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Situating Learning in AR Fantasy, Design Considerations for AR Game-Based Learning for Children

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Abstract: (1) Background: Augmented reality (AR) game-based learning, has received increased attention in recent years. Fantasy is a vital gaming feature that promotes engagement and immersion experience for children. However, situating learning with AR fantasy to engage learners and fit pedagogical contexts needs structured analysis of educational scenarios for different subjects. (2) Methods: We present a combined study using our own built AR games, MathMythosAR2 for mathematics learning, and FancyBookAR for English as second-language learning. For each game, we created a fantasy and a real-life narrative. We investigated player engagement and teachers' scaffolding through qualitative and quantitative research with 62 participants aged from 7 to 11 years old. (3) Results: We discovered that fantasy narratives engage students in mathematics learning while disengaging them in second-language learning. Participants report a higher imagination with fantasy narratives and a higher analogy with real-life narratives. We found that teachers' scaffolding for MathMythosAR2 focused on complex interactions, for FancyBookAR, focused on story interpretation and knowledge explanation. (4) Conclusions: It is recommended to mix fantasy and real-life settings, and use simple AR interaction and pedagogical agents that enable teachers' scaffolding seamlessly. The design of AR fantasy should evaluate whether the story is intrinsically related to the learning subjects, as well as the requirements of explicit explanation.

Keywords: augmented reality; game-based learning; fantasy; situated learning; serious game

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1. Introduction

Augmented reality (AR), presenting virtual graphics, 3D models, animation, and sound effects into physical materials or spaces, enables users to engage with real-world objects and virtual interactive overlays simultaneously [1,2]. Combining digital game features and physical situations, AR game-based learning allows games to be integrated into the classroom in situated learning in an engaging way. As the core of situated learning is to intrinsically link the knowledge to be learned to physical and cultural contexts where learning occurs [3], AR provides contexts that allow users to sense real-world situations and adapt digital instruction to them [4]. Integrating game features into instruction, game-based learning enables its participants to engage in learning without particularly focusing on the learning content, with a fun and immersive experience [5].

AR game-based learning has been used to playfully augment serious contexts and thereby present instructional goals in an engaging manner and has received increased attention in recent years [6–8]. Research on AR game-based learning incorporates computer science, pedagogy, and experience design [7]. To explore the application of AR game-based learning in 21st-century education, researchers need to simultaneously consider the current situations in learning, technological affordance, and user experience. One approach to improve technological benefits, enriching educational contexts, and player experience,

is by incorporating gaming features such as avatar customization [9], fantasy [10], or goal-setting [11] into AR learning. Among them, the game element that can provide motive-specific affective incentives [12,13] is fantasy, i.e., unreal and fictional settings that deviate from everyday life [14,15]. Fantasy can positively affect game-based learning, increasing players' engagement, especially for children who are not self-motivated to study [16–18].

Ways of incorporating fantasy in learning contexts have sparked academic interest in recent years [17,19,20]. To move beyond the entertaining features 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 [21], coaching and scaffolding during the initial steps [22], and articulation [23] to enable explicit expression of tacit knowledge [24], creating spaces for exploration of participants [23]. How to design a novel game-based learning experience that situates learning in AR fantasy, engages learners, and adheres to pedagogical principles requires disciplinary and context-specific analysis. For example, research to investigate the classroom context in which learning with AR fantasy is employed, exploratory research on the subjects such as language and mathematics to be learned, and more.

To further investigate situating learning in AR fantasy and game-based learning for different learning contexts, we present a combined study using our own designed AR games: MathMythosAR2, i.e., a game for mathematic learning and practising, and FancyBookAR, i.e., a game for English as second-language learning and practising. We prepared two narratives for each game: the fantasy and the real-life version. By comparing the fantasy and real-life versions, we explore the effect of fantasy on engagement and scaffolding and develop design considerations for 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 research benefits the pedagogy domains by offering inspiring practice, and practical solutions for the needs of situating learning in technological-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 learning. we offer innovative solutions that connect students and teachers with an engaging learning experience and strategies for scaffolding learning with AR fantasy. This research also contributes to the design research society in terms of offering innovative game design and practical design strategies for designing with AR fantasy, bringing the future of immersive technology closer to our lives.

2. Related Work

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 [25]. Perceptually, AR enhances the actual environment, leading to intensely immersive experiences [26]. AR promises to bring a better play–learn experience by (1) visualizing knowledge and concepts from alternative perspectives, for example by bringing to life 3D invisible and abstract concepts [27], (2) facilitating social interactions with tangible and virtual materials, regardless of geography or time restrictions [28], and (3) by bridging formal and informal learning by eliminating barriers between virtual and physical worlds [29,30]. 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.

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 [15,31]. Playful experience with fantasy game elements can invite users into an immersive world, which is called the "magic circle [32]," with a temporal and spatial boundary separating users from the real world. Such boundaries are blurred by AR technology, where players enter the virtual world, sensing the physical world simultaneously [33]. AR Fantasy can create a circle Stapleton et al. refer to as a "mixed fantasy continuum" [34], 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 et al. (2003) defined as imagination and analogy states of fantasy. These mental states are keys to a convincing mixed fantasy experience that allows participants to step into the magic circle with a "suspension of disbelief" [33]. To identify whether fantasy elements build a convincing magic circle, we need to understand players' fantasy states meanwhile analyze their engagement [35].

