Multimodal Technologies and Interaction

MDPI

Article

Investigating Immersion and Learning in a Low-Embodied versus High-Embodied Digital Educational Game: Lessons Learned from an Implementation in an Authentic School Classroom

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Received: 22 August 2019; Accepted: 10 October 2019; Published: 12 October 2019

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Abstract: Immersion is often argued to be one of the main driving forces behind children's learning in digital educational games. Researchers have supported that movement-based interaction afforded by emerging embodied digital educational games may heighten even more immersion and learning. However, there is lack of empirical research warranting these claims. This case study has investigated the impact of high-embodied digital educational game, integrated in a primary school classroom, on children's immersion and content knowledge about nutrition (condition1 = 24 children), in comparison to the impact of a low-embodied version of the game (condition2 = 20 children). Post-interventional surveys investigating immersion indicated that there was difference only on the level of engagement, in terms of perceived usability, while children's learning gains in terms of content knowledge did not differ among the two conditions. Interviews with a subset of the children (n = 8 per condition) resulted in the identification of (a) media form, (b) media content and (c) context-related factors, which provided plausible explanations about children's experienced immersion. Implications are discussed for supporting immersion in high-embodied educational digital games.

Keywords: embodied digital educational games; children; immersion; content knowledge; authentic educational settings

1. Introduction

Immersion, as a gradated and multi-level process of cognitive and emotional involvement in digital educational games is often argued as one of the main driving forces behind children's learning [1–3]. Dede [4] has stated, for instance, that immersion can enhance children's learning in different ways, by supporting: (a) multiple and complementary insights of complex phenomena, (b) situated learning, and (c) the transfer of skills in real world situations. Previous studies have provided empirical substantiation to these claims supporting that high levels of immersion in digital educational games can increase children's performance and subsequent learning [5–12].

The emergence of embodied digital educational games has renewed the interest on this topic, as researchers have argued that the affordances of embodied digital games for movement-based interaction may heighten even more experienced immersion [13,14]. In its essence, embodied digital educational games compose an emergent category of digital games, which integrate gestures or even full-body movement into the act of learning [15–20]. These innovative games, which are grounded in immersive interfaces and leverage the power of motion-based technologies and natural interfaces (e.g., Wii, Xbox Kinect, Leap Motion), it is argued, create new educational possibilities [21,22]. However, while an increasing number of studies has focused on the development and evaluation of embodied digital educational games [15,23,24], there is a lack of empirical research focusing on the investigation of children's experienced immersion [25], warranting these claims.

Existing research on the investigation of experienced immersion is largely focused on the use of non-educational embodied games with young-adult populations and has taken place mostly in highly-controlled laboratory settings [14,26–28]. As part of our literature review, we have identified one and only empirical study investigating middle school students' experienced immersion in embodied digital educational games, enacted in a university laboratory [29]. Despite some first evidence for the positive impact of embodied digital educational games on students' immersion and subsequent learning [29], this work requires replication and expansion in other contexts (e.g., authentic classrooms) as well as with students of various age groups (e.g., primary school children). Overall, the topic seems to be still under-investigated, while existing research has mostly taken place in highly-controlled laboratory settings rather than in authentic educational settings.

Acknowledging the vital role of immersion in relation to children's learning, it seems crucial to obtain a better understanding of whether and under what circumstances embodied digital educational games can have a positive impact on children's experienced immersion, when integrated in authentic educational settings. The present case study investigates the impact of a high-embodied digital educational game on children's immersion and content knowledge about nutrition (condition1 = 24), versus the impact of a low-embodied digital educational game (condition2 = 20), in a real school classroom. Acknowledging that experienced immersion can be influenced by media-related factors (including media form and media content factors), as well as by context-related factors [30–32], this case study aimed to investigate how such factors might differentiate the learning experience in the two conditions. Taking into account the impact of these factors, the study aimed at extracting a set of guidelines for supporting children's immersion in high-embodied digital educational games implemented in authentic learning settings.

In the rest of the paper we present the theoretical background, the rationale, and the research questions guiding the study, the materials and the methods, as well as the results derived from this study. The study continues with the discussion of the findings as well as of the main study limitations in relation to future research directions. Finally, we reflect on our findings, and we discuss the implications for supporting children's immersion in high-embodied digital games implemented in authentic educational settings.

2. Theoretical Background

2.1. Defining Immersion in HCI

Immersion is a widely-used construct in the field of Human-Computer Interaction (HCI) and has received a great attention in the literature of digital games. In particular, immersion has been operationalized as a multi-level continuum of cognitive and emotional involvement in a given digital game [1]. According to Cheng, She, and Annetta [2] the first level, "Engagement", is based on *attraction*, *time investment*, and *usability*; to enter this level players need to first like the activity, perceive the game-based activity as a user-friendly one, and be willing to invest time playing the game. If the aforementioned conditions are accomplished, then players may be able to become further involved and enter "Engrossment", which is the second level of immersion. At this level, *decreased perceptions* of the surrounding real world and *emotional attachment* are the determinant factors, as the activity becomes the most important part of players' attention. Finally, during the "Total immersion" stage, players experience *presence*, as a sense of being within the digital game, and *empathy* with the game-based characters.

According to Dede [4] immersion has been defined "as the participant's suspension of disbelief that she or he is 'inside' a digitally enhanced setting" (p.66), whilst immersion has been also considered among the most crucial aspects for a successful digital game. Ermi and Mäyrä [33] have provided, for instance, one of the most prevalent models in the HCI field indicating that a successful digital game should promote three types of immersion: (a) sensory immersion (taking place when the sensory information of the real world is overpowered by the sensory stimuli provided in the digital game), (b) challenge-based immersion (taking place when there is a balance between the abilities of the player and the game-based tasks), and (c) imaginative immersion (taking place when the player is absorbed with the narrative plot and identifies with the game-based characters).

