. https://doi.org/10.1177/1046878102238607
Ghasemi, A., & Zahediasl, S. (2012). Normality tests for statistical analysis: a guide for non-statisticians. International Journal of Endocrinology and Metabolism, 10(2), 486.
Grabinger, R. S., & Dunlap, J. C. (1995). Rich environments for active learning: a definition. Alt-J, 3(2), 5–34. https://doi.org/10.1080/0968776950030202
Grace, L. (2005). Game Type and Game Genre Game Type. Retrieved February, 22(2009), 8.
Gray, T. (2012). Elements: A visual exploration of every known atom in the universe. Hachette UK.
Greenberg, B. S., Sherry, J., Lachlan, K., Lucas, K., & Holmstrom, A. (2010). Orientations to video games among gender and age groups. Simulation and Gaming, 41(2), 238–259. https://doi.org/10.1177/1046878108319930
Habgood, J., & Ainsworth, S. (2011). Motivating Children to Learn Effectively : Exploring the Value of Intrinsic Integration in Educational Games. June 2014. https://doi.org/10.1080/10508406.2010.508029
Habgood, M. P. J., Ainsworth, S. E., & Benford, S. (2005). Endogenous fantasy and learning in digital games. Simulation and Gaming, 36(4), 483–498. https://doi.org/10.1177/1046878105282276
Hayes, A. F. (2017). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. Guilford publications.
Heater, C. (1992). Being there: The subjective experience of presence. Presence Teleoperators Virtual Environ., 1(2), 262–271.
Henderson, B., & Moore, S. G. (1980). Children's responses to objects differing in novelty in relation to level of curiosity and adult behavior. Child Development, 457–465.
Hidi, S., & Harackiewicz, J. M. (2000). Motivating the academically unmotivated: A critical issue for the 21st century. Review of Educational Research, 70(2), 151–179. https://doi.org/10.3102/00346543070002151
Higgins, E. T. (1987). Self-Discrepancy: A Theory Relating Self and Affect.

Psychological Review, 94(3), 319–340. https://doi.org/10.1037/0033-295X.94.3.319
Hoffman, B., & Schraw, G. (2009). The influence of self-efficacy and working memory capacity on problem-solving efficiency. Learning and Individual Differences, 19(1), 91–100. https://doi.org/10.1016/j.lindif.2008.08.001
Huang, T.-L., & Tseng, C.-H. (2015). Using augmented reality to reinforce vivid memories and produce a digital interactive experience. Journal of Electronic Commerce Research, 16(4), 307.
Hughes, C. E., Stapleton, C. B., Hughes, D. E., & Smith, E. M. (2005). Mixed reality in education, entertainment, and training. IEEE Computer Graphics and Applications, 25(6), 24–30. https://doi.org/10.1109/MCG.2005.139
Huizinga, J. (2014). Homo ludens ils 86. Routledge.
Huizinga, J. (2020). Homo ludens. Editora Perspectiva SA.
Hung, Y., Chen, C., & Huang, S. (2017). Applying augmented reality to enhance learning: a study of different teaching materials. Journal of Computer Assisted Learning, 33(3), 252–266.
Ibáñez, M. B., Uriarte Portillo, A., Zatarain Cabada, R., & Barrón, M. L. (2020). Impact of augmented reality technology on academic achievement and motivation of students from public and private Mexican schools. A case study in a middle-school geometry course. Computers and Education, 145(October 2019). https://doi.org/10.1016/j.compedu.2019.103734
Iuppa, N., & Borst, T. (2012). Story and simulations for serious games: tales from the trenches. CRC Press.
Jacob Habgood, M. P., & Ainsworth, S. E. (2011). Motivating children to learn effectively: Exploring the value of intrinsic integration in educational games. Journal of the Learning Sciences, 20(2), 169–206. https://doi.org/10.1080/10508406.2010.508029
Jang, Y. B., Kim, W. R., & Ryu, S. H. (2010). An exploratory study on avatar-self similarity, mastery experience and self-efficacy in games. International Conference on Advanced Communication Technology, ICACT, 2, 1681–1684.
Jarvis, H. L., & Gathercole, S. E. (2003). Verbal and non-verbal working memory and achievements on National Curriculum tests at 11 and 14 years of age. Educational and Child Psychology, 20(3), 123–140.
Job, V., & Brandstätter, V. (2009). Get a taste of your goals: Promoting motive–goal congruence through affect-focus goal fantasy. Journal of Personality, 77(5), 1527–1560.
Johnson, D., Gardner, M. J., & Perry, R. (2018). Validation of two game experience scales: The Player Experience of Need Satisfaction (PENS) and Game Experience Questionnaire (GEQ). International Journal of Human Computer Studies, 118(August 2017), 38–46. https://doi.org/10.1016/j.ijhcs.2018.05.003
Johnson, W. L. (2007). Serious use of a serious game for language learning. Frontiers in Artificial Intelligence and Applications, 158, 67.