Engagement is a process of getting involved and connected with [36]. According to research on indicators that reflect different aspects of learning engagement [37–39], we synthesize a table of indicators for engagement (Table 1). 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.

Table 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

Players' emotional engagement comes from the pleasure of immersion [36], which fantasy elements can facilitate [40]. Players' cognitive engagement reflects "one's effort to put into self-regulated learning, involving a process of making sure oneself comprehend the game content." [41]. 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 [20]. Therefore, it is still an open question if incorporating fantasy in AR game-based learning may result in users' sufficient understanding that leads to positive behavioral and cognitive engagement.

In addition to qualitative methods of measuring engagement, we collect players' self-reported enjoyment parts of intrinsic motivation through intrinsic motivation inventory (IMI) in this study. Malone et al. connect endogenous fantasy with intrinsic motivation, in which learners are driven by qualities such as enjoyment and self-fulfilment. Endogenous fantasy in game-based learning can let players engage with affective incentives [13] without focusing on the learning goals [42].

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

2.3.1. Fantasy and Situated Learning

Situated learning refers to learning practical applications through communication and interaction with environments [3]. Immersive technologies such as 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 students explore, discuss and construct concepts of real-world issues they can relate to [43]. Authentic learning refers to activities that involve learning by solving issues, studying cases, and practising situations that are similar to those encountered in complex real-life situations [44]. 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 [45]. However, tracing back to the criteria of authentic learning, we found the essential was to learn grounded knowledge in the fields instead of memorizing abstract knowledge [46]. Fantasy contexts can be integrated with knowledge in fields and positively engage learners. The critical question is whether a convincing and immersive magic circle to an accessible learning context is constructed.

2.3.2. Scaffolding and the Role of Teachers

Balancing learners' motivation and comprehension in an immersive game-based learning magic circle requires careful design from game designers and proper guidance from teachers. The role of teachers in situated game-based learning is different from a traditional tutoring context. In the traditional education context, teachers guide students through scaffolding, which means offering temporal support to complete learning targets [47]. Whereas in a game-based learning context, players can also be guided by instructional content with natural progressions from the game's storyline [48]. Students who are fully immersed in the environment might require a less direct explanation from teachers [49]. Certain circumstances, allowing teachers to turn over controls of the learning context to students, encourage autonomous learning by students [50]. However, it also challenges teachers in terms of assisting students and tuning students' attention on the learning focus without interfering with their autonomy [51], i.e., their determination to interact based on their interests and values [52]. AR engages students with the virtual world while also maintaining a portion of their attention in the real-life classroom [53]. Properly designed AR game-based learning allows students to seamlessly move between virtual exploration and real-world interaction, creating spaces to insert teachers' roles.

Incorporating the role of teachers necessitates a detailed assessment of how students perform in different educational contexts. Pivec et al. summarize a criterion for different degrees of problem-solving skills of tasks, based on Vygotsky's 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 [54,55]. A further in-depth assessment of students' task completion using this criterion, in combination with their engagement analysis, can help situate teachers' roles in scaffolding towards specific contexts.

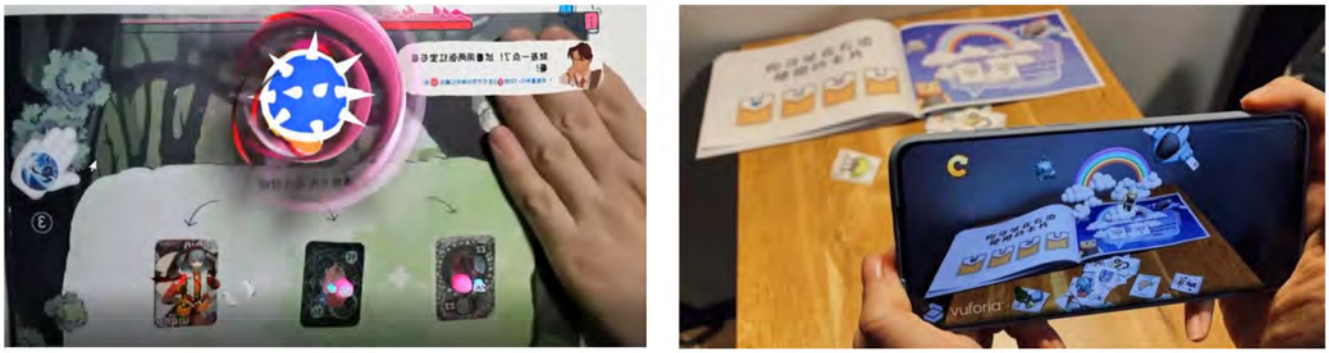
To construct a convincing and immersive magic circle in an accessible learning context, designing fantasy in game-based learning needs careful consideration based on an analysis of participants' real-world interaction and reaction to subject matter learning contexts. An exploratory study with design intervention is needed to explore the effect of AR fantasy on player engagement and teachers' scaffolding. Through the design study, we would like to understand the following research questions about situating learning in AR fantasy of game-based learning:

- RQ1: Whether fantasy in AR game-based learning for a classroom creates more engaging and immersive mental states for players?
- RQ2: What is teachers' role in scaffolding children in fantasy construction and learning?
- RQ3: How to situate learning in the AR fantasy of game-based learning to improve learners' engagement, experience, and the teachers' scaffolding?