The phenomenon of immersing oneself into a digital game has been established widely in the HCI research community, as entertainment and learning around digital games are assumed to be dependent on the degree of experienced immersion, namely the degree to which users become cognitively and emotionally engaged with a given digital game [2,3]. However, while immersion is a desirable gaming aspect, existing research has indicated that high levels of immersion are often difficult to be achieved due to impact and interaction of several factors. In particular, immersion has been previously argued to depend on various factors which are related to the *Media characteristics*, the *User characteristics* and the *Context characteristics*. Media characteristics are further distinguished in *Media form* related factors, which refer to the affordances of the platform being used for enacting a digital game, and *Media content* related factors, which refer to the features of the game-based content [30,32]. According to Bleumers et al. [31], *User* related factors (which relate to the psychological characteristics and predispositions of the players to become immersed in the digital world of the game) and *Context* related factors (which refer to the characteristics of the environment in which the game is contextualized), may interact with the media so that they enhance, dampen or even eliminate experienced immersion. Following this reasoning, it does not come as a surprise that high levels of immersion are often not easy to be achieved.

2.2. Immersion in Embodied Digital Games

The emergence of embodied digital games has recently brought up the topic of immersion at the foreground again. As researchers have supported, embodied digital games could heighten even more experienced immersion due to their affordances for movement-based interaction [13,14]. In particular, as has been argued, the motion-based affordances of embodied digital games contribute to immersion as they allow more natural and richer interactions with the task to be achieved; they offer additional engaging stimuli and cues which facilitate unobtrusive feedback; they reduce physical passivity as the players' use their bodies during the gameplay; and they provide an additional channel to the players for feeling challenged, intrigued and excited [14,26,34].

In support of this claim, an emerging corpus of empirical studies has started to investigate players' experienced immersion in high-embodied digital games when compared to low-embodied digital games. For instance, Lindley et al. [28] compared the use of *Donkey Konga bongos* with a standard controller to investigate how affording motion through an input device affected university students' immersion. According to their findings, the higher the degree of body movement afforded by the digital game, the more was the players' experienced immersion. Likewise, Coppi et al. [27] in a more recent study investigated the experienced immersion of 20 young adults playing *Angry Birds: Star Wars* twice: once with a normal controller (joystick) and another with a motion sensitive input device (Kinect). According to their findings the embodied gaming elicited higher levels of immersion in comparison to the non-embodied playing experience. Despite these promising findings, existing empirical studies on the topic are still limited and have mostly taken place in highly controlled, laboratory settings, focusing on the investigation of non-educational embodied digital games played, mainly, by adult populations.

Technology-enhanced embodied learning, as a contemporary pedagogical approach grounded in the theory of embodied cognition theory, has just started gaining ground during the last decade, due to the emergence of motion-based educational digital games [15,19,20,35]. As such, learning via embodied digital educational games is still a relatively nascent field. According to Johnson-Glenberg and her colleagues [22,36,37], embodied digital educational games, as an emerging gaming genre, are defined by three main aspects: (a) the high amount of sensorimotor engagement, as achieved through bodily motion, (b) the high amount of gestural congruency, which is achieved through the relevance of the gestures with the content to be learned, as well as (c) the high amount of immersion, which is influenced to a great degree by the type and configuration of the content's display. In particular, embodied digital educational games are usually equipped with motion tracking systems (e.g., Wii, Xbox Kinect, or Leap Motion) to enable hand gestures or body movements that are sometimes (but not always) mapped to the educational content to be learned. In addition, embodied digital educational games are usually projected on large screen displays, interactive floors, 360° head-mounted displays (HMD), virtual reality or mixed reality rooms, which are perceived as highly immersive.

However, despite these affordances, there is lack of empirical research with a clear focus on the investigation of children's experienced immersion in embodied educational games. Prior work has mostly adopted experimental research in highly-controlled laboratory settings for investigating the hypothesis that embodied digital educational games have an impact on learning [15]. Others have conducted design-based research, in order to generate recommendations for the design of more effective embodied digital educational games [24]. In addition, a few prior studies have taken place in special education units [38], rather than in mainstream educational settings [39,40].

As part of our literature review, we have identified one and only relevant empirical study by Lindgren et al. [29], which focused on immersion in the context of embodied digital educational games. As part of this study, which adopted an experimental research design, the researchers investigated middle school students' learning, attitudes, and immersion (sense of presence) in an immersive whole-body simulation versus a desktop version of the same simulation about gravity and planetary motion. According to the findings of this study, the middle school students who participated in the whole-body simulation outperformed their counterparts, who participated in the desktop-based simulation in terms of their conceptual understanding, attitudes towards learning science and experienced sense of presence. However, in their study Lindgren et al. [29], focused exclusively on experienced presence, as a component of the higher level of immersion, rather than investigating how immersion, as a process of cognitive and emotional involvement, was affected in the two conditions. In addition, the study took place in a highly-controlled laboratory setting (within a university laboratory) as opposed to taking place in an authentic educational context (real classroom). Finally, by taking a quantitative approach, Lindgren et al. [29] did not focus on the investigation of the factors which affected (positively or negatively) students' sense of presence in the two conditions. Overall, it seems that further investigation of immersion in relation to children's learning in the context of high embodied digital games, enacted in authentic educational settings (real classrooms), is needed.

2.3. Learning with Embodied Digital Games

The idea of employing games for learning is not a new one. Annetta, Mangrum, Holmes, Collazo, and Cheng [41] have stated, for instance, that "from peek-a-boo to video games, people have learned for eons" (p. 1091). However, as immersive technologies have become more pervasive, computer games are being promoted to the forefront of teaching and learning, due to their potential to provide more engaging and immersive learning experiences [42]. According to de Freitas [43], immersive games for educational purposes could be defined as "applications using the characteristics of video and computer games to create engaging and immersive learning experiences for delivering specified learning goals, outcomes and experiences" (p. 9). As the argument goes, when highly immersed in these digital educational games, children feel as being part of the gaming environment, give their attention over to it, and engage with the learning content related to the topic being addressed, as they fail to perceive or acknowledge the existence of the interface as well as of the gaming controls during the gameplay experience [12,44,45]. In support of these claims, an emerging corpus of studies has provided empirical substantiation that high levels of immersion in digital educational games can increase children's performance and subsequent learning [5–12].