Kaufmann, H., Steinbügl, K., Dünser, A., & Glück, J. (2005). Improving Spatial Abilities by Geometry Education in Augmented Reality - Application and Evaluation Design Proceedings. VRIC Laval Virtual 2005, 25–34.
Kellogg, J., English, S. E., April, N., & Markowsky, J. K. (1975). Why Anthropomorphism in Children ' s Literature ? Published by : National Council of Teachers of English Linked references are available on JSTOR for this article : Why Anthropomorphism in Children ' s Literature ? 52(4), 460–462.
Kenny, R. F., & Gunter, G. A. (2007). Endogenous fantasy-based serious games: intrinsic motivation and learning. International Journal of Social Sciences, 2(1), 8–13. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.135.1365&rep=rep1&type=pdf
Kerawalla, L., & Crook, C. (2005). From promises to practices: The fate of educational software in the home. Technology, Pedagogy and Education, 14(1), 107–125.
King, G., & Krzywinska, T. (2006). Tomb Raiders and Space Invaders: Video Games in the 21st Century. IB Tauris.
Klimmt, C., Hefner, D., Vorderer, P., Roth, C., & Blake, C. (2010). Identification with video game characters as automatic shift of self-perceptions. Media Psychology, 13(4), 323–338. https://doi.org/10.1080/15213269.2010.524911
Klopfer, E., & Yoon, S. (2005). Developing games and simulations for today and tomorrow's tech savvy youth. TechTrends, 49(3), 33–41. https://doi.org/10.1007/bf02763645
Konijn, E. A., & Hoorn, J. F. (2005). Some like it bad: Testing a model for perceiving and experiencing fictional characters. Media Psychology, 7(2), 107–144. https://doi.org/10.1207/S1532785XMEP0702_1
Korhonen, H., Montola, M., & Arrasvuori, J. (2009a). Understanding Playful User Experience Through Digital Games. October, 274–285.
Korhonen, H., Montola, M., & Arrasvuori, J. (2009b). Understanding Playful User Experience Through Digital Games. October, 274–285. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.586.7146&rep=rep1&type=pdf
Kori, K., Pedaste, M., Leijen, Ä., & Tõnisson, E. (2016). The role of programming experience in ICT students' learning motivation and academic achievement. International Journal of Information and Education Technology, 6(5), 331.
Ladley, P. (2010). Games Based Situated Learning:games-ED Whole Class Games and Learning Outcomes. games-ED.
Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge university press.
Lee, Jaejin. (2015). Effects of Fantasy and Fantasy Proneness on Learning and Engagement in a 3D Educational Game. The University of Texas at Austin.
Lee, Jaejin, & Liu, M. (2017). Design of fantasy and their effect on learning and engagement in a serious game. In Handbook of Research on Serious Games for Educational Applications (pp. 197–216). IGI Global.

Lee, Jihyun, & Shute, V. J. (2010). Personal and social-contextual factors in K-12 academic performance: An integrative perspective on student learning. Educational Psychologist, 45(3), 185–202. https://doi.org/10.1080/00461520.2010.493471

Lee, JungSook. (2014). The relationship between student engagement and academic performance: Is it a myth or reality? The Journal of Educational Research, 107(3), 177–185.

Li, D., Liau, A. K., & Khoo, A. (2013). Player-Avatar Identification in video gaming: Concept and measurement. Computers in Human Behavior, 29(1), 257–263. https://doi.org/10.1016/j.chb.2012.09.002

Li, J., van der Spek, E. D., Feijs, L., Feng, W., & Hu, J. (2017). Augmented reality games for learning: A Literature review. In Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 10291 LNCS (Issue July). https://doi.org/10.1007/978-3-319-58697-7

Li, J., van der Spek, E. D., Hu, J., & Feijs, L. (2019). Turning your book into a game: Improving motivation through tangible interaction and diegetic feedback in an AR mathematics game for children. CHI PLAY 2019 - Proceedings of the Annual Symposium on Computer-Human Interaction in Play, 73–85. https://doi.org/10.1145/3311350.3347174

Li, J., van der Spek, E. D., Yu, X., Hu, J., & Feijs, L. (2020). Exploring an augmented reality social learning game for elementary school students. Proceedings of the Interaction Design and Children Conference, IDC 2020, 508–518. https://doi.org/10.1145/3392063.3394422

Li, J., van der Spek, E., Hu, J., & Feijs, L. (2018). See me roar: On the over-positive, cross-cultural response on an AR game for math learning. Joint International Conference on Serious Games, 54–65.

Lim, K. Y. T., & Lim, R. (2020). Semiotics, memory and augmented reality: History education with learner-generated augmentation. British Journal of Educational Technology, 51(3), 673–691. https://doi.org/10.1111/bjet.12904

Lin, M. H., Chen, H. C., & Liu, K. S. (2017). A study of the effects of digital learning on learning motivation and learning outcome. Eurasia Journal of Mathematics, Science and Technology Education, 13(7), 3553–3564. https://doi.org/10.12973/eurasia.2017.00744a

Liu, S., & Kang, J. (2014). An overview of game based learning: Motivations and authentic learning experience.

Liu, T. (2009). A context-aware ubiquitous learning environment for language listening and speaking. Journal of Computer Assisted Learning, 25(6), 515–527.

Lombardi, M. M., & Oblinger, D. G. (2007). Authentic learning for the 21st century: An overview. Educause Learning Initiative, 1(2007), 1–12.

Lukosch, S., Billinghurst, M., Alem, L., & Kiyokawa, K. (2015). Collaboration in Augmented Reality. Computer Supported Cooperative Work: CSCW: An

International Journal, 24(6), 515–525. https://doi.org/10.1007/s10606-015-9239-0
Ma, M., & Oikonomou, A. (2011). Serious games and edutainment applications: Volume II. In London: Springer: Vol. II. https://doi.org/10.1007/978-3-319-51645-5
MacKinnon, D. P., Fairchild, A. J., & Fritz, M. S. (2007). Mediation analysis. Annual Review of Psychology, 58, 593–614. https://doi.org/10.1146/annurev.psych.58.110405.085542
Malone, T. W. (1980). What makes things fun to learn? heuristics for designing instructional computer games. Proceedings of the 3rd ACM SIGSMALL Symposium and the First SIGPC Symposium on Small Systems - SIGSMALL '80, 162, 162–169. https://doi.org/10.1145/800088.802839
Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. Cognitive Science, 5(4), 333–369. https://doi.org/10.1016/S0364-0213(81)80017-1
Malone, T. W. (1982). Heuristics for Designing Enjoyable User Interfaces. Proceedings of the 1982 Conference on Human Factors in Computing Systems., 63–68. https://doi.org/10.1145/800191.805663
Malone, T. W., & Lepper, M. R. (1987). Making Learning Fun, A Taxonomy of intrinsic Motivations for Learning.
Manly, T., Anderson, V., Nimmo-Smith, I., Turner, A., Watson, P., & Robertson, I. H. (2001). The differential assessment of children's attention: The Test of Everyday Attention for Children (TEA-Ch), normative sample and ADHD performance. The Journal of Child Psychology and Psychiatry and Allied Disciplines, 42(8), 1065–1081.
Martín, C. T., Acal, C., Honrani, M. El, & Estrada, Á. C. M. (2021). Impact on the virtual learning environment due to covid-19. In Sustainability (Switzerland) (Vol. 13, Issue 2, pp. 1–16). https://doi.org/10.3390/su13020582
Matheson, D., & Spranger, K. (2006). Content Analysis of the Use of Fantasy, Challenge, and Curiosity in School-Based Nutrition Education Programs. Journal of Nutrition Education, 33(1), 10–16. https://doi.org/10.1016/s1499-4046(06)60004-3
Mathews, R. (2016). Fantasy: The liberation of imagination. Routledge.
McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. Research Quarterly for Exercise and Sport, 60(1), 48–58.
McCall, R., Wetzel, R., Löschner, J., & Braun, A. K. (2011). Using presence to evaluate an augmented reality location aware game. Personal and Ubiquitous Computing, 15(1), 25–35. https://doi.org/10.1007/s00779-010-0306-8
McDaniel, S. R., Lee, S. C., & Lim, C. (2005). Re-Examining the Relationship between Fantasy and Optimum Stimulation Levels. Imagination, Cognition and Personality, 20(4), 355–372. https://doi.org/10.2190/6c0t-l259-4ma7-cdgc
McGregor, G. L. (2007). Situations of Play: Patterns of Spatial Use in Videogames. Situated Play–DiGRA07, 537–545. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.95.6556&rep=rep1&type=pdf
Mendlesohn, F. (2013). Rhetorics of fantasy. Wesleyan University Press.