3. Material and Methods

To answer the proposed research questions, we introduce our design, MathMythosAR2, and FancyBookAR, two storybook-based AR games focusing on learning mathematics and English. According to our findings through experiments and data analysis, we answer RQ1 and RQ2 and address design strategies to answer RQ3.

Both FancyBook AR and MathmythosAR 2 were designed with Unity3D, an engine that enables interactive experience through scene building and C#, and Vuforia, an engine that supports the functionality of AR through image recognition. The educational contents of both games are derived from actual educational practices. For the game MathMythos AR2, we combined the form of mathematical word problems [56] with game narrative and interactions. Similarly, in FancyBookAR, game features were integrated with the cloze test, a practice that requires participants to place the missing language items [57]. We invited 2 local English teachers to have the content checked. The fantastical game features used in FancyBookAR are comparable to those found in MathMythosAR2, employing a similar portrayal of innovation [15]—magic, technology, and aesthetics. The same game mechanics were used, such as cards, storybooks, and phone applications (Figure 1). Narrative genres of fantasy were applied in both games. 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.



(a) (b)

Figure 1. (**a**) MathmythosAR 2; (**b**) FancyBook AR.

3.1. MathMythosAR2

MathMythosAR2 is an AR game that encourages children to learn the addition techniques of mathematic calculation and practice their learned techniques. There are seven chapters in each game version. Students 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 Character). Then players will be introduced to the addition technique. Players need to hold the virtual button and trigger the randomly generated numbers (randomization of correct answers $\pm$ 3), releasing when the right numbers pop up. Players 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, players play a role of a magician. Players learn math magic to save a village from evil. Players complete the game task by making choices about the magic narratives and completing calculation practice about the math magic. We list a table of key narratives and options available in each section with screenshots in Table 2.

Table 2. The fantasy version of the game MathMythosAR2.

Section 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 $\pm$ 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 is 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 one level of the evil spell. (One time of single-digit addition, two times of two-digit addition.)	Choices available are between the correct answer $\pm$ 3.
	Oh, you saved my life! Thank you, young magician!	1. What??? You are a human? 2. I'm glad you are back! Is everything ok?

The "real-life" version (Table 3) of MathMythosAR2 retains the same narrative framework and gameplay mechanics. However, players play a role of a daily life student, Robin. The main tasks are summing up total prices and shopping for the class party. Key narratives and options are presented in Table 3.

Table 3. The real-life version of the game MathMythosAR2.

Section 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 us 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 is 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 am sorry for the inconvenience. Thank you for your assistance with the calculation.	1. I would not have come to your store if I knew that. 2. No problem, I am willing to help. It is just simple mathematics.

3.2. FancyBookAR

FancyBookAR is a set of AR games that encourage children to learn English words and form sentences using their learned words. There are five sections in the game. In each section, players will first receive vocabulary cards and a storybook with incomplete

sentences that need words to fill in the blanks. To complete the sentences, players need to understand the meaning of the words on each card and the possible context wherein they fit. A correctly constructed sentence with cards will trigger the completion of a game scene. As a result of completing tasks on the current scene, players activate the animation of the characters and complete the stories. There are two types of narrative in FancyBook AR, a fantasy and a real-life version.

In the fantasy narrative version, players play a role of a magician, the catperson. Players need to complete the story by choosing the options set in a fantasy genre. We list a table of key narratives and options available in each section with screenshots in Table 2.

The "real-life" version (Table 4) of FancyBook AR retains the same narrative framework and gameplay mechanics. However, the catperson 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 5).

Table 4. The fantasy version of the game FancyBook AR.

Section Screenshots	Key Narratives	Options
	It is 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 5. The real-life version of the game FancyBook AR.

Section Screenshots	Key Narratives	Options
	It is 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 is playtime! I _with my friend.	1. Dance 2. Watch TV

Using the two games described above, each having two narrative versions, we experimented with game types (FancybookAR vs MathMythosAR2) as the between-subject factor and the narrative versions (real-life vs fantasy) as the within-subject factor. We compare the mathematic and language learning games that AR fantasy incorporates to explore ways and patterns of using AR fantasy to achieve increased engagement with two distinct learning subjects. We compare 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 in light of previous work.

3.3. Participants and Procedure

This research 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 years old 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 years old to 14 years old were invited to play the game FancyBook AR. 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 children using a blank version with only text and 3D sphere models, letting participants get used to scanning image targets and holding virtual buttons. The students would then be asked to play one of the versions by the assistant, who also served as an instructor and gave help if children asked. After completing the version, the student would be asked to complete a questionnaire before going to the other version and completing another questionnaire. Besides the experience and engagement-related questions, the questionnaire 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 schoolteachers and participants' guardians. The procedure, game contents, and questionnaire were approved by the Eindhoven University of Technology ethical review board with the approval number ERB2020ID165.

