Exploring Fantasy Play in MathMythos AR

Tengjia Zuo†[1], Max V. Birk[2], Erik D. van der Spek[3], Jun Hu[4]
Department of Industrial Design, Eindhoven University of Technology,
Eindhoven, The Netherlands
[1]t.zuo@tue.nl, [2]m.v.birk@tue.nl, [3]e.d.v.d.spek@tue.nl, [4]j.hu@tue.nl

ABSTRACT

Fostering fantasy play for young children through augmented reality has the potential to support 21st century learning activities by stimulating creativity, communication, and flexibility. We present a design exploration of MathMythos AR, an augmented reality card-based math addition game that enables children to engage in basic math tasks embedded in fantastical narratives. We provide insights into our design process, the effects of fantasy and everyday narratives, and discuss implications for AR card games that show potential to foster motivation for learning math. The presented insights are the foundation for the the next iteration of MathMythos AR, where we aim to create compelling and immersive AR narratives for learning.

CCS CONCEPTS

• Human-centered computing~Human computer interaction (HCI)~HCI design and evaluation methods•Applied computing~Computers in other domains~Personal computers and PC applications~Computer game.

KEYWORDS

Fantasy; serious games; augmented reality.

ACM Reference format:

Tengjia Zuo, Max V. Birk, Erik D. van der Spek, and Jun Hu. 2020. Exploring Fantasy Play in MathMythos AR. In *Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play* (CHI PLAY'20 EA), Nov. 2--4, 2020, Virtual Event, Canada. ACM, New York, NY, USA, 5 pages. DOI: https://doi.org/10.1145/3383668.3419882

1 Introduction

In the global digital society, learning 21st-century skills [12] in a virtual context is regarded as the future for education [28], because of the convenient and immersive experience it brings. These virtual contexts usually take the form of games for learning, or serious games, because of their added motivating potential [9]. However, on aggregate, evidence for the motivating qualities of serious games is still lacking [9]. One reason may be that serious game designers sometimes struggle to align serious learning content with an engaging fantasy [27, 34].

The COVID-19 pandemic in 2020 has furthermore accelerated a shift towards remote education [1]. Serious games could be a solution here, but fully digital interactions could favor boys over girls and in general young children seem to prefer tangible interactions when learning [20, 25]. The lack of physical contact both in the school and with school materials creates a need for approaches that provide tangible interactions in virtual contexts [17]. Augmented reality blends virtual world experiences with the physical world and enables technology-supported fantasy play [21].

When engaging in fantasy play, positive social competencies such as affective role-taking or peer social skills grow and story comprehension is enhanced [5]. Vygotsky 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" [31]. Fantasy play in learning is a promising direction with the potential to provide different perspectives on how today's educational structure engages children. However, designing for fantasy play and engagement is challenging and requires careful consideration of the development stage of the child, the educational material, the learning context, and the supporting technology. Aiming to bridge learning and playing, our research is focused on turning traditional instruction into a compelling, augmented fantasy scenario.

We explore fantasy play with the player's avatar in the context of our augmented reality card game "MathMythos AR". MathMythos AR asks players to compute the sum of two cards to trigger a narrative event. By integrating the learning activity as the core mechanic of the game [9], we aim to prevent the negative effects of educational games, while exploring the advantages of augmented reality fantasy play to support learning in the context of remote learning. The insight we gain from our preliminary research will support the future development of MathMythos AR to create compelling and immersive AR narratives to support learning. Meanwhile, our work provides researchers and designers with design strategies for card-based fantasy AR games for learning maths.

2 Related Work

"Fantasy play" was initially introduced by Saltz & Johnson as thematic fantasy play, children's playful behaviours in roles and themes that are different from their experience in real lives [24]. Fantasy play has been shown to increase children's motivation to learn and to engage with the learning material [7]. Going beyond just learning, fantasy is a key concept of exploration, curiosity and unrestricted engagement with tasks [18]. When performing

†Corresponding author

CHI PLAY '20 EA, November 2–4, 2020, Virtual Event, Canada

ACM ISBN 978-1-4503-7587-0/20/11…$15.00
https://doi.org/10.1145/3383668.3419882

cognitive tasks such as basic mathematical operations, fantasy play enables players to engage with the task-independent of their mathematical abilities [6]. An opportunity to learn tacitly without an explicit focus on the mathematical challenge [30].