Merckelbach, H., Horselenberg, R., & Muris, P. (2001). The Creative Experiences Questionnaire (CEQ): A brief self-report measure of fantasy proneness. Personality and Individual Differences, 31(6), 987–995. https://doi.org/10.1016/S0191-8869(00)00201-4
Michael, D. R., & Chen, S. L. (2005). Serious games: Games that educate, train, and inform. Muska & Lipman/Premier-Trade.
Michalos, A. C. (1981). The Grasshopper: Games, Life and Utopia. Teaching Philosophy, 4(1), 91–92.
Michel, R. (2007). Design research now. Essays and Selected projects. Essays and Selected Projects, London, 214.
Microsoft. (n.d.). minecraft. 2022. https://www.minecraft.net
Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995). Augmented Reality: A Class of Displays on the Reality-virtuality Continuum. Telemanipulator and Telepresence Technologies, 2351(December 1995), 282–292. https://doi.org/10.1117/12.197321
Miller, K. (2005). Communication theories. USA: Macgraw-Hill.
Miller, K. A., Deci, E. L., & Ryan, R. M. (1988). Intrinsic Motivation and Self-Determination in Human Behavior. Contemporary Sociology. https://doi.org/10.2307/2070638
Molnar, A., Miron, G., Elgeberi, N., Barbour, K., Huerta, L., Shafer, R., & Rice, K. (2019). Virtual Schools in the U.S. 2019: Executive Summary. National Education Policy Center., 0249(May). http://nepc.colorado.edu/publication/virtual-schools-annual-2019-exec-summary
Montola, M. (2005). Exploring the Edge of the Magic Circle: Defining Pervasive Games. Proceedings of the 6th Digital Arts and Culture Conference (DAC 2005), 1966, 16–19. https://doi.org/10.1.1.125.8421
Mozelius, P. (2014). Game based learning-a way to stimulate intrinsic motivation. Proceedings of the International Conference on E-Learning, ICEL, June, 272–278.
Nakamura, J., & Csikszentmihalyi, M. (2009). Flow theory and research. Handbook of Positive Psychology, 195–206.
Nelson, C. (2010). The Magical Mystery Four: How is Working Memory Capacity Limited, and Why? Current Directions in Psychological Science, 19(1), 7.
Newmann, F. M., Marks, H., & Gamoran, A. (1995). Authentic pedagogy: Standards that boost student performance. Issues in Restructuring Schools.
Ng, M., & Lin, J. (2016). Testing for mediation effects under non-normality and heteroscedasticity: a comparison of classic and modern methods. International Journal of Quantitative Research in Education, 3(1/2), 24. https://doi.org/10.1504/ijqre.2016.073643
Nieuwdorp, E. (2005). The pervasive interface; Tracing the magic circle.
Nintendo. (2020). Animal crossing: New horizons. https://www.animal-crossing.com/new-horizons.
Novak, E. (2012). Linking gaming characteristics with learning: A literature review.

35th Annual Proceedings–Louisville, KY, 1(2006), 145–158.
O'malley, J. M., O'Malley, M. J., Chamot, A. U., & O'Malley, J. M. (1990). Learning strategies in second language acquisition. Cambridge university press.
Once upon a time...life official website. (2022). https://www.hellomaestro.fr/en
Owens, M., Stevenson, J., Norgate, R., & Hadwin, J. A. (2008). Processing efficiency theory in children: Working memory as a mediator between trait anxiety and academic performance. Anxiety, Stress and Coping, 21(4), 417–430. https://doi.org/10.1080/10615800701847823
Pappas, C. (2014). Cognitive load theory and instructional design. Cognitive Load Theory And Instructional Design By.
Paras, B. (2005). Game, motivation, and effective learning: An integrated model for educational game design.
Parker, L. E., & Lepper, M. R. (1992). Effects of Fantasy Contexts on Children's Learning and Motivation: Making Learning More Fun. Journal of Personality and Social Psychology, 62(4), 625–633. https://doi.org/10.1037/0022-3514.62.4.625
Parmar, D. (2017). Evaluating the effects of immersive embodied interaction on cognition in virtual reality. Clemson University.
Patrick, E., Cosgrove, D., Slavkovic, A., Rode, J. A., Verratti, T., & Chiselko, G. (2000). Using a large projection screen as an alternative to head-mounted displays for virtual environments. Conference on Human Factors in Computing Systems - Proceedings, 2(1), 478–485. https://doi.org/10.1145/332040.332479
Pavonetti, L. M., Brimmer, K. M., & Cipielewski, J. F. (2000). TITLE Accelerated Reader: What Are the Lasting Effects on the Reading Habits of Middle School Students Exposed to Accelerated Reader in Elementary Grades? 150.
Pellas, N., Fotaris, P., Kazanidis, I., & Wells, D. (2019). Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning. Virtual Reality, 23(4), 329–346. https://doi.org/10.1007/s10055-018-0347-2
Pellegrini, A. D., & Galda, L. (1982). The Effects of Thematic-Fantasy Play Training on the Development of Children's Story Comprehension. American Educational Research Journal, 19(3), 443–452. https://doi.org/10.3102/00028312019003443
Pertierra, M., Lawsky, S., Hemberg, E., & O'Reilly, U. M. (2017). classifying serious games. CEUR Workshop Proceedings, 2143(January 2016). https://doi.org/10.4018/978-1-60960-495-0.ch006
Pfister, M., Moser Opitz, E., & Pauli, C. (2015). Scaffolding for mathematics teaching in inclusive primary classrooms: A video study. ZDM, 47(7), 1079–1092.
Piaget, J., Cartalis, E., Escher, S., Hanhart, U., & Hahnloser, L. (1947). Le jugement et le raisonnement chez l'enfant. Delachaux et Niestlé Neuchâtel-Paris.
Pierson, H. O. (2012). Handbook of carbon, graphite, diamonds and fullerenes: processing, properties and applications. William Andrew.
Pitair, A. (2003). Aspects of game-based learning Cite this paper Related papers.
Pivec, M., Dziabenko, O., & Schinnerl, I. (2003a). Aspect of Game-Based Learning.