3.4. Data Collection

We collected and analyzed both qualitative and quantitative data to answer our research question in this research. To answer RQ1, we collected the children's self-reported immersion through the immersion section of the Player experience of need satisfaction questionnaire (PENS). PENS is a questionnaire that measures the psychology of satisfying experiences of playing through aspects of competence, autonomy, relatedness, and immersion [58,59]. To identify their engagement qualitatively during gameplay, we invited two experts to analyze the gameplay videos and code the children's engagement using the indicators (Table 1) we summarized from a literature review. 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 students' understanding and the teacher's scaffolding through video analysis of how they completed the tasks. Timelines including tasks that were well understood and completed by students independently were marked as "independent." Tasks that students completed with the teacher's assistance were marked as "with assistance." Tasks that students did not complete even with help from the teachers were marked "uncompleted." Questions students raised when seeking help were also recorded.

To further investigate players' fantasy states during the learning process, we collected their self-reported data of imagination and analogy using the fantasy state scale (FSS). We use 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 [60], we used a 4-point animated smiley scale developed by Li, Van Der Spek, Hu, and Feijs (2019) (Figure 2) for the PENS and IMI questionnaires [61]. We translated from the original English version and had a language expert check the translation.

Figure 2. The scale was modified according to Li et al's 4-point animated smiley scale.

3.5. Data Analysis

Two experts coded the students' types of engagement, comprehension, and teacher's assistance using MAXQDA 2020. There were 12 video recordings from 10 participants for each narrative type in 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 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 [62] to organize the keywords of user engagement in a structure containing game types, narrative versions, and engagement types. Based on the areas of confusion when users wanted assistance, we drew up representative user journey maps that included students' engagement and teachers' scaffolding.

3.6. 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 Cronbach's 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 from Qingdao had a slightly lower average age than those from Anhui, young children around this age (M = 9.2) with their understanding of reversibility still developing [63] 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.

4. Results

4.1. Players' Self-Reported Experience and Engagement

We analyzed the students' presence, imagination, analogy, enjoyment, and autonomy data using SPSS. We performed a within-between mixed-factor analysis of variance (ANOVA), setting the game type (MathMythosAR2 or Fancybook AR) 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 6. Mixed two-way ANOVA with the game type (MathmythosAR2/FancybookAR) as between-subject, the narrative type (fantasy /real-life) as within-subject variable.

DV	Source	SS	F	*p*
Autonomy	**Game type**	**4.27**	**6.92**	**0.01**
	Narrative type	0.02	0.10	0.76
	Interaction	0.40	1.68	0.20
Presence	**Game type**	**11.65**	**17.56**	**0.00**
	Narrative type	0.00	0.00	1.00
	Interaction	**0.42**	**4.37**	**0.04**
Enjoyment	**Game type**	**2.73**	**5.01**	**0.03**
	Narrative type	0.30	3.10	0.08
	Interaction	0.21	2.16	0.15
Imagination	**Game type**	**5.29**	**7.81**	**0.01**
	Narrative type	**4.19**	**22.25**	**0.00**
	Interaction	0.06	0.34	0.56
Analogy	**Game type**	**5.45**	**6.35**	**0.01**
	Narrative type	**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: $p \leq 0.05$.

Table 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 8. Pairwise comparisons Fantasy vs Real-life, Bonferroni adjusted.

Measure	Game Type	Mean Difference	Std. Error	Sig.b
Autonomy	MathmythosAR2	0.140	0.123	0.260
	FancyBookAR	−0.086	0.123	0.487
Presence	MathmythosAR2	0.117	0.079	0.145
	FancyBookAR	−0.117	0.079	0.145
Enjoyment	MathmythosAR2	−0.016	0.079	0.839
	FancyBookAR	**−0.181 ***	**0.079**	**0.026**
Imagination	**MathmythosAR2**	**0.323 ***	**0.110**	**0.005**
	FancyBookAR	**0.413 ***	**0.110**	**0.000**
Analogy	MathmythosAR2	−0.032	0.136	0.814
	FancyBookAR	**−0.355 ***	**0.136**	**0.012**

* $p < 0.05$

Table 9. Pairwise comparisons MathmythosAR2 VS Fancybook AR, Bonferroni adjusted.

Measure	Game Version	Mean Difference	Std. Error	Sig.b
Autonomy	**Fantasy**	**0.484 ***	**0.152**	**0.002**
	Real-life	0.258	0.179	0.154
Presence	**Fantasy**	**0.730 ***	**0.157**	**0.000**
	Real-life	**0.496 ***	**0.157**	**0.002**
Enjoyment	**Fantasy**	**0.379 ***	**0.154**	**0.016**
	Real-life	0.215	0.133	0.113
Imagination	**Fantasy**	**0.368 ***	**0.159**	**0.024**
	Real-life	**0.458 ***	**0.175**	**0.011**
Analogy	**Fantasy**	**0.581 ***	**0.208**	**0.007**
	Real-life	0.258	0.175	0.146

* $p < 0.05$

4.2. Players' Engagement through Video Analysis by Experts

We created an affinity map of engagement patterns (Figure 3) for each game and narrative version by synthesizing the most frequent types of player engagement. The result suggests both games engage participants more emotionally than the real-life versions. Part of this finding contradicts what we discovered in their self-reported data, in which children 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 fantasy versions, lots of children showed negative engagement on the cognitive level, showing confusion about the context, while they were more confident about playing the real-life version and showed positive emotional engagement such as "focused."