An important catalyst for fantasy play is identification with the player's character or avatar [4]. Identification with an avatar has shown to increase self-reported motivation and playtime in the short-term [2] and in the long-term [3]. A common measure of player identification is the Player Identification Scale (PIS, [15]). PIS measures three different aspects of avatar identification: wishful identification, similarity identification, and embodied presence. PIS has been used to investigate relationships between identification and intrinsic motivation [2], social capital [22], and self-discrepancy [29].

While children and adults are fantastical thinkers [33] children also seem to find wonder in realistic stories [32], and hence are able to identify with a wider range of agents, including common animals. An interesting observation for game-design, because it suggests that younger children find pleasure in mundane scenarios.

That AR games for mathematics learning can be highly engaging for elementary school children has been shown among others by Li et al [13], who additionally found that the inclusion of a fantasy world as part of diegetic performance feedback increases the children's motivation [14]. However, how the children construct fantasies in a blended space, and which fantasties they engage in in a classroom context, is still poorly understood. Therefore we hope to shed light on this in a research-through-design process of our game MathMythos AR, together with an explorative study on the way children identify with different fantasy representations in an AR game for learning.

3 Method

Building on previous work on the classification of fantasy in serious games [35], for MathMythos AR we aim to foster an immersive experience following principles of endogenous [16] or integrated [10] fantasy design.

3.1 MathMythosAR

MathMythos AR was built using Unity (2019, 2.8f1) and the AR Engine Vuforia (2019, 8.5). MathMythos AR is played using a set of four cards: an interactive role card, two item cards with a numerical indicator on each card, and a target card. The four cards combined tell a narrative, for example, the character "Luca" buys and delivers food to their brother; see Figure 1. To accomplish their mission, Luca needs to correctly add up the price for ramen (271¥) and the price for sushi (124¥) to a total of 395¥. To bring the narrative to life, each card is tracked using a standard webcam and overlaid 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 to specify the location of a digital object on the cards. A "digital button"—an area that is constantly tracked and responds 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. We decided to keep the presented options within ±2 of the target sum to avoid frustration. Releasing the digital button while the correct sum is presented triggers the interactive role to interact with the target card—the character Luca, for example, gathers ramen and sushi on a tray and delivers the food to their brother.

To further explore the role of fantasy on identification, we created four different scenarios that present a visual narrative involving either a human or an animal and are either set in a fantasy context or an everyday life context. The four conditions presented in Figure 1 (from top to bottom) are the Warlock 'Rubin' (fantasy/human), the Student 'Luca' (everyday/human), the Dragon 'Buddy' (fantasy/ animal), and the Cow 'Vicky' (everyday/animal).

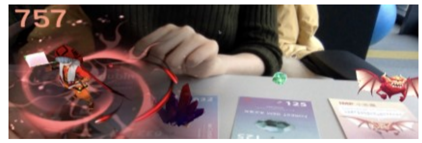
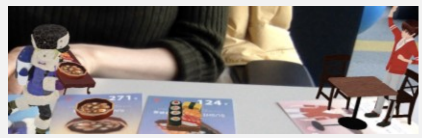
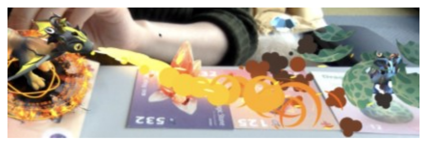
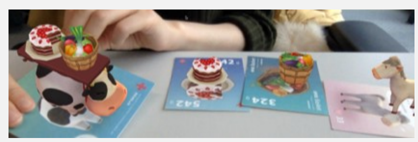
	The Warlock 'Rubin' (fantasy/human)
	The Student 'Luca' (everyday/human)
	The Dragon 'Buddy' (fantasy/ animal)
	The Cow 'Vicky' (everyday/animal)