Embodied digital educational games, as an emerging genre of immersive educational games, are argued to support students' learning. A couple of explanations of why embodied digital environments can positively impact learning have been offered. First, the theory of embodied cognition suggests that including body movement and gestures could support student learning of even abstract information [46,47]. Second, by defining learning not only as a visio-cognitive activity but also, as a physical one, researchers have argued that this can engage students with multimodal interactions which in turn might allow deeper levels of processing of the educational content to be learned [48]. Third, digital games for embodied learning are aligned with more effective modalities for feedback provision as they support the visualization of the body movement in relation to learning goals to be achieved [49]. This type of real-time feedback is also less intrusive in comparison to verbal feedback protocols [29], while at the same time, it provides opportunities for reflection and immediate remediation of conceptual misconceptions [36]. Finally, research has also shown that movement can allow students to reduce their cognitive load, leaving more cognitive capacity for other activities or cognitive processes. This idea relates to "how children exploit physical action to dynamically offload parts of mental operations to physical action in the environment" [50].

Despite these suggested learning affordances, incorporating innovative embodied and natural user interfaces in the school classroom introduces new challenges to teaching and learning; therefore, their incorporation in mainstream education is at a very slow pace [51]. According to Karakostas, Palaigeorgiou, and Kompatsiaris [52] existing research on embodied learning technologies has been fragmented and has taken place mostly in laboratory settings focusing on the participants' interactions with the embodied environments, therefore lacking a clear focus on investigating their efficacy in authentic educational contexts. Moreover, while a number of technology-enhanced embodied learning environments have received positive evaluation in high-controlled laboratory settings [29,53], the limited number of studies conducted in authentic school classrooms had not be as successful as initially expected in promoting students' learning gains, compared to low-embodied, desktop-based environments [54,55]. The later warrants further investigation towards shedding light on the efficacy of high-embodied vs. low-embodied learning environments in authentic classroom settings.

2.4. Designing for Immersive Learning Experiences in Embodied Digital Games

The educational design of immersive digital games is still an emerging research area [56–58], and studies linking game attributes to learning are relatively sparse and limited [59–62]. Acknowledging the value of linking game to learning attributes for creating an immersive and transferable learning experience to the students, Lameras, Arnab, Dunwell, Stewart, Clarke, and Petridis [63] conducted an extensive literature review and synthesis on the design and use of serious games in higher education. As part of their review effort Lameras et al. [63] linked game mechanics with different types of feedback indicators (social, cognitive, affective, motivational, progress) explaining how various gaming attributes may support in-game meaningful feedback to foster students' engagement with the learning process as follows: (a) Social feedback (e.g., via visual feedback, discussion thread, in-game chat, non-player characters interaction, communal discovery), (b) Cognitive feedback (e.g., via prompts, in-game hints, assessment tools, game levels, gaining/losing lives), (c) Affective (e.g., via missions, game challenges, scoring, achievement, storytelling), (d) Motivational (e.g., via experience points, game levels, role-playing, timers, storytelling, bonuses, contests, lives, virtual coins, inventories) and (e) Progress (e.g., via progress bar, achievements, dashboards, assessment tool, game levels, challenge repetition). However, according to Lameras et al. [63] this taxonomy needs to be empirically investigated in various contexts while also taking into account different gaming genres, such as for instance high-embodied digital educational games which are the focus of the present study.

Prior studies presenting the development of high-embodied educational digital games are still limited and even more limited are the studies which involved children, adopting a participatory design process and providing a window on children's preferences and expectations from these games [64–66]. Malinverni, Schaper, and Pares [64] presented, for instance, an evaluation-driven design approach to develop a full-body interaction game supporting children's learning in environmental education. As part of this study, taking into account children's intuitive embodied interactions, Malinverni et al. [64]

found that children were requesting for more bodily interaction with the game (e.g., rather than standing still for five seconds impersonating the seed to create plants on that spot, children preferred to touch or rub the floor projection as if they were sowing the seed). They did also identify various children's misconceptions provoked by the design of the system, suggesting that embodied interactions and game mechanics should be carefully designed to contribute to the development of more accurate environmental models and concepts for the children. However, according to our knowledge, there is still lack of empirical studies investigating children's perceptions about the factors affecting their experienced immersion in this emergent genre of games. Consequently, little is yet known on the principled design of high-embodied educational games supporting children's immersion and subsequent learning.

3. Rationale and Research Questions

Acknowledging the vital role of immersion in relation to children's learning, the present case study aims at obtaining a better understanding of whether and under what circumstances (i.e., what contributing factors) high-embodied digital educational games can have a positive impact on students' experienced immersion and subsequent content knowledge, when integrated in authentic educational settings. This study investigates the impact of a high-embodied digital educational game (Kinect-based version) on children's immersion and content knowledge about nutrition, in comparison to a low-embodied version (Desktop-based version) of the same game, when integrated in an authentic school classroom. In particular, the present case study aimed at the investigation of the three following research questions:

1. Is there a difference in children's experienced immersion between the low- and high-embodied digital educational game conditions?
2. What were the main factors contributing to experienced immersion in the two conditions, as perceived by the children?
3. Is there a difference in children's learning gains on content knowledge between the low- and high-embodied digital educational game conditions?

4. Materials and Methods

4.1. Participants

Forty-four 4th graders (aged 8–9 years old), who were enrolled in a public primary school in the Eastern Mediterranean, participated in this case study. Children were randomly assigned to the two conditions. Group1 (Kinect-based gaming condition) had 24 children (12 boys, 50%) and Group2 (Desktop-based gaming condition) had 20 children (11 boys, 55%). Before the intervention consent forms were obtained by the children's legal guardians regarding the data collection.

4.2. Research Design

This case study was part of a broader project investigating issues of classroom orchestration, referring to how teachers design technology-enhanced learning settings grounded on *Embodied*, *Embedded*, *Enacted* and *Extended* cognition theories (4E cognition theories) and manage the learning activities and constraints in real-time. The case study is grounded in an explanatory sequential design, composed of two sequential phases [67]. During the first phase, we adopted a two-group quasi-experimental design to investigate children's learning and immersion per condition. Next, we proceeded with a qualitative data collection phase to deepen our understanding of the factors contributing to children's immersion in each condition.