In 3rd International Conference on Knowledge Management, 2–4.
Pivec, M., Dziabenko, O., & Schinnerl, I. (2003b). Aspects of game-based learning. 3rd International Conference on Knowledge Management, Graz, Austria, 216–225.
Plain, C. (2007). Build an affinity for KJ method. Quality Progress, 40(3), 88.
Qian, M., & Clark, K. R. (2016). Game-based Learning and 21st century skills: A review of recent research. Computers in Human Behavior, 63, 50–58. https://doi.org/10.1016/j.chb.2016.05.023
Radu, I. (2014). Augmented reality in education: A meta-review and cross-media analysis. Personal and Ubiquitous Computing, 18(6), 1533–1543. https://doi.org/10.1007/s00779-013-0747-y
Reeve, J., Jang, H., Hardre, P., & Omura, M. (2002). Providing a rationale in an autonomy-supportive way as a strategy to motivate others during an uninteresting activity. Motivation and Emotion, 26(3), 183–207. https://doi.org/10.1023/A:1021711629417
Regnath, F., & Elmezeny, A. (2019). Me , myself and others : Connecting player identification to gaming social capital. August.
Richard, van E. (2010). Gaming and Cognition : Theories and Practice from the Learning Sciences. In North.
Rigby, S., & Ryan, R. (2007). The player experience of need satisfaction (PENS) model. Immersyve Inc, 1–22.
Rivu, R., Abdrabou, Y., Pfeuffer, K., Esteves, A., Meitner, S., & Alt, F. (2020). StARe: Gaze-Assisted Face-to-Face Communication in Augmented Reality. Eye Tracking Research and Applications Symposium (ETRA). https://doi.org/10.1145/3379157.3388930
Rodrígues, P., & Bidarra, J. (2014). Transmedia storytelling and the creation of a converging space of educational practices. International Journal of Emerging Technologies in Learning, 9(6), 42–48. https://doi.org/10.3991/ijet.v9i6.4134
Rogers, K., Aufheimer, M., Weber, M., & Nacke, L. E. (2018). Exploring the role of non-player characters and gender in player identification. CHI PLAY 2018 - Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts, 271–283. https://doi.org/10.1145/3270316.3273041
Rosenfeld, E., Huesmann, L. R., Eron, L. D., & Torney-Purta, J. V. (1982). Measuring patterns of fantasy behavior in children. Journal of Personality and Social Psychology, 42(2), 347–366. https://doi.org/10.1037/0022-3514.42.2.347
Rötkönen, E., Najmul Islam, A., & Sutinen, E. (2019). Toward pedagogy driven virtual reality learning space design. IFIP Advances in Information and Communication Technology, 564, 235–244. https://doi.org/10.1007/978-3-030-28764-1_26
Ryan, R. M., & Deci, E. L. (2000a). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. Contemporary Educational Psychology, 25(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Ryan, R. M., & Deci, E. L. (2000b). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist, 55(1), 68.
Ryan, R. M., & Grolnick, W. S. (1986). Origins and pawns in the classroom: Self-report and projective assessments of individual differences in children's perceptions. Journal of Personality and Social Psychology, 50(3), 550.
Ryan, R. M., Rigby, C. S., & Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. Motivation and Emotion, 30(4), 347–363. https://doi.org/10.1007/s11031-006-9051-8
Sahin, D., & Yilmaz, R. M. (2020). The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. Computers and Education, 144(December 2018), 103710. https://doi.org/10.1016/j.compedu.2019.103710
Salen, K., Tekinbaş, K. S., & Zimmerman, E. (2004). Rules of play: Game design fundamentals. MIT press.
Saltz, E., Dixon, D., & Johnson, J. (1977). Training disadvantaged preschoolers on various fantasy activities: Effects on cognitive functioning and impulse control. Child Development, 367–380.
Sanford, K., Starr, L. J., Merkel, L., & Kurki, S. B. (2015). Serious games: Video games for good? E-Learning and Digital Media, 12(1), 90–106. https://doi.org/10.1177/2042753014558380
Sapounidis, T., & Demetriadis, S. (2013). Tangible versus graphical user interfaces for robot programming: Exploring cross-age children's preferences. Personal and Ubiquitous Computing, 17(8), 1775–1786. https://doi.org/10.1007/s00779-013-0641-7
Schell, J. (2014). The Art of Game Design. In CRC Press. https://doi.org/10.1201/b17723
Schnotz, W., & Kürschner, C. (2007). A Reconsideration of Cognitive Load Theory. Educational Psychology Review, 19(4), 469–508. https://doi.org/10.1007/s10648-007-9053-4
Schwartz, L. (2006). Fantasy, realism, and the other in recent video games. Space and Culture, 9(3), 313–325. https://doi.org/10.1177/1206331206289019
Scott, J. (2000). Children as respondents: The challenge for quantitative methods. Research with Children: Perspectives and Practices, 2, 87–108.
Sedano, C. I., Leendertz, V., Vinni, M., Sutinen, E., & Ellis, S. (2013). Hypercontextualized Learning Games: Fantasy, Motivation, and Engagement in Reality. Simulation and Gaming, 44(6), 821–845. https://doi.org/10.1177/1046878113514807
Segaran, K., Mohamad Ali, A. Z., & Hoe, T. W. (2021). Does avatar design in educational games promote a positive emotional experience among learners? E-Learning and Digital Media, 18(5), 422–440. https://doi.org/10.1177/2042753021994337