Figure 1. Four scenarios of the MathMythos AR game

3.1.1 Design Process

First, we developed a monster strike game where players were expected to calculate the required damage of their weapon, based on their basic damage and the health points of a monster, to kill a monster with one strike. The idea was evaluated with three experts in design research and math teaching, who identified three limitations: First, the task would require subtraction, which conflicted with a task 9-10 years old students could engage with, without any pretraining. Second, violence is perceived differently, and while some children find violence engaging others are repelled [8]. Third, aiming for comparing fantasy characters with human characters, a violent scenario is acceptable by teachers in a fantasy environment, e.g., a knight slaying a dragon, but a non-fantasy scenario is less acceptable in an educational context, e.g., a hunter killing a tiger. Therefore, we decided to move away from violence. Further, we also aimed for a gender-neutral experience by deciding on characters and themes that do not overly pronounce male or female stereotypes to assure that MathMythos AR is enjoyable for everyone.

We also recognized instabilities regarding the AR recognition of the cards. To improve the experience, we increased the complexity and contrast of the tracking markers on the cards. Besides, we added the number indicators on the item cards on the top and the bottom of the cards to increase readability.

3.2 Preliminary research

To learn how MathMythos AR is experienced by primary school students, we cooperated with a primary school in Changzhou, Jiangsu Province, China. Our study was approved by the Ethics Review Board at the Eindhoven University of Technology. We obtained consent from participants, their legal guardians, and the primary school.

In total, 34 primary school students (19 male and 15 female) between 9 and 10 years old participated in our study. In appreciation of the students' time, we provided a lecture about design and AR for the entire class. Participants' demographic information was provided by the schoolteacher. Participants played first one round of instructional content to familiarize themselves with the content, and then played the four conditions of the game in a 4x4 Latin square counterbalanced sequence, answered questions about their motivation using a translated version of the Intrinsic Motivation Inventory [19], and filled in a translated version of the Player Identification Inventory [15]. To gain further insights, we interviewed our participants and encouraged them to freely express their thoughts on MathMythos AR. In our analysis, we also draw from our observations and personal insights. In the end, we invited 4 participants to take one of their favorite cards and elaborate on their choice and thoughts.

4 Results

The difficulty of the arithmetic problem generally fits children's abilities. However, some children responded slowly to the task, while others complained that the task was "not challenging enough". While we did not investigate if our participants' abilities to perform simple addition improved, we found that even participants from the same classroom have different levels of mathematical abilities. One possible solution for varying ability levels might be the implementation of a dynamic difficulty adjustment strategy. Furthermore, a subset of children wanted to pass on what they had learned and engaged unprompted in teaching other children in adding up numbers, interacting with AR cards, and using the virtual button autonomously. Some participants also tried to compete with others through the means of completion time. Our observations indicate that the AR game with physical cards led to a social setting, where competition and cooperation in fantasy play could also increase engagement.

There is no statistically significant effect of the type of aesthetics (fantasy versus everyday, human versus animal) on the enjoyment of the game by children. In fact, they give very high scores for all conditions (Figure 2). However, our observation and interview gives valuable information. An interesting phenomenon happened when four children were allowed to pick a single favorite card of the avatar cards home. Three participants chose Fantasy/Human, the warlock Rubin card. One participant who mentioned "my favorite character is Luca (the everyday human character) because of its kindness and willingness for help" in the previous interview, instead picked Rubin immediately to take home and stated "it is cool". The situation could highlight that young children tend to please adults by giving overly positive feedback and that they also adjust to preferences in their peer group [11]. Conversely, asking them to pick their favorite card to take home could subsequently be a more direct way to tell their preference rather than asking them to rate characters on a scale. Participants who pick their favorites also mentioned their wish to show the AR when they are back at home. A few of them said, "it is a pity I can not see the virtual parts when I have this card at home."

	Min	Max	Mean	Std. Deviation
Fantasy Animal	2.25	5.00	4.4412	0.75141
Fantasy Human	2.00	5.00	4.4632	0.78367
Animal	2.50	5.00	4.3456	0.75382
Human	2.50	5.00	4.4412	0.72053

Figure 2. Score for gameplay enjoyment in 4 conditions of the MathMythos AR game.