4.3. The Digital Game

As part of the teaching intervention we have employed the "Alien Health" digital game, which was designed to teach 4th to 12th grades about nutrition, while also encouraging children's discourse and reflection in relation to making more healthy food choices [17]. According to the backstory of the game, children are asked to help an alien, who is in charge of stopping the collision of an asteroid with the Earth; however, the alien is hungry, and he cannot communicate. Children's mission is to make the right nutritional choices for the alien to make him feel better. To achieve this goal, during the gameplay, children are presented with combinations of food (including earth and even alien foods), and are requested to make a choice, within a predefined timeframe, considering a constellation of five nutrients per food (protein, fats, carbohydrates, fiber, and vitamins/minerals). By figuring out the healthiest foods for the alien, children receive constant feedback and information about the nutritional value of common foods [68]. The alien, which is represented by an avatar has the form of a non-player character expressing his health and wellbeing through facial and body animations to provide both positive and negative feedback for the player when choosing foods [62]. When the alien is fully energized ("super fit") then he is able continue his travel with his bio-linked ship to complete his missions. Table 1 provides an overview of the four game modes in relation to the game mechanics and rules, as presented in the study of Hermans, van den Broek, Nederkoorn, Otten, Ruiter, and Johnson-Glenberg [69].

Table 1. Game modes, rules, and game mechanics of the "Alien Health" as presented by Hermans et al. [69].

Game Modes	Rules	Game Mechanics
Food Selection Game Mode	• Player must choose the healthiest food between 2 presented options • Player may not cancel or change a previous choice • Food choices change the state of the Alien • The Player wins when the Alien is in the "Super Fit" state	• Binary Choices to reach a goal
Quick Sort Game Mode	• Player must choose the healthiest food between 2 presented options • Player may not cancel or change a previous choice • A countdown timer counts down to 0 • Game ends when all pairs of food are sorted or the timer hits 0	• Rapid Binary Choices to assess nutrition comprehension and rapid decision making
Build a Meal Game Mode	• Player is presented with a carousel of foods organized by main course, side dish, drink and dessert • Player must choose one food from each carousel to place on the plate • Healthier foods chosen award the player with bonus shields for the alien's ship	• Cumulative Choices to build a set of foods that benefit or harm the player's survival chances in the Ship Runner Game Mode
Ship Runner Game Mode	• Player jumps at least 1 m to the left or the right to steer the ship left or right • Hitting an asteroid reduces shields by 1 • Coins give the player points • Seeds are needed to win the level • Player wins when they reach the end of the level with specified number of seeds • Player loses when all shields are gone	• Goal Runner on 3 rails • Player uses embodied gestures to steer ship • Timing to avoid obstacles and collect coins and seeds • Survive to reach the goal

The specific digital learning game was chosen for three main reasons. First, the digital game was available in both a low-embodied (desktop-based) and in a high-embodied (Kinect-based) versions.

According to the four-level taxonomy of embodiment suggested by Johnson-Glenberg, Birchfield, Tolentino, and Koziupa [39] desktop-based games are included in the two lowest levels of the taxonomy as they provide no opportunities for sensorimotor engagement. In contrast, Kinect-based games, which allow hand gestures or body movements closely mapped to the educational content that must be learned, are included in the upper levels of the taxonomy. Second, the digital game was aligned with the educational curriculum of the 4th graders as it was directly related with the thematic of "Health, food and nutrition" included in the subject of "Health Education". Third, the digital game was subjected to a feasibility study and findings indicated its acceptability by the children as well as its affordances to improve content knowledge [17,68,69]. However, although the game was designed to instruct about nutrition, as part of this study, we were interested in investigating other aspects of this digital game, focusing primarily on children's experienced immersion.

4.4. The Interventions

Considering the research goals of this study, an 80-minute intervention was developed and implemented in an authentic school classroom for each condition. Taking into account that within a typical classroom there are usually 18–24 children, a different classroom set up was employed per condition to integrate more effectively the low- and the high-embodied version of the game. Children in the low-embodied (desktop) condition were divided into pairs and used the desktop-based version of the digital game; in this version children used mouse, keyboard and a typical-size computer screen for making a choice and feeding the alien (Figure 1). On the other hand, in the Kinect-based condition, the children worked in groups of four as the projection screen was large enough to allow viewing access to all the members of the group (Figure 2). In both conditions, the children were grouped by their teacher, who took into account children's relationships, collaboration skills, and academic background, thus creating mixed-ability and functional teams.

Figure 1. A group in the low-embodied condition.

Figure 2. Two groups in the high-embodied condition.

It should be also noted that although the game was based on a single player mode, some collaborative learning elements were included to the test conditions. In particular, the children in each group took turns for playing; the child(ren) in the rest of the group was/were asked to provide feedback to the player, and after each round, all the players were gathered together for reporting their food choices on structured worksheets, discussing their choices.

4.5. Data Collection and Analysis

The data collection process included the collection of baseline data about children's gaming attitudes/attitudes towards computers using a survey, pre-post conceptual tests, administration of a post-activity immersion survey, as well as individual interviews with a subset of the children. It should be noted that given the young age of the children, for all surveys, data were carefully collected with the classroom teacher reading, explaining and simplifying each single item at the classroom plenary, making sure that each statement was totally understandable, before the children selecting their answer. The following sub-sections provide more information about the data collection methods and the data analysis followed.

4.5.1. Baseline Data

We collected baseline data using a survey, aiming at establishing the equivalency of the two conditions. The survey, which was administered by the 4th graders' teacher and was completed individually by the participating children, had two main parts: *Gaming attitudes* and *Attitudes towards computers*. *Gaming attitudes* was measured using a Likert scale with 11 items on a five-point Likert scale, derived from the survey of Bonanno and Kommers [70], as this was adapted and validated in the study of Bressler and Bodzin [71]. The Cronbach's alpha for the adapted instrument was 0.73. Children's attitudes towards computers were assessed using the *Computer Attitude Measure for Young Students* (CAMYS) [72], which was composed of 12 items on a five-point Likert scale. The CAMYS is considered a valid instrument and has a documented reliability alpha coefficient of 0.85. Differences between the two conditions were examined using the Mann–Whitney U test, given the small sample size in each condition and the lack of normal distribution in the data.

4.5.2. Pre-Post Conceptual Tests

Pre- and post-conceptual tests were completed individually by the participating children to evaluate content knowledge acquisition about nutrition. The conceptual test employed was developed by Johnson-Glenberg and Hekler [68] for evaluating children's content knowledge learning gains in the Alien Health game. The conceptual test was translated and adapted in the native language of the children. The maximum possible score was 20 marks. Differences within and between the two conditions were examined using the Wilcoxon Signed-Rank test and Mann–Whitney U test respectively, given the small sample size of each condition and the lack of a normal distribution in the data.