Regarding specific game types, some children 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 finish the game tasks showed more positive emotion and active participation with the same game's fantasy narrative.

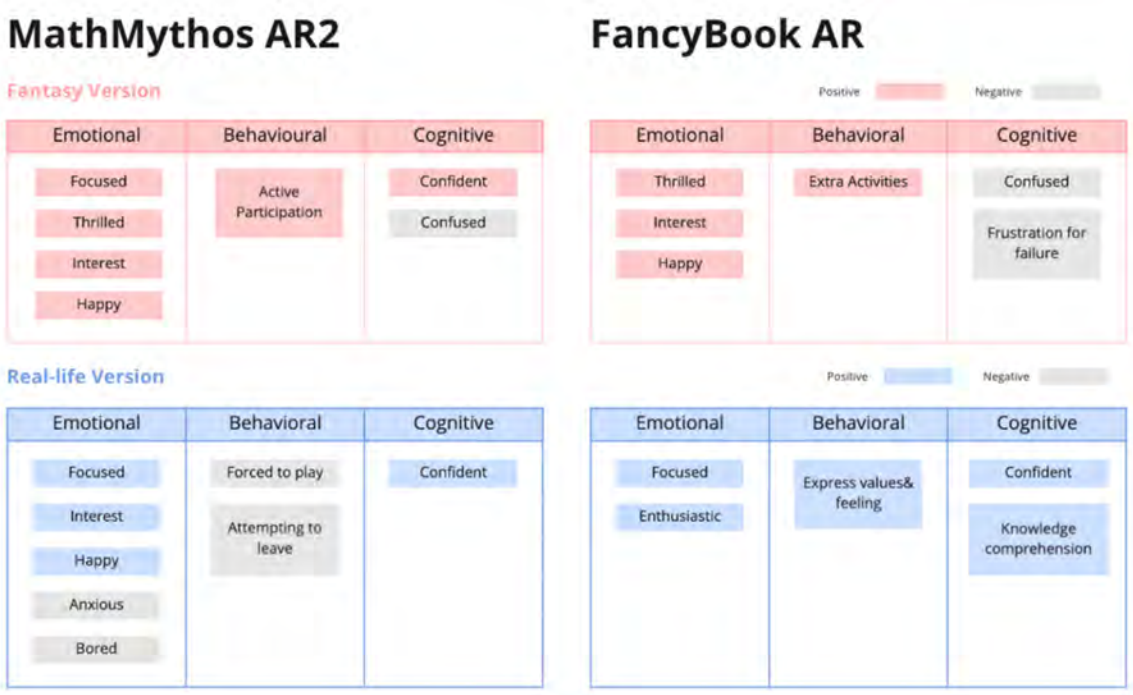


Figure 3. The affinity map of engagement by game types and narrative types (with coloured tags representing positive signs, grey tags representing negative signs).

Children who played both versions of FancyBookAR showed positive emotional engagement, such as focused and enthusiastic engagement in the real-life version, as well as affective emotions when engaging in the fantasy version. When children 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, students spoke out more frequently about the meaning of the sentence in their native language when completing the tasks, being more confident about the result.

4.3. Players' Comprehension and the Teacher's Assistance through Video Analysis by Experts

The timelines as a result of the expert analysis are displayed in Figures 4 and 5 in the form of a user journey map, where ten horizontal lines represent ten samples in the video analysis in each game's narrative. Based on the game scenes, we also highlighted the negative and positive engagement moments described in Figure 3. We investigated the teachers' assistance and students' engagement to assess students' comprehension and the role of teachers with different game types and narrative types.

4.4. MathMythosAR2: Differences between Two Narratives Versions

In the fantasy version, when students had difficulty adding two-digit numbers together, the teacher helped them break it down into single-digit addition to recall the addition they had already memorized. It is possible that this help differentially affected the students' fantasy experience of the game, since a school teacher helping students with math questions is part of the real-life narrative of MathMythos AR2, whereas in the fantasy narrative it is a magic teacher, and a school teacher intervening could take students out of the experience. The experiment showed that reported presence was higher in the fantasy condition, so if this effect occurred, it was likely not very strong.