Selwyn, N., & Aagaard, J. (2021). Banning mobile phones from classrooms—An opportunity to advance understandings of technology addiction, distraction and cyberbullying. British Journal of Educational Technology, 52(1), 8–19. https://doi.org/10.1111/bjet.12943
Shabani, K. (2012). Dynamic assessment of L2 learners' reading comprehension processes: A Vygotskian perspective. Procedia - Social and Behavioral Sciences, 32(2010), 321–328. https://doi.org/10.1016/j.sbspro.2012.01.047
Shi, Y.-R., & Shih, J.-L. (2015). Game Factors and Game-Based Learning Design Model. International Journal of Computer Games Technology, 2015, 1–11. https://doi.org/10.1155/2015/549684
Skovbjerg, H. M., Bekker, T., d'Anjou, B., Johry, A., & Quinones, K. K. P. (2022). Examining theory use in design research on fantasy play. International Journal of Child-Computer Interaction, 32, 100400. https://doi.org/10.1016/j.ijcci.2021.100400
Sobel, D. M., Bloom, P., Weisberg, D. S., & Goodstein, J. (2013). Young children are reality-prone when thinking about stories. Journal of Cognition and Culture, 13(3–4), 383–407. https://doi.org/10.1163/15685373-12342100
Sotiriou, S., & Bogner, F. X. (2008). Visualizing the invisible: augmented reality as an innovative science education scheme. Advanced Science Letters, 1(1), 114–122.
Spector, J. M., & Merrill, M. D. (2004). Handbook of research on educational communications and technology. In British Journal of Educational Technology (Vol. 35, Issue 4). https://doi.org/10.1111/j.1467-8535.2004.00409_15.x
Squire, K. D., & Jan, M. (2007). Mad city mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. Journal of Science Education and Technology, 16(1), 5–29. https://doi.org/10.1007/s10956-006-9037-z
Stapleton, C., Hughes, C., & Moshell, M. (2003). MIXED FANTASY: Exhibition of entertainment research for mixed reality. Proceedings - 2nd IEEE and ACM International Symposium on Mixed and Augmented Reality, ISMAR 2003, May 2014, 354–355. https://doi.org/10.1109/ISMAR.2003.1240757
Stapleton, C., Hughes, C., Moshell, M., Micikevicius, P., & Altman, M. (2002). Applying mixed reality to entertainment. Computer, 35(12), 122–124. https://doi.org/10.1109/MC.2002.1106186
Steffe, L. P., Nesher, P., Cobb, P., Sriraman, B., & Greer, B. (2013). Theories of mathematical learning. Routledge.
Stoeber, J., Feast, A. R., & Hayward, J. A. (2009). Self-oriented and socially prescribed perfectionism: Differential relationships with intrinsic and extrinsic motivation and test anxiety. Personality and Individual Differences, 47(5), 423–428. https://doi.org/10.1016/j.paid.2009.04.014
Sullivan, C. W. (2018). High fantasy. In International companion Encyclopedia of Children's literature (pp. 436–446). Routledge.
Sun, L., Ruokamo, H., Siklander, P., Li, B., & Devlin, K. (2021). Primary school

students' perceptions of scaffolding in digital game-based learning in mathematics. Learning, Culture and Social Interaction, 28(August 2020), 100457. https://doi.org/10.1016/j.lcsi.2020.100457
Susi, T., Johannesson, M., & Backlund, P. (2007). Serious Games - An Overview. 2017 IEEE 8th Annual Ubiquitous Computing, Electronics and Mobile Communication Conference, UEMCON 2017, 1–24. https://doi.org/10.1109/UEMCON.2017.8249059
Syawaludin, A., Gunarhadi, & Rintayati, P. (2019). Development of augmented reality-based interactive multimedia to improve critical thinking skills in science learning. International Journal of Instruction, 12(4), 331–344. https://doi.org/10.29333/iji.2019.12421a
Taufiq, M., Nuswowati, M., & Widiyatmoko, A. (2021). Study of the Applicability Level of Merge Cube Augmented Reality Media on Junior Hight School Science Teachers. Unnes Science Education Journal, 10(3), 132–136. https://journal.unnes.ac.id/sju/index.php/usej/article/view/49804
Ten Berge, T., & Van Hezewijk, R. (1999). Procedural and Declarative Knowledge: An Evolutionary Perspective. Theory & Psychology, 9(5), 605–624. https://doi.org/10.1177/0959354399095002
Tenório, M., Lopes, R., Góis, L., Mesquita, C., & Santos Júnior, G. (2018). The experience of the application of a gamified virtual learning environment in higher education. ICERI2018 Proceedings, 1(November), 4486–4494. https://doi.org/10.21125/iceri.2018.2009
Thibodeau, R. B., Gilpin, A. T., Brown, M. M., & Meyer, B. A. (2016). The effects of fantastical pretend-play on the development of executive functions: An intervention study. Journal of Experimental Child Psychology, 145, 120–138. https://doi.org/10.1016/j.jecp.2016.01.001
Tobar-Muñoz, H., Baldiris, S., & Fabregat, R. (2017). Augmented Reality Game-Based Learning: Enriching Students' Experience During Reading Comprehension Activities. Journal of Educational Computing Research, 55(7), 901–936. https://doi.org/10.1177/0735633116689789
Trilling, B., & Fadel, C. (2009). 21st century skills: Learning for life in our times. John Wiley & Sons.
Turkay, S., & Kinzer, C. K. (2014). The effects of avatar-based customization on player identification. International Journal of Gaming and Computer-Mediated Simulations (IJGCMS), 6(1), 1–25.
UNESCO. (2020). COVID-19 Educational Disruption and Response. https://en.unesco.org/covid19/educationresponse
Ute, R., Michael, C., & Peter, V. (2009). Serious Games: Mechanisms and Effects - Google Books. https://doi.org/10.4324/9780203891650
Vallerand, R. J., & Blssonnette, R. (1992). Intrinsic, extrinsic, and amotivational styles as predictors of behavior: A prospective study. Journal of Personality, 60(3), 599–620.