4.5.3. Immersion Survey

After the implementation, children in each condition completed individually the Game Immersion Questionnaire (GIQ) which measured their experienced immersion [2]. In particular, children were asked to complete:

- The *Engagement* scale, which is comprised of three subscales with a total of 9 items (Cronbach's alpha = 0.86): *Attraction* (4 items, Cronbach's alpha = 0.81), *Usability* (2 items, Cronbach's alpha = 0.73), and *Time investment* (3 items, Cronbach's alpha = 0.70);
- The *Engrossment* scale, which is comprised of two subscales with a total of 7 items (Cronbach's alpha = 0.86): *Decreased perceptions* (4 items, Cronbach's alpha = 0.79) and *Emotional attachment* (3 items, Cronbach's alpha = 0.79);
- The *Total Immersion* scale, which is comprised of two subscales with a total of 8 items (Cronbach's alpha = 0.92): *Presence* (4 items, Cronbach's alpha = 0.88) and *Empathy* (4 items, Cronbach's alpha = 0.87).

Differences between the two conditions were examined using the Mann–Whitney U test, given the small sample size of each condition and the lack of normal distribution in the data.

4.5.4. Post-Activity Interviews

Eight children from each condition participated in semi-structured individual interviews, which took place after the intervention. The sample was purposive, ensuring that each child came from a different team, in an attempt to have representatives from as many groups/pairs as possible. Children were initially asked to report their feelings as these were related to their experienced immersion during the game-based activity (e.g., *To what extent did you feel as being within the digital game rather than in the real environment? To what degree did the gaming activity capture all your senses?*), and then they were probed to discuss the factors which contributed to their experienced immersion positively or negatively (e.g., *What were the main factors contributing to your sense of being [or not] in the digital game? How did these factors contribute [or not] in your gaming experience?*)

All interviews were analyzed qualitatively using a top-down thematic analysis approach [73]. That is, our thematic analysis was theoretically driven, as it was guided by our research focus in classifying children's self-reported positively or negatively contributing factors as: (a) *Media* related factors, including *Media form* related factors (referring to the affordances of the gaming platform) and *Media content* related factors (referring to the features of the gaming content) and (b) *Context* related factors (referring to the characteristics of the physical environment and the pedagogical setting in which the game was contextualized). In particular, the group interviews were transcribed and then, analysis of the verbal data was employed according to the multi-step procedure proposed by Chi [74], as follows: (a) reduction of the transcribed protocols (keeping for analysis only the students' reports about their experienced immersion), (b) segmentation of the reduced protocols according to stand-alone "units of meaning" indicating factors affecting students' experienced immersion, (c) coding and grouping of the codes (factors) under the pre-defined higher order categories (*Media form* related factors, *Media content* related factors, and *Context* related factors), (d) review of the coded evidence and agreement upon the final classification of the emerged factors in the higher-order categories, (e) representation of the coded data in a tabular form, and (f) interpretation and discussion of the emerged categories, focusing on the most salient topics.

5. Results

5.1. Setting the Baseline

A Mann–Whitney U test was used to identify any potential differences between children in the two conditions, in terms of their gaming attitudes and attitudes towards computer use. Results (Table 2) showed that there were no statistical differences in the children's gaming attitudes ($U(42) = 217$, $z = -0.54$, $p > 0.05$) and attitudes towards computers ($U(42) = 203$, $z = -0.87$, $p > 0.05$) between the groups.

Table 2. Baseline assessment of gaming attitudes and attitudes towards computers per condition

	Condition 1 Kinect-Based Game		Condition 2 Desktop-Based Game		Z
	Mean	**SD**	**Mean**	**SD**	
Gaming attitudes	3.38	0.65	3.23	0.63	−0.54
Attitudes towards computers	3.93	0.70	3.71	0.79	−0.87

Note. * $p < 0.05$, ** $p < 0.01$. *** $p < 0.001$.

5.2. Learning Gains

A Mann–Whitney U test was initially used to identify any potential differences between groups in children's pre-test scores. Results showed that there were no statistical differences in the children's pre-test scores ($U(42) = 229.5$, $z = -0.26$, $p > 0.05$), indicating that children had not difference in their prior content knowledge about nutrition. A comparison of children's performance in the experimental group, before and after the digital intervention, using the Wilcoxon signed-rank test statistical analysis, indicated that children in the experimental group improved their performance from pre to post testing; this difference was statistically significant ($W(23) = 2$, $z = -3.85$, $p < 0.001$). Likewise, children in the comparison group improved their performance from pre to post testing and this difference was also statistically significant ($W(19) = 0$, $z = -3.92$, $p < 0.001$). However, in both conditions children's post-scores remained at relatively low levels as they were much below the average (M = 10 marks). To further examine the comparison of the differences between the post-test and pre-test scores in each group, normalized learning gains were computed i.e., (PostTest scores – PreTest scores)/(100% – PreTest scores). Difference in children's normalized learning gains between the two groups were examined using the Mann–Whitney U test. Results (Table 3) showed that were no statistically differences between the two groups ($U(40) = 175.5$, $z = -1.52$, $p > 0.05$).

Table 3. Pre-test scores, post-test scores and normalized learning gains on content knowledge about nutrition per condition.

	Condition 1 Kinect-Based Game		Condition 2 Desktop-Based Game		Z
	Mean	**SD**	**Mean**	**SD**	
Pre-test scores	1.33	1.49	1.40	1.60	−0.26
Post-test scores	5.52	2.99	7.05	2.81	−1.84
Normalized learning gains	0.30	0.14	0.22	0.18	−1.52

Note. * $p < 0.05$, ** $p < 0.01$. *** $p < 0.001$.