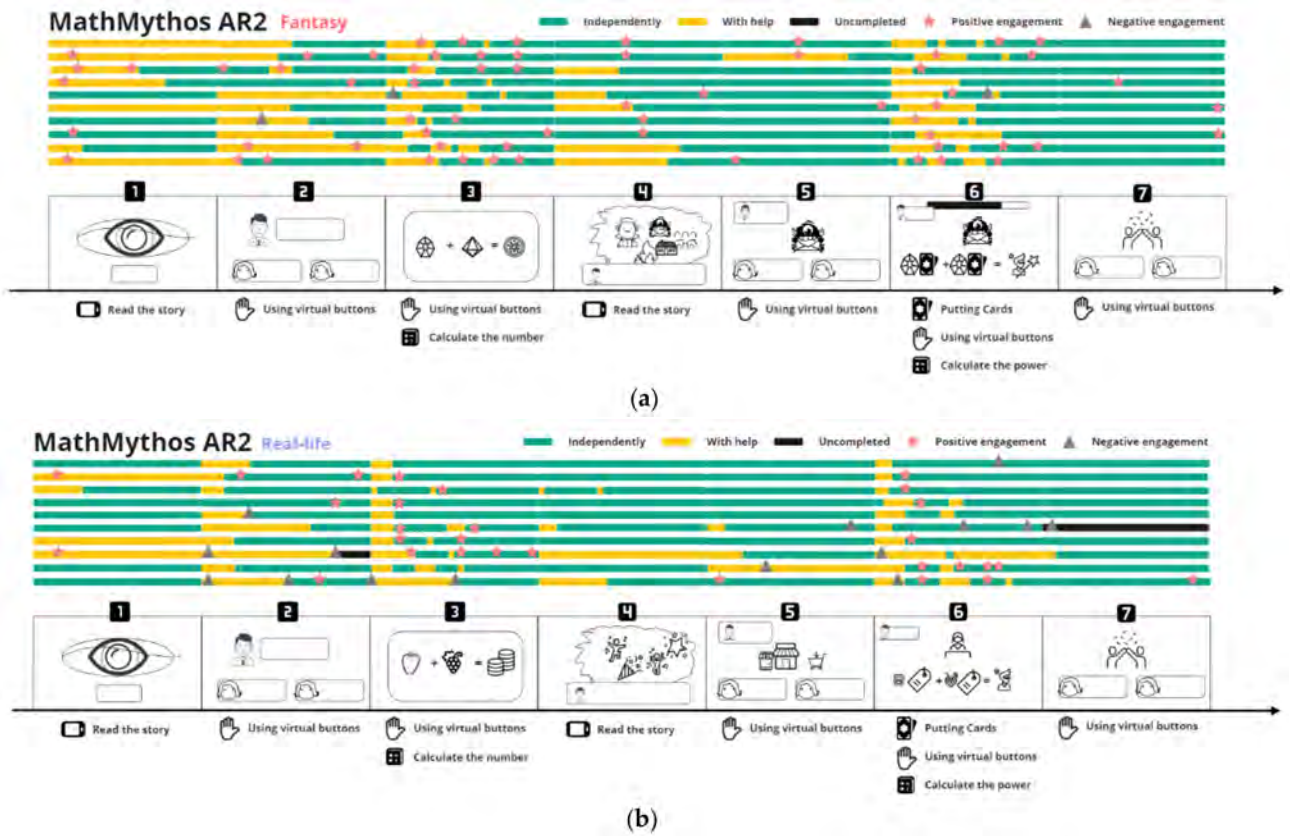


Figure 4. User journey maps of MathMythos AR2 with (**a**): the real-life version and (**b**): the fantasy version.

