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NutriQuest VR Game: An Immersive Serious Game for Promoting Healthy Dietary Behaviors Among Children

Konstantinos Salomidis *, Olga Malisova and Georgios D. Styliaras

Department of Food Science and Technology, University of Patras, 30131 Agrinion, Greece; omalisova@upatras.gr (O.M.); gstyl@upatras.gr (G.D.S.)
* Correspondence: up1052743@ac.upatras.gr

Abstract

Childhood obesity has become a major public health concern worldwide, highlighting the need for innovative educational interventions that promote healthier dietary behaviors from an early age. Virtual reality (VR) serious games have emerged as a promising approach for supporting behavior change through immersive and interactive learning experiences. This paper presents the *NutriQuest VR* game, an immersive serious VR game designed to improve children's nutritional decision-making through repeated food-selection tasks based on the Nutri-Score classification system. A total of 33 middle-school students participated in a six-week intervention consisting of six gameplay sessions. Children's adherence to the Mediterranean diet was assessed before and after the intervention using the validated KIDMED 2.0 questionnaire, while participants' in-game performance was recorded throughout the intervention. The results demonstrated a statistically significant improvement in children's adherence to the Mediterranean diet, with mean KIDMED 2.0 scores increasing from 5.67 to 6.55 (p = 0.013, Cohen's d = 0.459). Participants also showed a significant improvement in their in-game performance between the first and final gameplay sessions, with mean scores increasing from 300.15 to 327.27 ($p < 0.001$, Cohen's d = 1.270). Overall, the findings provide preliminary evidence of improved reported Mediterranean diet adherence and in-game performance within the study sample.

Keywords: childhood obesity; virtual reality; serious games; KIDMED 2.0; Nutri-Score

1. Introduction

Obesity has become one of the most important public health challenges worldwide and affects not only adults but also children. Childhood obesity is associated with an increased risk of developing several chronic diseases later in life, including diabetes, cancer, cardiovascular diseases, and other life-threatening non-communicable diseases (NCDs) [1]. According to recent estimates, approximately one in ten children worldwide lives with obesity [2]. According to experts from Harvard T.H. Chan School of Public Health, childhood obesity in the U.S. has reached its highest rate ever recorded [3], with approximately one in five children affected [4]. Similar trends are observed across Europe. According to data collected during the sixth round of the WHO European Childhood Obesity Surveillance Initiative (COSI), approximately one in four children aged 7–9 years are living with overweight (including obesity), while one in ten is living with obesity [1].

Obesity is defined by the World Health Organization (WHO) as a chronic, relapsing disease arising from complex interactions between genetics, neurobiology, eating behaviors, access to healthy diet, market forces, and the broader environment [5]. Childhood obesity is

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a multifactorial condition influenced by biological, environmental, and behavioral factors. Biological determinants include genetic predisposition, epigenetic mechanisms, endocrine disorders, and other medical conditions [6]. Lifestyle factors also play a major role and include poor dietary habits, insufficient physical activity, inadequate sleep, obesogenic environments, excessive energy intake, socioeconomic inequalities, and psychosocial stress [6]. Among these factors, unhealthy dietary behavior represents one of the most modifiable risk factors; therefore, the present study focuses specifically on promoting healthier eating habits as an approach to obesity prevention.

Technology is increasingly viewed as an important part of the solution to the growing challenges of health promotion and disease prevention [7]. Digital health interventions provide new opportunities to support behavioral change through engaging, personalized, and interactive experiences. Among these technologies, virtual reality (VR) has emerged as one of the most promising educational tools.

VR is defined as a computer-generated simulation that represents a real place or situation and enables users to interact with it in a seemingly real or physical way through dedicated electronic equipment [8]. Due to its immersive nature, VR has been recognized as a promising technology for supporting behavior change through learner-centered experiences [9]. Immersive educational interventions that stimulate episodic memory have been shown to improve knowledge retention and facilitate meaningful learning [10]. Immersion itself is considered a fundamental state of consciousness resulting from sustained engagement with attention-capturing and interest-inducing stimuli [11]. Furthermore, immersive learning environments promote emotional engagement and motivation through narrative experiences and storyliving [12].