5.3. Experienced Immersion

A Mann–Whitney U test was used to identify any potential differences in children's experienced immersion (three immersive levels and their dimensions) between the groups (see Table 4). Results showed that there were no statistical differences between the children's *Engagement* ($U(42) = 171$, $z = -1.63$, $p > 0.05$), *Engrossment* ($U(42) = 233.5$, $z = -0.153$, $p > 0.05$) and *Total immersion* ($U(42) = 218$, $z = -0.519$, $p > 0.05$) in both conditions. Also, there were no statistically significant differences in the dimensions of the three immersive levels, with one exception; that is, children in the low-embodied condition perceived the gaming activity as a more user-friendly one compared to the children in the high-embodied condition, and this difference was statistically significant ($U(42) = 153$, $z = -2.09$, $p < 0.05$).

Table 4. Pre-test scores, post-test scores, and normalized learning gains per condition.

	Condition 1 Kinect-Based Game		Condition 2 Desktop-Based Game		Z
	Mean	**SD**	**Mean**	**SD**	
L1-Engagement: Attraction	4.24	0.86	4.34	0.69	−0.29
L1-Engagement: Usability	3.29	1.03	3.95	0.78	−2.09 *
L1-Engagement: Time investment	3.65	0.90	4.00	0.75	−1.21
L2-Engrossment: Decreased perceptions	3.29	0.65	3.28	1.07	−0.40
L2-Engrossment: Emotional attachment	3.83	0.91	3.70	0.72	−0.72
L3-Total immersion: Presence	3.49	0.79	3.23	1.22	−0.75
L3-Total immersion: Empathy	3.29	1.02	3.18	1.12	−0.20

Note. * $p < 0.05$, ** $p < 0.01$. *** $p < 0.001$.

5.4. Factors Affecting Immersion

The thematic analysis of the post-activity interviews resulted in a set of factors affecting children's immersion (Table 5).

Table 5. Factors affecting experienced immersion.

	Codes *(Student Comments)*	Condition 1 Kinect-Based Game *	Condition 2 Desktop-Based Game *
Media-related factors [Media form]	Projection *(size of the screen)*	√	x
	Interface *(use of novel technologies)*	√	x
	Controls *(user-friendliness of the gaming controls)*	x	√
	Bodily movement *(players' kinesthetic activity)*	√	n/a
	Embodiment (*gesture-based interactions)*	√	n/a
	Single-player mode *(lack of multiplayer affordances)*	x	x
	Synchronization *(belated projection of movements on the screen)*	x	n/a
	Technical bugs *(due to players' proximity to the Kinect camera)*	x	n/a
Media-related factors [Media content]	Narrative plot *(storyline framing the learning tasks)*	√	√
	Gaming features *(points and rewards)*	√	√
	Learning nature *(innovative educational approach)*	√	√
	Scaffolding *(available hints and prompts)*	√	√
	Unrealistic items *(virtual objects of low fidelity and realism)*	x	x
	Time pressure *(tasks to be completed in limited timeframe)*	x	x
	Task difficulty *(level of the gaming challenges)*	x	x
	Navigation *(ways of navigating the game)*	x	x
Context-related factors	Peer feedback *(support provided by the groupmates)*	√	√
	Collaboration *(dialogue, exchange of views and ideas)*	√	√
	Waiting time *(time in queue between turns)*	x	n/a
	Classroom arrangement *(other groups' interventions)*	x	n/a
	Classroom noise *(external sounds/noise)*	x	x

* (√) indicates the positively evaluated factors, (x) indicates the negatively evaluated factors, and (n/a) indicates any factors that were not reported by the children per condition.

5.4.1. Media Form Related Factors

According to the children using the high-embodied version of the game, the *large projection* (i.e., bigger screen providing more heightened sensory stimuli), the *interface* (i.e., use of novel technologies), the affordances of the gaming platform for promoting *bodily movement* (i.e., via the players' kinesthetic activity), and *embodiment* (via the gesture-based interactions) contributed to their experienced immersion. For example,

> *"There was a large screen which seemed nicer and easier. I could see everything in that big screen. I could have better control of the game, and I could feel like being in the game!" [#Boy -I-, Kinect-based version]*

However, the children reported that the *controls* of the game were rather different from traditional gaming controls (e.g., keyboard, mouse). In particular, according to the children one of the main embodied parts of the game was moving the game screens forward with a hand closing action which was clunky and tiresome, thus having a negative effect on their experienced immersion. For example,

> *"Often, it was difficult for us to play the game using our hands. It was difficult to close your hand in a way that … We had to repeat the hand closing action several times for the game to capture our movement!" [#Boy -P-, Kinect-based version]*

In addition, the children reported that the *single-player mode* of the game (i.e., lack of multiplayer affordances), which transformed more of the group members as spectators, some *synchronization* issues (i.e., belated projection of player's movements on the screen), as well as some *technical bugs* (provoked by children's proximity to the Kinect), affected their experienced immersion negatively. For example,

> *"Sometimes there were problems with the technology. The game blocked, and our hand signal was not appearing on the screen or was presented in a wrong position. This cost us time as we had to wait for the problem to be resolved!" [#Boy -I-, Kinect-based version]*

On other hand, the children using the low-embodied version of the game evaluated negatively most of the media form related factors. In particular, consistent with the children using the high-embodied version of the game they disliked the *single-player mode* of the game. In addition, they reported that the *small projection* (i.e., limited desktop screen) and the *interface* (i.e., traditional desktop-based technologies) had a negative effect on their experienced immersion. For example,

> *"I would prefer playing the game in front of bigger screen. I would like to play the game and move within the game world via a bigger screen." [#Girl -E-, Desktop-based version]*

However, in contrast to the high-embodied condition, the children using the low-embodied version of the game explained that the desktop-based computer with its familiar *gaming controls* kept them engaged in the activity. For example,

> *"Handling the game via the mouse was really easy. All you needed to do was just a 'click'!" [#Boy -A-, Desktop-based version]*

5.4.2. Media Content Related Factors

Given that the gaming content was similar in both conditions, it is not surprising that children in the high- and low-embodied setting evaluated the media content similarly, in relation to their experienced immersion. In particular, children in both conditions, highlighted the positive impact of the *narrative plot* (i.e., storyline framing the learning tasks), the *gaming features* (i.e., points and rewards), the integrated *scaffolding* (i.e., available hints on the nutritional value of each food), as well as the *learning nature* of the game (i.e., the innovative educational approach). For example,