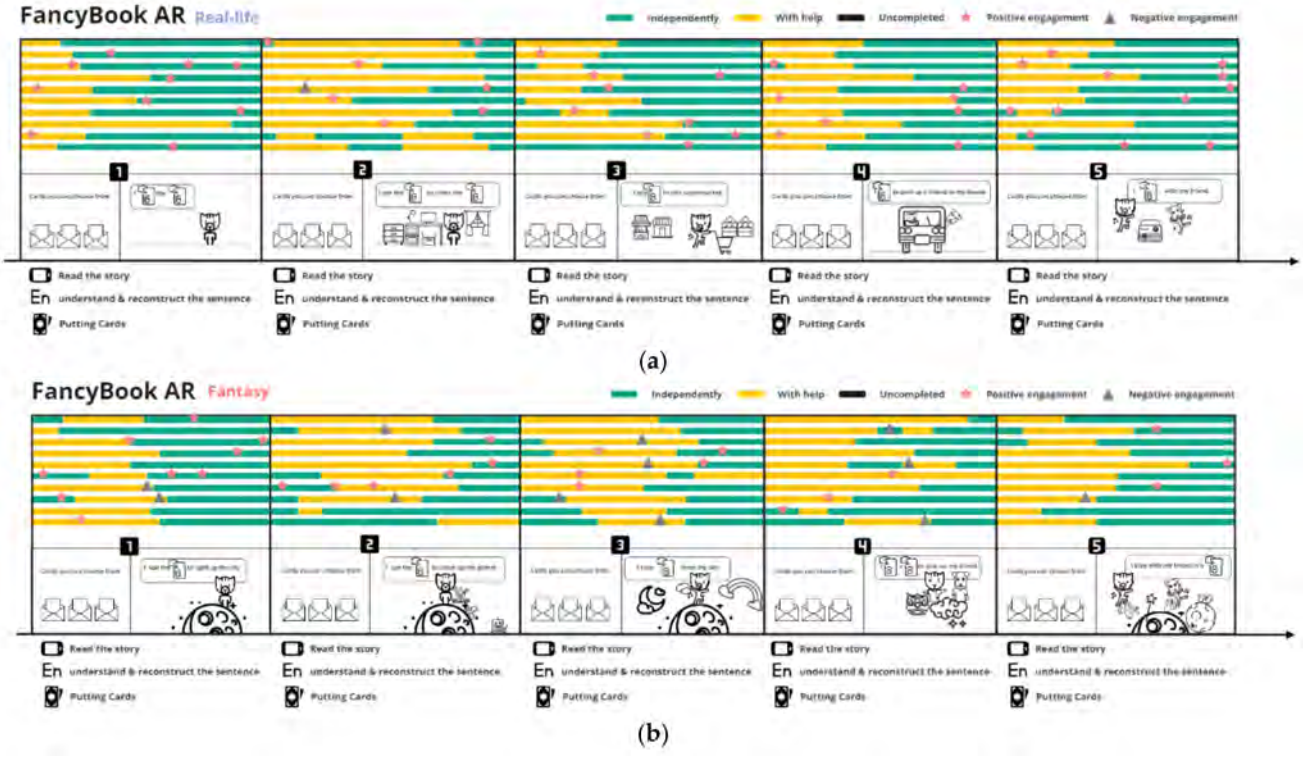


Figure 5. User journey maps of FancyBook AR with (**a**): the real-life version and (**b**): the fantasy version.

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 whispered voice the mathematical operations they had learned before. We also found differences in teachers' role of instruction on story-telling and gameplay. Students listened carefully to the teacher's introduction on the real-life version's interaction first and then tried it out with the teacher's guidance. In the fantasy version, students showed more tendency in trying the game first instead of waiting for instruction (more green lines appear before yellow lines). However, it was still frequent that their initial attempts had failed, requiring scaffolding from teachers. With the fantasy version, the teacher spent more time helping students understand the narrative than with the real-life version.

An additional sign of positive engagement marked by experts was that students in the fantasy condition tended to hold the cards they received in Figure 5, section 3 when most students put cards aside in the real-life version. Only a few students showed signs of disengagement with the fantasy narrative, confused about the fantasy narrative and the virtual buttons' insensitivity at the beginning of the gameplay. Most students showed positive engagement with or without assistance in the fantasy narrative. In contrast, most positive engagements occurred when students finished the task independently in the real-life version. However, more students showed anxiousness at the beginning of the gameplay in the real-life version, whereas others expressed boredom at later stages where most tasks were repetitive practice.

4.5. FancyBook AR: Commonalities between the Two Narrative Versions

In both versions, students 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 played the role of checking whether students properly understood the sentence they constructed, as some children just picked random cards to activate the animation effect without fully understanding the sentence. Therefore, the teacher and students interacted more frequently, but the communication states vary depending on narrative versions.

4.6. FancyBook AR: Differences between Two Narratives Versions

More students 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 such as "trash-eating monster" and "magic stick" were alien to the students. They showed signs of confusion and prolonged hesitation even after teachers translated these words into Chinese.

5. Discussion

5.1. Whether Fantasy in AR Game-Based Learning for a Classroom Creates More Engaging and Immersive Mental States for Players?

We combined quantitative and qualitative results to address this research question. 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 FancyBook AR, students perceived significantly higher enjoyment and immersion in the real-life version than the fantasy version. Combining their self-reported enjoyment (Table 8) with patterns of engagement (Figure 3), we found fantasy in FancyBook led to less enjoyment and negative cognitive engagement for students. Despite children 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 conflict 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.

Students 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 does not influence children's enjoyable and immersive experiences. Children showed signs of negative engagement such as boredom, anxiety, and being forced to play with the real-life narrative. Despite the results, simply interpreting the data as fantasy settings may favourably engage children in math learning while adversely engaging children in second-language learning are inadequate. Instead, we wish to understand these occurrences via the lens of children's experiences and games' fantasy integration within subject matter features.

5.1.1. Contextual Reasons for Differences in Players' Experience and Engagement

The learning of English for pupils is topic-based, taught via subject matter material, which is a key contrast between mathematics learning and second-language acquisition [64]. With FancyBookAR, the subject matter learners simultaneously acquired the narrative content and linguistic knowledge of English, where the unfamiliarity of the content influenced their 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 [65]. However, unproficiency with the 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 described as foreign language anxiety and content-related anxiety, causing negative engagement such as feelings of frustration [66]. Similarly, pervasive and immersive games often need "reinterpretation of meaning conventions [67]." Players may 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 MathMythos AR2 since solving mathematical problems such as calculation can be tackled independently of story comprehension with abstract thinking methods [68]. The phenomenon we found that students 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 closed 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 [69]. Therefore, confusion occurred among some children with math learning in the fantasy narrative, but this did not seem to influence their enjoyable, immersive experience and overall engagement. When children are satisfied with meaning interpretation and construction [67], they achieve a suspension of disbelief, feeling more immersed and engaged with their emotional response [70]. Conversely, not understanding the words immediately impacted the understanding of the story in the FancyBookAR.

5.1.2. Analogy and Imagination for Comprehension and Engagement

Our research 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 [71]. 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 [40]. Both mental states are fundamental in AR game-based learning for different stages of play. A potential point is that challenges may have an inverse effect on the imagination. Learners need to connect to prior knowledge when making sense of things [20]. 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 while playing.