Alongside VR, serious games have attracted considerable attention as effective tools for achieving educational, training, and health-related objectives [13]. A serious game is a digital game designed not only for entertainment but also to accomplish one or more additional goals such as learning or health promotion [14]. Serious games have been successfully applied across diverse domains, including education, healthcare, public policy, and advertising, with the aim of influencing users' knowledge, attitudes, and behaviors [15]. Within the health domain, serious games have demonstrated both physiological and psychological benefits while supporting self-directed care, cognitive functioning, and healthy lifestyle behaviors [16].

The combination of VR and serious games is particularly promising for educational interventions, as the immersive and interactive characteristics of VR can complement the learning objectives of serious games [17,18].

Recent research has also continued to explore the use of VR and extended reality technologies in health promotion and behavioral interventions involving children and adolescents [19–21]. However, relatively few have investigated immersive VR serious games specifically designed to improve children's dietary behaviors. Moreover, limited attention has been given to the integration of established game design frameworks together with evidence-based behavior change techniques within a single VR intervention. To address this gap, the present study introduces the *NutriQuest VR* game, an immersive VR serious game developed to promote healthier dietary behaviors among children through interactive nutritional decision-making. The effectiveness of the proposed intervention was evaluated by examining changes in children's adherence to the Mediterranean diet, in-game performance, and the relationship between these outcomes.

2. Related Work

Our review of the literature on VR-based serious games focusing on nutrition revealed a limited number of existing applications and games. In this section, we first present

VR applications and games that address nutrition and health-related topics, followed by serious games that were developed on other digital platforms, such as mobile or desktop, but share conceptual and educational similarities with our approach.

2.1. VR Applications About Nutrition

This subsection presents existing VR applications that address nutrition and health related topics.

The VR Diet Museum [22] is a VR application designed to raise awareness about nutrition through exploratory learning. Its function is based on the Fogg behavior model [23], according to which behavior change is influenced by motivation, ability and prompts. Users navigate in a virtual museum environment and get informed about health impacts of different dietary choices, aiming to increase their nutrition-related habits. The application was evaluated through an iterative process involving a cognitive walkthrough with six interaction design experts, followed by semi-structured user testing with six participants. Findings suggested that the immersive and interactive nature of the experience increased participants' interest in nutrition-related information, encouraged reflection on their own eating habits, and promoted engagement with the educational content. However, the authors acknowledged limitations regarding the precision of the recommendations and the educational effectiveness of the system.

You Better Eat to Survive is a VR game that demands actions in the real world [24]. It is designed for two players—one uses the VR headset, and the other helps them to eat food in the real world—who must cooperate in order to escape from a virtual island. The game was evaluated through a user study involving 22 participants who played in pairs and subsequently reflected on their experiences. The findings indicated that incorporating real eating into gameplay enhanced players' sense of presence, strengthened trust and interdependence between players, and made the survival experience more authentic. Based on these findings, the authors proposed design themes for future VR games incorporating cooperative eating interactions.

The *Hydration* VR game [25] is a serious game developed in VR with a specific focus on promoting awareness of hydration. In the game, the player assumes the role of a waiter working at a beach bar during the summer season. While serving customers, the player must also manage their own hydration status; failure to drink water leads to dizziness and eventually resulting in game failure. Through this mechanic, the game aims to train the player to remember to stay hydrated in their daily activities. The preliminary study focused primarily on the technological implementation and usability aspects of the application. A heuristic evaluation involving three experts with experience in serious games and educational technologies indicated that the game was generally perceived as intuitive, engaging, and easy to use, while also identifying areas for further refinement. However, the study did not investigate behavioral outcomes related to hydration practices. Future work was proposed to examine whether repeated exposure to the game can contribute to meaningful changes in hydration-related behaviors.

Although VR applications addressing nutrition are emerging, most of the identified applications focus primarily on awareness raising, information provision, or isolated educational experiences. At the same time, existing research has provided theoretical and empirical evidence that VR may support behavioral change processes [26,27]. However, the existing empirical evidence in the context of dietary behavior has focused on adult participants, while relatively limited research has examined the potential of VR interventions to promote healthier dietary behaviors specifically among children. Furthermore, among the identified VR applications addressing nutrition, limited attention has been given to structured interventions that combine repeated nutritional decision-making scenarios,

nutrition-specific feedback, and behavior change techniques within an immersive environment. This gap motivated the development of *NutriQuest VR*, which was designed to integrate these elements into a single educational intervention aimed at promoting healthier food choices among children.

2.2. Serious Games About Nutrition

This subsection presents digital serious games that aim to support nutrition education and influence eating-related behaviors among children.