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Briere, N. M., Senecal, C., & Vallieres, E. F. (1992). The academic motivation scale: A measure of intrinsic, extrinsic, and amotivation in education. Educational and Psychological Measurement, 52(4), 1003–1017. https://doi.org/10.1177/0013164492052004025

Van Abswoude, F., Van Der Kamp, J., & Steenbergen, B. (2019). The roles of declarative knowledge and working memory in explicit motor learning and practice among children with low motor abilities. Motor Control, 23(1), 34–51. https://doi.org/10.1123/mc.2017-0060

van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in Teacher–Student Interaction: A Decade of Research. Educational Psychology Review, 22(3), 271–296. https://doi.org/10.1007/s10648-010-9127-6

van der Spek, E. D., Sidorenkova, T., Porskamp, P., & Matthias, R. (2014). The effect of familiar and fantasy aesthetics on learning and experience of serious games. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 8770, 133–138. https://doi.org/10.1007/978-3-662-45212-7_17

van Looy, J., Courtois, C., & De Vocht, M. (2010). Player identification in online games: Validation of a scale for measuring identification in MMORPGs. ACM International Conference Proceeding Series, April 2014, 126–134. https://doi.org/10.1145/1823818.1823832

van Looy, J., Courtois, C., De Vocht, M., & De Marez, L. (2012). Player Identification in Online Games: Validation of a Scale for Measuring Identification in MMOGs. Media Psychology, 15(2), 197–221. https://doi.org/10.1080/15213269.2012.674917

Vedechkina, M., & Borgonovi, F. (2021). A Review of Evidence on the Role of Digital Technology in Shaping Attention and Cognitive Control in Children. Frontiers in Psychology, 12, 1–44. https://doi.org/10.3389/fpsyg.2021.611155

Vermunt, J. (1996). Metacognitive, cognitive and affective aspects of learning styles and strategies: A phenomenographic analysis. Higher Education, 31(1), 25–50. https://doi.org/10.1007/BF00129106

Vermunt, J., & Donche, V. (2017). A Learning Patterns Perspective on Student Learning in Higher Education: State of the Art and Moving Forward. Educational Psychology Review, 29(2), 269–299. https://doi.org/10.1007/s10648-017-9414-6

Vincenzi, D. A., Valimont, B., Macchiarella, N., Opalenik, C., Gangadharan, S. N., & Majoros, A. E. (2003). The Effectiveness of Cognitive Elaboration Using Augmented Reality as a Training and Learning Paradigm. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 47(19), 2054–2058. https://doi.org/10.1177/154193120304701909

Vollmer, H. J. (2009). Language across the curriculum. Proceedings from the Conference of Languages in Education, Ljubljana, Slovenia, 27–39.

Vygotsky, Lev S. (1978). The role of play in development. Mind in Society, 5, 92–104.

Vygotsky, Lev Semenovich, & Cole, M. (1978). Mind in society: Development of higher psychological processes. Harvard university press.
Vyotsky, L. (1978). Mind in society: The development of higher psychological processes. Cambridge: Harvard University Press.
Waal, B. de. (1995). Motivations for video game play : a study of social, cultural and physiological factors. http://summit.sfu.ca/item/6647
Wauck, H., Lucas, G., Shapiro, A., Feng, A., Boberg, J., & Gratch, J. (2018). Analyzing the effect of avatar self-similarity on men and women in a search and rescue game. Conference on Human Factors in Computing Systems - Proceedings, 2018-April, 1–12. https://doi.org/10.1145/3173574.3174059
Weisberg, D. S., Sobel, D. M., Goodstein, J., & Bloom, P. (2013). Young children are reality-prone when thinking about stories. Journal of Cognition and Culture, 13(3–4), 383–407. https://doi.org/10.1163/15685373-12342100
Whitton, N. (2007). Motivation and computer game based learning. ASCILITE 2007 - The Australasian Society for Computers in Learning in Tertiary Education, 1063–1067.
Wilkinson, P. (2016). A Brief History of Serious Games Phil. Entertainment Computing and Serious Games, 9970, 17–41. https://doi.org/10.1007/978-3-319-46152-6
Wilson, R., & Joseph, A. (2018). Looking into the High Fantasy Elements in Deepa Agarwal ' s Anita and the Game of Shadows. People, 5(3), 1112–1114.
Winarto, W., Syahid, A., & Saguni, F. (2020). Effectiveness the use of audio visual media in teaching islamic religious education. International Journal of Contemporary Islamic Education, 2(1), 81–107.
Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C., Schramm, H., Saari, T., Laarni, J., Ravaja, N., & Gouveia, F. R. (2007). A process model of the formation of spatial presence experiences. Media Psychology, 9(3), 493–525.
Wolf, M. J. P. (Ed.). (2002). The Medium of the Video Game. University of Texas Press.
Woolley, J. D. (1997). Thinking about Fantasy: Are Children Fundamentally Different Thinkers and Believers from Adults?
Wouters, P., Van der Spek, E. D., & Van Oostendorp, H. (2009). Current Practices in Serious Game Research : Outcomes Perspective. Games-Based Learning Advancements for Multi-Sensory Human Computer Interfaces: Techniques and Effective Practices, 232–250. http://biblio.uabcs.mx/html/libros/pdf/9/c13.pdf
Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van Der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. Journal of Educational Psychology, 105(2), 249.
Wouters, P., & van Oostendorp, H. (2016). Overview of Instructional Techniques to Facilitate Learning and Motivation of Serious Games. Instructional Techniques to Facilitate Learning and Motivation of Serious Games, 1–16. https://doi.org/10.1007/978-3-319-39298-1_1