> *"I liked the game's narrative plot as there was an alien trying to go back to his planet. We had to feed the alien with healthy foods. I liked the fact that every new planet was a new stage in the game with a new activity to do. It was an educational game because you could learn about nutrients in food." [#Girl -L-, Desktop-based version]*

On the other hand, children in both conditions highlighted that the *unrealistic items* (i.e., alien creatures of low fidelity and realism), the *task difficulty* (due to their lack of prior knowledge on the topic), the *navigation* within the game, and the *time pressure* (given that there were game-based tasks which had to be accomplished in a limited timeframe) had often a negative effect on their experienced immersion. For example,

> *"In some parts of the game the time that we had was limited. It would be nice to have more time. In some cases, we were not able to complete the tasks as we had only a few seconds to think and act." [#Boy -E-, Kinect-based version]*

5.4.3. Context Related Factors

Focusing on the context related factors, the low-embodied condition appears to be positively linked to the children's experienced immersion. More specifically, the children highlighted that the collaborative activity which framed the game, allowed a *productive collaboration* with their teammates (i.e., dialogue, exchange of views and ideas), while also promoted *peer feedback*. For example,

> *"During the gameplay we were helping each other. We would see the food combinations, we would discuss them, we would compare them and exchange our ideas, and then we would make a selection. We had a great fun during our collaboration!" [#Girl -A-, Desktop-based version]*

The only negative evaluated factor by the children using the low-embodied version was the *classroom noise*, which in some cases could even distract children's attention from the game.

In contrast, according to the children using the high-embodied version of the game, it seems that three of the reported context-related factors were linked to the children's experienced immersion in a negative way. In particular, although children in this condition reported positively with respect to *peer feedback* and *collaboration*, they negatively elaborated on the *classroom arrangement* (allowing other groups' interventions) and the *waiting time* in the activity. These characteristics seemed to result in high levels of *classroom noise*, which was the most frequently reported factor negatively linked to children's experienced immersion in the high-embodied condition. For example,

> *"The game was for a single player. All the other members of the group stayed aside, they had conversations with each other about topics unrelated to the game's content and they were often not concentrated in their team members' actions." [#Girl -A-, Kinect-based version]*

6. Discussion

In recent years, high-embodied digital learning games, grounded in motion-based technologies (e.g., Kinect, Wii, Motion) and immersive interfaces (e.g., virtual or mixed reality technologies) have started to emerge and enter the educational arena. The prevalence of these innovative digital games in comparison to low-embodied digital educational games is often attributed to their perceived affordances to facilitate experienced immersion by creating an embodied sense of being into the digital game [15,25,39]. However, despite these arguments, empirical research is mainly focused on the evaluation of experienced immersion in highly controlled laboratory settings with young adult populations, using non-educational high-embodied digital games.

Acknowledging the vital role of immersion in relation to children's learning, this case study has extended prior research in the educational context by investigating children's immersion in a high-embodied digital educational game (Condition1 = 24), versus a low-embodied digital educational game (Condition2 = 18), in an authentic school classroom. This case study also aimed at extracting a set of guidelines for supporting children's immersion in high-embodied digital educational games implemented in authentic learning settings. What follows below is the discussion of our findings per research question.

6.1. Experienced Immersion

Our findings are opposed to the findings of existing research in laboratory settings, which have previously supported the prevalence of high-embodied versus low-embodied games in young adults' experienced immersion [27,28]. Likewise, our findings are also opposed to the study of Lindgren et al. [29], which indicated that middle school students who participated in a high-embodied condition (whole-body interactive simulation), outperformed their counterparts who participated in a low-embodied condition (desktop version of the same simulation), in terms of their experienced immersion and subsequent learning. In particular, the analysis of our post-interventional surveys indicated that there was no difference in most dimensions of experienced immersion with one exception: The children who participated in the low-embodied condition deemed the gaming setting as a more user-friendly one, in comparison to their counterparts in the high-embodied condition.

6.2. Factors Affecting Immersion

Subsequent analysis of children's interviews regarding the factors affecting immersion between the two groups shed more light on our findings about the children's experienced immersion per condition.

In particular, a set of factors related to the media form characteristics indicated that despite the affordances of a *larger projection*, *interface*, *locomotion*, and *embodiment*, children in the high-embodied condition experienced difficulties with the *gaming controls*. The hand-closing action (which was the dominant body movement that children were requested to employ for moving the game screens forward) was clunky and tiresome; in turn this had a negative effect on the experienced immersion. This finding is aligned to the previous remark of Pasch et al. [14], who supported that, while movement-based interfaces often provide a venue for more natural interactions than mouse and keyboard, such interfaces could also be criticized by the players when they do not resemble movements in real life or when not responding to players' expectations. Acknowledging the value of responding to the young players' needs and expectations, Malinverni et al. [64] have therefore suggested that the development of educational embodied digital games should be based on a participatory design approach, involving children for taking into account their intuitive embodied interactions.

In addition, the children in the high-embodied condition also reported on *synchronization problems* and subsequent *technical bugs*. These usability issues seem to have had a detrimental effect on children's experienced immersion and could provide a plausible explanation for the difference in children's perceived usability between the two conditions. Additionally, aligned with the theoretical conceptualization of immersion as a multi-level process of cognitive and emotional involvement, such usability issues could serve as a major barrier in children's successful transit via the immersive progression [1–3].

On the other hand, it is not a surprise that we have identified no difference on the media content factors when comparing the high- and low-embodied educational conditions, given that the gaming content was the same in both settings. In particular, many content characteristics such as the *narrative* (storytelling framing the learning tasks), the *gaming features* (points and rewards), and the *scaffolding* (available hints and prompts) were positively evaluated by the children in both groups. This finding is aligned with the literature review and synthesis of Lameras et al. [63] who have proposed that such gaming mechanics are linked to desirable learning attributes, ensuring an immersive and transferable learning experience. In contrast, what seemed to have a negative influence on children's experienced immersion was the *lack of realism and fidelity* as well as the perceived *tasks' difficulty* in combination with *time pressure* and *navigation difficulties* within the game.