Food Decisions [28] is a computer-based gamified intervention designed to improve young people's understanding and use of nutrition labels to support healthier food choices. The game provides experiential learning activities in virtual food environments, where players learn to interpret nutrition label information and identify healthier food products. The intervention was formatively evaluated in a school-based study involving 30 Year-10 pupils aged 14–15 years using a single-group, noncontrolled pre–post design. Participants completed questionnaires assessing their confidence, knowledge, and perceptions of nutrition label use before and after the intervention. The results indicated that participants' confidence in making healthier food choices increased significantly, while most participants also reported that the game was fun. The authors concluded that the intervention was feasible for use in secondary schools and showed potential for supporting nutrition label education and healthier food choices.

Mole's Veggie Adventures App [29] is a mobile application targeting children aged 3–6, and it has been evaluated with preschoolers in Poland and Finland. Players guide a mole character through a vegetable garden across different seasons, completing activities that encourage fruit and vegetable consumption while also promoting self-regulation and social interaction skills. The application was evaluated through a cluster-randomized intervention study involving 221 preschool children from early childhood education centers. Parents reported children's fruit and vegetable acceptance before and after a 3–4 week intervention period during which educators used the application with children on a regular basis. The results indicated significantly higher fruit and vegetable acceptance scores among children in the intervention group compared to the control group, suggesting that the application can effectively support food education and promote healthier eating behaviors in preschool settings.

NutritionRush [30] aims to raise awareness about malnutrition through interactive gameplay. The game includes a nutrition library that introduces players to key dietary concepts such as energy intake, nutrients, calories, and carbohydrates, supporting informed daily food choices. The prototype was evaluated with 14 participants, including potential users and nutrition experts, through gameplay sessions, questionnaires, and follow-up interviews assessing user experience, gameplay quality, nutritional content, and the perceived potential of the game to promote healthier eating behaviors. The findings suggested that participants considered the game easy to use and educationally valuable, while also identifying several areas for improvement related to gameplay variety, challenge, visual design, and motivational features. Overall, the authors concluded that *NutritionRush* represents a promising initial approach for nutrition education and provides a solid foundation for future development and evaluation.

Foodbot Factory [31] was developed to help Canadian schoolchildren become familiar with the Canada Food Guide. The game consists of thematic modules addressing core food groups, including beverages, whole grains, fruits, vegetables, and protein sources, and combines game mechanics with established behavior change techniques. The evaluation of the application was carried out through a randomized controlled trial involving children aged 8–10 years who played the game for five consecutive days and completed pre- and

post-intervention nutrition knowledge assessments using the validated Nutrition Attitudes and Knowledge (NAK) questionnaire. The results indicated that children who used *Foodbot Factory* achieved significantly greater improvements in overall nutrition knowledge compared with the control group, suggesting that the game was effective in supporting nutrition education and learning outcomes.

VitaVillage [32] is an Android-based serious game in which players assume the role of a farmer responsible for improving the health of a virtual town. Progression is achieved by completing quests and responding to nutrition-related questions, thereby strengthening players' dietary knowledge. In this game, the evaluation consists of a quasi-experimental school-based study involving Year 5 and 6 students from two Australian primary schools. Participants completed a nutrition knowledge questionnaire at baseline and one week later, with students in the intervention group playing *VitaVillage* for two 20 min sessions while the control group received no nutrition education intervention. Results showed that children who played *VitaVillage* demonstrated significantly greater improvements in overall nutrition knowledge compared with the control group, particularly regarding recommended serving sizes and balanced meals. In addition, participants reported positive perceptions of the game, with a mean likeability score of 77 out of 100. The authors concluded that *VitaVillage* has the potential to improve nutrition knowledge among children aged 9–12 years and could serve as a promising nutrition education tool following further development and refinement.

Fit, Food, Fun [33] targets children and adolescents in Germany and focuses on improving nutritional literacy and supporting behavior change. Players travel across different European countries and participate in three mini-games—the Card Game, Estimation Game, and Backpack Game—each addressing country-specific nutritional themes. While two mini-games emphasize nutritional knowledge, the third highlights the balance between diet and physical activity. The game was evaluated in a pilot school-based study involving secondary school students aged 12–14 years. Participants played the game for 15 min on each of three consecutive days, and nutritional knowledge was assessed through pre- and post-intervention questionnaires. Results showed a significant improvement in overall nutrition knowledge following gameplay. Although traditional classroom teaching produced larger knowledge gains, the findings suggested that *Fit, Food, Fun* can serve as an engaging and effective tool for short-term nutrition education among children and adolescents.