In the tested version of MathMythos AR, the characters' background stories were a description printed on each card. Some participants are willing to read and discuss the narratives, a few participants, however, have doubts about the stories, as one says "I don't think the story is strong, there is nothing but words on cards." Surprisingly, some children expressed interest in alternative endings for the characters'stories. One participant asked, "what would happen to Rubin if I give the wrong answer to the magic power calculation? " Such feedback points out the possibility to further enrich the storytelling by adding dialogues, animation, and sound to the next version of MathMythos AR. Providing multiple narrative endings could be a way of building a compelling and immersive fantasy play experience.

Mechanics	Stories	Aesthetics	Technology
Adaptive challenge to accommodate different proficiency levels	Alternative Endings	Animations as reward for exploration	Larger image targets for better tracking
Possession/ Collection	Interactive Narratives	(Spoken) Dialogue, Sound/Music	A mobile version with more convenient gameplay
Cooperation / possibility to teach other children Competition			

Figure 3: Design insight concluded based on interview and observation data.

Having all the interview and observation categorized under Schell's Elemental Tetrad of "Mechanics, Stories, Aesthetics, Technology" [26], we conclude a table of insights (Figure 3) that can facilitate our next move on the design and the research of the MathMythos AR.

6 Discussion & Future Work

Our preliminary insights suggest that AR is a promising technology to create engaging learning experiences for children and has the potential to teach simple math skills. The choice between fantasy/everyday aesthetics ostensibly does not seem to matter much, as long as there is room for roleplaying or narrative exploration. However, in a more indepth study with a small subset of students, a preference for the fantasy human seems to arise. Outside of the insights mentioned above, another insight that we found interesting was the remark that children wanted to take their favorite cards home. Currently, the cards are little more than tangible interaction markers with a nice visual for the game. But the remark indicated to us a novel potential of the cards, beyond being simple markers for the serious game. Students may engage in a form of transmedia storytelling [23], where the learning is augmented, but outside of the classroom (or remote learning) context, the physical cards hold potential for further fantasy elaboration, or at least maintaining the fantasy, where children can relive, extend and share the fantasy at home. In this way, the children are reminded of the fantasy and can possibly be more easily engaged when they are back in the classroom setting. This also creates possibilities for further personal customization.

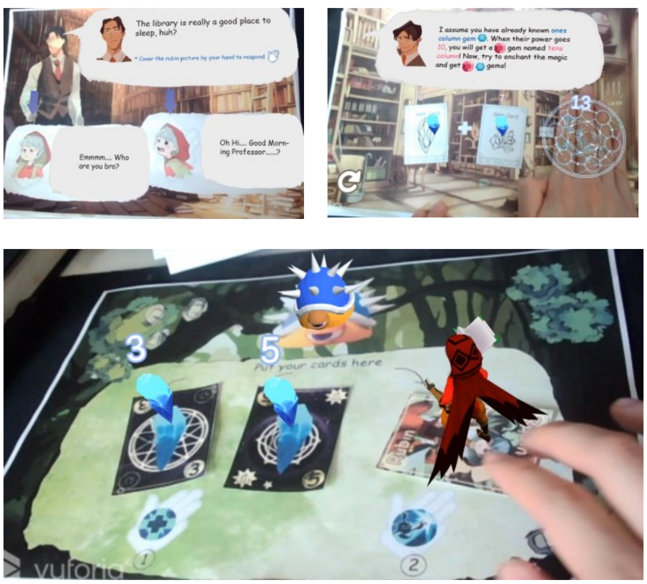


Figure 4: Our next version of the MathMythos AR game with interactive stories and complex game mechanics.

In the future, we want to explore the value of tangible cards and books by allowing students to collect and trade cards and interact with stories in a book, so that the fantasy of the game can persist and be elaborated on when the virtual augmentation is turned off. As MathMythos AR is a simple game of summing up two numbers, we see the potential for extending the same mechanic to more complex mathematic challenges, and in a longer story-line. Currently, we are designing an AR book based on the character "Rubin the Warlock", which the childrens declared as their favorite character (Figure 4). The book features animated storytelling and interactive dialogues. Users' performance will influence the direction of the the narrative and the number of cards players receive. More complicated computation related to these cards will be triggered as the story unfolds. We plan to explore how fantasy play in AR games with multiple narrative lines enables children to surpass their expectations and let their curiosity enable them to learn about the world around them.