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. Computers and Education, 62, 41–49. https://doi.org/10.1016/j.compedu.2012.10.024

Young, M. F. (1993). Instructional design for situated learning. Educational Technology Research and Development, 41(1), 43–58. https://doi.org/10.1007/BF02297091

Yuen, S. C.-Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented Reality: An Overview and Five Directions for AR in Education. Journal of Educational Technology Development and Exchange, 4(1). https://doi.org/10.18785/jetde.0401.10

Yusoff, A., Crowder, R., Gilbert, L., & Wills, G. (2009). A conceptual framework for serious games. Proceedings - 2009 9th IEEE International Conference on Advanced Learning Technologies, ICALT 2009, 21–23. https://doi.org/10.1109/ICALT.2009.19

Zhou, S., Sun, X., Shi, Z., & Lu, Y. (2020). The use of augmented reality for solving arithmetic problems for preschool children. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 12206 LNCS, 574–584. https://doi.org/10.1007/978-3-030-50506-6_39

Zuo, T., Birk, M. V., van der Spek, E. D., & Hu, J. (2020). Exploring fantasy play in MathMythos AR. CHI PLAY 2020 - Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play, 413–417. https://doi.org/10.1145/3383668.3419882

Zuo, T., Birk, M. V, van der Spek, E. D., & Hu, J. (2022). The mediating effect of fantasy on engagement in an AR game for learning. Entertainment Computing, 100480.

Zuo, T., Feijs, L., van der Spek, E. D., & Hu, J. (2019). A classification of fantasy in serious games. CHI PLAY 2019 - Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play, 821–828. https://doi.org/10.1145/3341215.3356294

Curriculum Vitae

Tengjia Zuo is a Ph.D. Candidate in Industrial Design at the Eindhoven University of Technology. She holds a Master's degree in Interaction and Experience Design from Jiangnan University and a Bachelor's degree in Industrial Design from Fuzhou University. Tengjia's thesis titled "Design with fantasy in AR game-based learning" investigates how fantasy contributes to interactive educational experiences in augmented reality. Her user-centered design approach innovates educational settings and explores the power of fantasy to engage and educate, utilizing quantitative and qualitative approaches in multiple languages and cultural contexts. Tengjia's award-winning work draws from interaction design, narrative theory, and cutting-edge XR content development. Her work has been published in international journals (e.g., Entertainment Computing) and computer sciences venues (e.g., CHI PLAY), has been displayed at leading design exhibitions (e.g., Dutch Design Week), and won the EAI Intetain Best Design Award in 2021.

Publication List

1. Investigating the Motivational Effect of Fantasy and Similarity Through Avatar Identification in AR Game-Based Learning
Zuo, T., Van Der Spek, E. D., Hu, J. & Birk, M. V., 25 Mar 2022, Intelligent Technologies for Interactive Entertainment - 13th EAI International Conference, INTETAIN 2021,

2. Situating Learning in AR Fantasy, Design Considerations for AR Game-Based Learning for Children
Zuo, T., Jiang, J., van der Spek, E., Birk, M. & Hu, J., 27 Jul 2022, In: Electronics. 11, 15, 22 p., 2331.

3. The effect of fantasy on learning and recall of declarative knowledge in AR game-based learning [Entertaining Computing Review Pending]

4. The mediating effect of fantasy on engagement in an AR game for learning
Zuo, T., Birk, M. V., van der Spek, E. D. & Hu, J., May 2022, In: Entertainment Computing. 42, 8 p., 100480.

5. An Introduction to ChemiKami AR
Zuo, T., Van Der Spek, E. D., Birk, M. V. & Hu, J., 22 Oct 2021, International Conference on Entertainment Computing. Baalsrud Hauge, J., Baalsrud Hauge, J., C.S. Cardoso, J., Roque, L. & Gonzalez-Calero, P. A. (eds.). p. 521-526 6 p.

6. Exploring Fantasy Play in MathMythos AR
Zuo, T., Birk, M. V., Van Der Spek, E. D. & Hu, J., 2 Nov 2020, CHI PLAY '20: Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play. Association for Computing Machinery, Inc, p. 413-417 5 p.

7. A classification of fantasy in serious games
Zuo, T., Feijs, L., van der Spek, E. D. & Hu, J., 17 Oct 2019, CHI PLAY 2019 - Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play. New York: Association for Computing Machinery, Inc, p. 821-828 8 p.

Acknowledgement

Games with rich fantasy activate the purest and simple passions and enjoyments. I enjoy playing games as they can always transpose me back to the joyful time of my childhood when friends invited each other to play Doraemon Monopoly, Pokémon Ruby, Story of Seasons, Devil May Cry and more. It was a time when we turned a single-player game into “local multiplayer”: friends gathered around a device and watched in awe while one was playing the game, and the other declared excitedly, “it’s my turn” at the previously agreed-upon game level. However, childhood is fleeting with growing pains. I grew up and entered one of the area’s top high schools, where high academic achieving and book-smart kids were the most self-assured. As a “cool” kid who was talented in painting, I was not one of them (In this regard, oriental and western schools may have a different atmosphere). The massive academic load from courses I was uninterested in but were necessary for entering a respected university, combined with competitive peer pressure, made me feel quite anxious and unsure about myself for a while. I was lucky to gain moments of peace from painting and gaming, finding joy in creation and fantasy. It was not until I entered the university and began studying design, a topic I am passionate about, that I discovered the joy and my own pace of learning. My enthusiasm for learning even expanded to the subjects I was not good at and interested in before. During these years, I did not know what intrinsic and extrinsic motivation was. Still, I was in the midst of it and experienced the anxiety and confusion as a disengaged learner and the passion and enjoyment as an autonomous learner.

Standing in the present and looking back, I am grateful that my PhD journey is the comprehension and exploration of the field, as well as the answers to the unsure and loss I encountered. I sincerely wish that this research can inspire learners or educators that help learners who are similarly befuddled in learning to discover the joy of learning at their own pace.