Finally, what seemed to differentiate at a major degree children's experienced immersion were a set of factors related to the context characteristics. In alignment with the study of Anderson and Wall [54], who investigated the integration of a high-embodied digital educational game in an authentic school classroom, we too found, for instance, that while the children enjoyed the collaborative activity into which the game was contextualized, *collaboration* in the high-embodied condition was often quite unstructured. The detrimental effect on children's experienced immersion was also reinforced by the *classroom arrangement* in groups of four children, which increased the *waiting time* between players' turns, and resulted in children's off-task behaviors and *classroom noise*. These factors point to issues of classroom orchestration, which grant further attention and could be addressed in the design of future research implementations [75]. Overall, our findings provide empirical substantiation on the claim of Bleumers et al. [31] that context related factors may interact with the media affordances so as to reinforce, prohibit, or even eliminate experienced immersion.

6.3. Learning Gains

As part of this study, while we have observed a statistically significant difference in children's pre-and post-test learning scores in each condition, children in the high-embodied condition did not outperformed their counterparts in the low-embodied condition. These findings are aligned with existing studies [5–12], providing empirical support for the positive relationship between children's experienced immersion, performance, and subsequent learning gains. In particular, as already reported, this study showed no difference in children's experienced immersion in the low- and high-embodied digital educational game. Despite the immersive affordances of high-embodied digital educational games in this study, we found that a set of usability issues as well as various contextual factors derived from the integration of the high-embodied digital educational game in an authentic school classroom suppressed children's experienced immersion.

On a different note, while there was a statistically significant difference between students' pre-test and post-test scores in both conditions, children's post-scores remained at relatively low levels, as they were much below the average. This finding could be attributed to the relatively short intervention period. As previously posed, for instance, by Annetta Minogue, Holmes, and Cheng [76]: "Most 'gamers' must play a given game many times for many hours before they learn to navigate and negotiate in the synthetic world efficiently let alone learn content embedded in the game." (p. 79). Hence, while gaming can increase students' learning, according to a corpus of prior empirical studies in the field [76–78] the short duration of children's exposure to a given educational game may keep children's learning gains in relatively low levels or make it difficult to identify any direct correlation between game use and academic success [79].

7. Limitations and Future Studies

Even though the findings of this case study contribute to a better understanding of experienced immersion in high- and low-embodied digital games contextualized in authentic educational settings, some limitations of this work are important to note. First, challenges related to classroom orchestration such as time pressure, classroom noise, classroom arrangements, etc., seem to have affected children's experienced immersion, especially in the high-embodied condition. Future research should aim to address these challenges and re-examine children's immersion. Second, the sample of the study was small and drawn from two classrooms in a public primary school. Future research could replicate this study with a larger sample of classrooms (clusters), ideally drawn from randomly-selected schools (e.g., clustered sampling) to increase external validity. Third, this study mostly relies on self-reported and retrospective measures which may be regarded as a limitation. Future studies could use in-situ and objective measurements, such as eye gaze measurement via eye-trackers, EEGs, and multimodal learning analytics for investigating how immersion and technology-enhanced embodied learning unfold during the intervention. Finally, our findings are most relevant to the "Alien Health" as a specific desktop-based (low-embodied version) and Kinect-based (high-embodied version) digital game. However, this is only one example of an embodied digital educational game integrated in the learning discipline of "Health Education" and the thematic area of "Health, food and nutrition". Future studies could focus on different embodied digital educational games integrated in additional learning disciplines (e.g., in science education, mathematics education, physical education) and their impact on children's immersion to examine the consistency of the reported findings in other contexts and settings (i.e., ecological validity).

8. Conclusions and Implications

Despite the limitations, the present case study provides empirical evidence supporting that children's heightened levels of immersion during the implementation of high-embodied digital games in authentic educational contexts should not be taken as a given. At the same time, grounded on our empirical findings, we could state a set of guidelines for supporting children's immersion in high-embodied digital games implemented in authentic educational settings, as follows:

1. Develop embodied digital educational games that integrate intuitive movements and natural interactions that resemble movements in real life and are aligned to the users' skills, needs, and expectations.
2. Organize a training/demonstration session before the gaming activity to allow the children to familiarize themselves with the gaming controls as well as with the technological affordances and limitations of the game.
3. Introduce and discuss with the children the learning topic before the gaming activity, as this could reduce the tasks' difficulty embedded in the game.

4. Plan for a classroom set-up which allows up to four Kinect-based stations (one per classroom side), splitting children's groups among the four sides of the classroom, to avoid inter-group interventions and subsequent distractions.
5. Work with smaller cohorts of children (up to 12 children) and divide them in groups of 2–3 members per Kinect station, rather than bigger groups.
6. Contextualize the game in a scripted collaborative setting, where clear roles, responsibilities, and even turn taking will be clear to all members of the group.
7. Proceed with the development of build-in collaboration features in high-embodied digital educational games, to involve simultaneously all the group members in the gameplay.
8. Develop and implement high-embodied digital educational games with improved audio-visual characteristics for overpowering the sensory information derived from the physical world.
9. Develop tools for orchestration that allow the collection of data generated by the activity (e.g., multimodal interactions, learning analytics), their dynamic processing, and their use to support and enhance the embodied learning and teaching processes.

Overall, the aforementioned guidelines relate well to research on classroom orchestration which should be expanded to inform research on immersive learning. Addressing these ideas requires the contribution of people from different disciplines: designers, programmers, educators, and researchers, weaving together in the HCI, learning sciences, and data science communities.

Author Contributions: Conceptualization, Y.G. and A.I; methodology, Y.G., A.I., and M.I.; validation, Y.G. and A.I.; formal analysis, Y.G., A.I., M.I.; investigation, Y.G. and M.I.; writing—original draft preparation, Y.G.; writing—review and editing, A.I.; visualization, Y.G. and A.I.; project administration, Y.G and M.I.

Funding: This work is part of the project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 739578 (RISE-Call:H2020-WIDESPREAD-01-2016-2017-TeamingPhase2) and the government of the Republic of Cyprus through the Directorate General for European Programmes, Coordination and Development. This work is also part of the INTELed Project [INnovative Training via Embodied Learning and multi-sensory techniques for inclusive Education] (Project 2017-1-CY01-KA201-026733), which is co-funded by the Erasmus+ Programme of the European Union.

Acknowledgments: We would like to thank Embodied Games (https://www.embodied-games.com) for providing us access to the "Alien Health" game for the purposes of the present study.

Conflicts of Interest: The authors declare no conflict of interest.

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