6.1 Conclusion

With the goal to investigate avatar and identification in the context of a card-based AR math learning fantasy game, we designed the MathMythos AR. We explored fantasy role-play, avatars, and narratives in the AR game with 34 children at a Chinese school. Our preliminary insights suggest that fantasy role play in card-based AR games has the potential to increase motivation for learning and practices. Meanwhile, we converted users' needs into design opportunities based on the feedback we received. We found that adaption, collection, and social interaction are promising gameplay mechanics to promote engagement with AR math learning. Multiple directions and interactions in narratives supported by media solutions and smooth gameplay experiences can help to build gameplay that leads children to explore the world of math with curiosity and creativity. Based on our findings, we have developed MathMythos AR 2 where we continue to explore fantasy play, storytelling, and interactive narrative to further research correlates of presence, attention, and motivation in AR play for learning.

8 Acknowledgment

We would like to thank the China Scholarship Council to fund this project, teachers from Juqian Primary School, and friends who provided help in our preliminary research.

REFERENCES

[1] Basilaia, G. and Kvavadze, D. 2020. Transition to Online Education in Schools during a SARS-CoV-2 Coronavirus (COVID-19) Pandemic in Georgia. *Pedagogical Research*. 5, 4 (2020). DOI:https://doi.org/10.29333/pr/7937.

[2] Birk, M. V., Atkins, C., Bowey, J.T. and Mandryk, R.L. 2016. Fostering intrinsic motivation through avatar identification in digital games. *Conference on Human Factors in Computing Systems - Proceedings*. (2016), 2982–2995. DOI:https://doi.org/10.1145/2858036.2858062.

[3] Birk, M. V. and Mandryk, R.L. 2018. Combating attrition in digital self-improvement programs using avatar customization. *Conference on Human Factors in Computing Systems - Proceedings*. 2018-April, (2018), 1–15. DOI:https://doi.org/10.1145/3173574.3174234.

[4] Cohen, J. 2001. Defining Identification: A Theoretical Look at the Identification of Audiences With Media Characters. *Mass Communication and Society*. 4:3, 1 (2001), 245–264. DOI:https://doi.org/10.1207/S15327825MCS0403_01.

[5] Connolly, J.A. and Doyle, A.B. 1984. Relation of social fantasy play to social competence in preschoolers. *Developmental Psychology*. 20, 5 (1984), 797–806. DOI:https://doi.org/10.1037/0012-1649.20.5.797.

[6] Cordova, D.I. and Lepper, M.R. 1996. Intrinsic Motivation and the Process of Learning: Beneficial Effects of Contextualization , Personalization , and Choice. 88, 4 (1996), 715–730.

[7] Ferguson, C.J. and Olson, C.K. 2013. Friends, fun, frustration and fantasy: Child motivations for video game play. *Motivation and Emotion*. 37, 1 (2013), 154–164. DOI:https://doi.org/10.1007/s11031-012-9284-7.

[8] Grineski, S. 1989. Children, games, and prosocial behavior—Insight and connections. *Journal of Physical Education, Recreation & Dance*. 60, 8 (1989), 20–25.

[9] Habgood, J. and Ainsworth, S. 2011. Motivating Children to Learn Effectively: Exploring the Value of Intrinsic Integration in Educational Games. June 2014 (2011). DOI:https://doi.org/10.1080/10508406.2010.508029.

[10] Kenny, R.F. and Gunter, G.A. 2007. Endogenous fantasy-based serious games: intrinsic motivation and learning. *International Journal of Social Sciences*. 2, 1 (2007), 8–13.

[11] Kuczynski, L. and Hildebrandt, N. 1997. Models of conformity and resistance in socialization theory. (1997).