5.2. What Is the Teachers' Role in Scaffolding Children with Fantasy Play in Game-Based Learning?

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

5.2.1. Interaction

Children are familiar with digital interactions such as screen touch and physical interactions such as turning pages. The interaction with the augmented physical world, which requires eyes on the digital layer and hands on the physical layer is unfamiliar and therefore sometimes challenging for children, especially at the beginning. Although we designed animated arrows and related instruction to highlight important areas and ways of interaction, we noticed that the teachers' 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 corrective gestures to help some students understand that triggering a virtual button is conducted 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 students on how to interact. Despite the necessity of scaffolding at the beginning, too much direct intervention in the middle of the game can interrupt students' immersion and flow experience [72]. This aspect led us to consider the necessity of designing complex interactions such as virtual buttons. A more straightforward and consistent approach to interacting, such as scanning cards in FancyBookAR, is effort-saving for teachers and helps students concentrate on the main task.

5.2.2. Narrative

We found that the teachers' role in facilitating students' understanding of the narrative differed between the two games. Using MathMythosAR2 for mathematics learning, students had more questions regarding the fantasy narrative. However, they also showed more initiative to try things out first regardless of whether the narrative was correctly interpreted or not. The teacher normally assisted students in gaining a better understanding of the narrative by describing the stories in simpler words when students 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 students and focusing their attention. To reduce feelings of interruption and provide a smoother play experience for the children, a pedagogical agent can therefore be designed that functions as an easy self-insert for the teacher.

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

5.2.3. 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 [66]. FancybookAR aims to engage second-language English learners through

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 students with the game FancyBookAR. Teachers, therefore, played a role in introducing the learning contents explicitly and directing students' 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 explanation from teachers. Certain phenomena reflected a need to introduce new knowledge to students with the FancyBook AR. A device-based or a teacher-led introduction regarding the explanation, pronunciation, and application of unfamiliar vocabularies and grammar is required to facilitate the learning procedure.

With both narrative MathMythosAR2, teachers spent little time instructing students with learning content directly. Since children of this age were already proficient in mathematical operations, and the narrative is not a necessary component of mathematical knowledge, children's incomplete understanding of the external narrative did not directly affect their ability to perform operations. Most cases requiring scaffolding are when students make repeated calculation errors. While instructing students, teachers often address arithmetic concepts outside of the narrative framework. Research suggests effective instruction for low achievers requires a context that facilitates teachers' explicit instructions and students' idea-sharing [73]. 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.

5.3. How to Situate Learning in AR Fantasy of Game-Based Learning in Consideration of Learners' Engagement, Experience, and the Teachers' Scaffolding?

Although endogenous fantasy is often regarded as an essential way of improving players' engagement, situating learning in AR fantasy of game-based learning does not necessarily require turning every learning goal into a fantasy representation and integrating each part endogenously. In combination with our result, we suggest designers firstly consider whether the narrative is intrinsically 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 players' imagination, further enhancing players' 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 students' comprehension of the knowledge. Design should consider activating users' analogy for real-life with narrative-related knowledge, facilitating understanding where fantasy can be applied as a next step after students have established a good understanding of explicit knowledge. To leverage endogenous fantasy's positive effects, designers can partly integrate learning content with fantasy. Designers can create fantasy and real-life mixed settings, e.g., an alien visitor settles down to regular life on Earth, allowing students to understand the learning context with imagination and interest.

To further support teachers' scaffolding on gameplay interaction, narrative, and knowledge understanding, we synthesize several strategies for situating learning in the AR fantasy of game-based learning. Regarding interaction, we suggest designing games with simple and consistent ways of interaction. Complex AR interaction for the first time needs real-world instruction. While 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 is feasible to design a pedagogical agent that enables instructors to take on the role of a scaffolder. To assist teachers in scaffolding new knowledge introduction and

providing 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.

5.4. Limitations

There is a possible weakness in our study groups from various locations since 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 analysis. 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.

6. Conclusions

We answered three research questions regarding situating learning in AR fantasy of game-based learning through experiments and analysis with qualitative and quantitative data. We discovered that fantasy narratives increase students' engagement in mathematics learning while disengaging students in second-language learning. They perceived stronger immersion with AR fantasy for mathematics learning than AR fantasy for second-language learning. Fantasy narrative activated players' 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 were more open to imagination and fantasy when there was less challenge in learning. We found that teachers' scaffolding mainly focused on complicated interaction in AR with MathMythosAR2 for learning math. With FancyBookAR for learning English, teachers' scaffolding mainly focused on narrative interpretation and knowledge explanation. We further contextualized and explained the phenomena we found and synthesized several strategies 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 effective incentives to immerse and engage students 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 challenge. (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 such as card tracking, which is effort-saving for teachers and task-concentrating for students. (5) It is feasible to design a pedagogical agent that enables teachers to take on the role of scaffolding seamlessly at any time. (6) Design should also prioritize analogy activation when constructing scenes for device-based or teacher-led presentations of new information for beginners, as well as clear explanations for low-achieving learners.

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