Likewise, I owe a debt of gratitude to many people who offered generous assistance, mindful care, support, encouragement and inspiration during this extraordinary research adventure (I struggled with the order for a while because you are equally the best, so I go alphabetically for names mentioned in each part). First of all, I would like to express my heartfelt thanks to all my supervisors, dr. Erik van der Spek, dr. Jun Hu, and dr. Max Birk, for guiding me into the fantastic world of scientific research.

Erik, you are a true mentor and a friend. Thank you for so many times that you rescued me from the pool of 999+ red errors I made as a novice coder. When I started writing my first academic paper, you carefully reviewed my sloppy work,

coming up with numerous spot-on comments. Your invaluable guidance on experiment design, data analysis, and scientific paper writing enabled me to adapt to new challenges and meet deadlines just in time. As a self-aware person who sometimes struggles with small talk during each initial meeting, I appreciate that you introduced me to the workshop and conferences and always encourage me to connect with other researchers. I am sad I cannot attend another carnival party with you, but I will never forget your Pikachu suit. You are the coolest supervisor.

Jun, you are always a well-respected mentor for both knowledge and personality. I am grateful that you recognized and encouraged me to embark on this research journey when we first met at the PhD Workshop CSC in Shanghai. It is the most fantastic decision I have made, and I could not have been so far without your encouragement and guidance. Thank you for guiding me into the world of science. I appreciate that your keen insight and sharp mind always offered constructive advice when I was unsure about a study approach, experimental design, or career choices. Thank you for your patience and detailed guidance throughout the study proposal, research methodologies, design development, and the thesis writing process. I will never forget the marks and comments in your handwriting that were left on my work, especially those marked with hand-drawn emoticons.

Max, you are the most attentive and committed instructor. I appreciate those moments you taught me every step of running statistical analysis, introducing and explaining abstract concepts with many vivid examples. Thank you for putting so much effort into revising my academic writing. I learned a lot from your invaluable suggestions regarding augmentation and articulation. You never hesitated to encourage me. The moment you approached me for a private chat, telling me that I did a great job, really motivated me a lot. I feel so lucky to have a supervisor like you with whom I share game choices in common. I enjoyed every small talk at the beginning of each meeting with you, and the game “Hades” you recommended is amazing!

Especially, I would like to express my gratitude to Prof. Dr Loe Feijs. Although it is a pity that I only had you as my mentor for one year before your retirement, this year of your mentoring allowed me to gain great knowledge of scientific research and design techniques. You were very patient in helping me form articulated sentences and explicit expressions in my first paper, shaping my savage graffiti into a decent work. Thank you for guiding me into the world of programming. Your revision of codes with simplicity and efficiency let me witness the elegance of programming.

I want to thank my doctorate committee opponents, Prof. dr. R.C. Veltkamp, Prof. dr. Ir. M.M. Bekker, Prof. dr. X. Sun, and dr. P.M.E. Van Gorp. I am sincerely grateful

for your time and interest in reading my thesis and offering insightful suggestions to polish my work.

Next, I would like to thank Angela Gedeller, Jixiang Jiang, Sandra van den Berg, Tao, and Yan Xu, who made the experiments feasible and helped coordinate experiment-related work. I also would like to thank Yixuan Bian, whose design was applied in the combined study in Chapter 7. Bian, I appreciate our time together, scratching our heads to find solutions to bugs we encountered, after which we eventually managed to have the program do its job (sometimes in a weird way, though.) I sincerely thank Xiang Sun, who offered technological support. I do not have many friends with a technological background. Your help that pulled me out of the swamp of bugs is especially precious. Also, I am deeply grateful to Prof. dr. Xiangyang Xin and dr. Juanfang Xu, who offered professional advice and mindful support.

I would also like to thank friends and colleagues for our pleasant memories. Thank you, Di Xiao, Qianhui Wei, and Rong Xu. Di, we had a great time shopping (mostly for food) at Jiangnan University. Frequent gatherings for delicacy and sharing recipes with you in Eindhoven filled my stomach and life aboard. Especially, I would like to thank you and Qianhui's help when I experimented with students in ISE. I cannot imagine not having your attentive support that day. Qianhui, I enjoyed the time we watched movies together. Nice choices of Edward Yang's and Martin Charles Scorsese's work! I appreciate the numerous times we talked and calmed each other down during this amazing and anxious journey. Rong, we have known each other for 15 years. I am lucky always to have a go-to girl like you. You were there when I was first in the Netherlands, when I conducted my first experiment, when I had difficulty understanding statistic concepts and when I struggled in making life choices. Thank you, Heqiu Song, Jingrui An, Sibo Pan, and Xinhui Ye. May the good time roll as the unforgettable trips we experienced together. Additionally, I want to thank my colleagues with whom I had pleasant interactions, Baisong Liu, Feiran Zhang, Israel Campero Jurado, Jingya Li, Kenji Wada, Mongru Xue, Mengyan Guo, Fan Li, Rui Wang, Roy van den Heuvel, Tisza Gabriella, Xiang Yu, Xu Lin, YunJie Liu, Yunxing Liu, Yudan Ma, Yuan Feng and Zhongya Zhang. I want to express my gratitude to Anne Jeuken and Marly Sluijsmans for organizing wonderful food-sharing activities and helping solve many problems during my PhD journey. Also, I would like to thank my friends in China, with whom I enjoy every game night: Houyi, Xiaowang, Yiko, Haoyuan Liu, and Yi Sun, to whom I frequently talked: Chen Yang, Xuanyan Chen, Xingyue Wang, Yichen Zhong. All our time means a lot, especially during the lockdown. Also, I would like to thank all my side kickers with whom I had a great time playing games when I was a kid, Jiamei Lin, Yue Li, and Yifan Ju. Those precious memories provide invaluable insights for my creation.

Just as importantly, I would like to express my deepest gratitude to my family members for their unconditional support and love. Thank you, mom, for being the superwoman for the family. You are my closest friend, always willing to listen and give heartfelt advice and attentive support. Thank you, dad, for repeatedly letting me know you are so proud of me. Thank you to my grandparents, who make me feel spoiled still. Thank you, Ziheng Zhang, My fiancé, for all the hugging and petting when I am happy or sad.

To all I shared beautiful memory in this extraordinary journey, thank you, this thesis is dedicated to you.

This research is partially supported by China Scholarship Council