[12] Kuhlthau, C.C., Maniotes, L.K. and Caspari, A.K. 2015. *Guided inquiry: Learning in the 21st century: Learning in the 21st century*. Abc-Clio.

[13] Li, J., Van der Spek, E., Hu, J. and 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* (2018), 54–65.

[14] Li, J., Van Der Spek, E.D., Hu, J. and 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.* (2019), 73–85. DOI:https://doi.org/10.1145/3311350.3347174.

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

[16] Malone, T.W. and Lepper, M.R. 1987. Making Learning Fun, A Taxonomy of intrinsic Motivations for Learning.

[17] Manches, A. and Claire, O. 2012. Tangibles for learning: A representational analysis of physical manipulation. *Personal and Ubiquitous Computing.* 16, 4 (2012), 405–419. DOI:https://doi.org/10.1007/s00779-011-0406-0.

[18] Matheson, D. and 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 (2006), 10–16. DOI:https://doi.org/10.1016/s1499-4046(06)60004-3.

[19] McAuley, E., Duncan, T. and 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 (1989), 48–58.

[20] Michael S. Horn, Erin T. Solovey, Crouser, R.J. and Jacob, R.J.K. 2009. Comparing the Use of Tangible and Graphical Programming Languages for Informal Science Education. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. 2009.* (2009), 975–984.

[21] Radu, I. 2014. Augmented reality in education: A meta-review and cross-media analysis. *Personal and Ubiquitous Computing.* 18, 6 (2014), 1533–1543. DOI:https://doi.org/10.1007/s00779-013-0747-y.

[22] Regnath, F. and Elmezeny, A. 2019. Me , myself and others : Connecting player identification to gaming social capital. August (2019).

[23] Rodrígues, P. and Bidarra, J. 2014. Transmedia storytelling and the creation of a converging space of educational practices. *International Journal of Emerging Technologies in Learning.* 9, 6 (2014), 42–48. DOI:https://doi.org/10.3991/ijet.v9i6.4134.

[24] Saltz, E., Dixon, D. and Johnson, J. 1977. Training disadvantaged preschoolers on various fantasy activities: Effects on cognitive functioning and impulse control. *Child development.* (1977), 367–380.

[25] Sapounidis, T. and Demetriadis, S. 2013. Tangible versus graphical user interfaces for robot programming: Exploring cross-age children's preferences. *Personal and Ubiquitous Computing.* 17, 8 (2013), 1775–1786. DOI:https://doi.org/10.1007/s00779-013-0641-7.

[26] Schell, J. 2014. *The Art of Game Design.*

[27] Spek, E.D. Van Der, Sidorenkova, T. and Porskamp, P. The Effect of Familiar and Fantasy Aesthetics on Learning and Experience of Serious Games. 133–138.

[28] Starkey, L. 2011. Evaluating learning in the 21st century: A digital age learning matrix. *Technology, Pedagogy and Education.* 20, 1 (2011), 19–39. DOI:https://doi.org/10.1080/1475939X.2011.554021.

[29] Turkay, S. and Kinzer, C.K. 2014. The effects of avatar-based customization on player identification. *International Journal of Gaming and Computer-Mediated Simulations (IJGCMS).* 6, 1 (2014), 1–25.

[30] ter Vrugte, J. and de Jong, T. 2017. Self-explanations in game-based learning: From tacit to transferable knowledge. *Instructional techniques to facilitate learning and motivation of serious games.* Springer. 141–159.

[31] Vygotsky, L.S. 1978. The role of play in development. *Mind in society.* 5, (1978), 92–104.

[32] Weisberg, D.S., Sobel, D.M., Goodstein, J. and Bloom, P. 2013. Young children are reality-prone when thinking about stories. *Journal of Cognition and Culture.* 13, 3–4 (2013), 383–407. DOI:https://doi.org/10.1163/15685373-12342100.

[33] Woolley, J.D. 1997. Thinking about Fantasy: Are Children Fundamentally Different Thinkers and Believers from Adults?

[34] Wouters, P. and 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.*

[35] Zuo, T., Feijs, L., Van Der Spek, E.D. and 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.* (2019), 821–828. DOI:https://doi.org/10.1145/3341215.3356294.