The *FIT Game* [34] is a game which took place in school cafeterias where comic-book-style episodes were displayed to students. Through a narrative involving heroic and villainous characters, children were encouraged, using virtual incentives, to help the protagonists by increasing their fruit and vegetable consumption. The game was evaluated in a cluster-randomized school-based study involving four elementary schools. Fruit and vegetable consumption was assessed using before-and-after lunch tray photographs, while skin carotenoid concentrations were measured as an objective biomarker of fruit and vegetable intake. Results showed significant increases in vegetable consumption during the intervention, with improvements partially maintained three months later. Students in the intervention schools also exhibited higher skin carotenoid concentrations compared to controls, indicating sustained increases in fruit and vegetable intake. These findings suggest that the *FIT Game* can effectively promote healthier eating behaviors in elementary school settings.

Squire's Quest! II: Saving the Kingdom of Fivealot [35] is an online game where players take on the role of knights completing food-related quests. Through progressive challenges, the game promotes healthy eating habits and increases fruit and vegetable intake. The game was evaluated with 400 fourth- and fifth-grade children using repeated 24 h dietary recalls collected at baseline and six months after the intervention. The study examined

the effects of different goal-setting strategies, including action and coping plans, on fruit and vegetable consumption. Results indicated that participants who created action or coping plans reported higher vegetable intake at dinner and increased fruit consumption at breakfast, lunch, and snack occasions six months after baseline. These findings suggest that combining serious game mechanics with structured goal-setting strategies can support long-term improvements in children's dietary behaviors.

FoodRateMaster [36] is a serious game developed in Mexico for primary school use. The game teaches children to distinguish between healthy and unhealthy foods, recognize them in real-life contexts, and make informed decisions about their consumption. It consists of six levels, each featuring an antagonist chef who prepares meals that players must evaluate based on nutritional criteria. The game was evaluated in a pilot study involving 60 children aged 8–10 years who completed 12 individual gameplay sessions over a six-week period. Nutritional knowledge and food consumption frequency were assessed before and after the intervention using food knowledge and food frequency questionnaires, while parents also reported perceived changes in their children's eating behaviors. Results showed significant improvements in nutritional knowledge following gameplay, alongside increased self-reported consumption of healthy foods and reduced intake of several unhealthy food items. Parents additionally reported positive changes in their children's attitudes toward healthy eating and greater interest in fruits, vegetables, and distinguishing healthy from unhealthy foods. These findings suggest that *FoodRateMaster* can effectively support nutrition education and promote healthier dietary behaviors among young children.

Alien Health Game [37] is a serious game where players must keep an alien pilot healthy by selecting appropriate foods, thereby learning about the nutritional properties of different food items. The game was evaluated with Dutch elementary school students. Using a randomized controlled design, 108 children aged 10–13 years were assigned either to play *Alien Health* using a Kinect-based interface or to an active control condition involving a web-based nutrition game. Nutritional knowledge was assessed before gameplay, immediately after the intervention, and at a two-week follow-up, while food intake was measured after the intervention and at follow-up. Results showed that children who played *Alien Health* demonstrated greater short-term improvements in knowledge of food macronutrients compared with the control group. However, these gains were not maintained at follow-up, and no significant differences were observed in actual food consumption between the two groups. The findings suggest that the game can effectively enhance nutrition knowledge in the short term, although its impact on longer-term knowledge retention and eating behavior appears limited.

Gustavo in Gnam's Planet [38] is a 2D online PC game addressing diabesity among adolescents. Players control Gustavo, a character stranded on a planet filled with food, who must adopt healthy eating habits in order to return home. The game is grounded in multiple behavior change theories, including the transtheoretical model, social cognitive theory, self-determination theory, and the elaboration likelihood model. In this game, Italian adolescents took part in the evaluation through a pilot study examining its usability, acceptability, and potential to support healthy eating behaviors. Participants completed questionnaires assessing game experience, engagement, and perceptions of the intervention after gameplay. Results indicated high levels of acceptance and enjoyment, with adolescents reporting positive attitudes toward the game and its educational content. The findings suggested that theory-driven serious games such as *Gustavo in Gnam's Planet* may represent a promising approach for promoting healthy eating behaviors among adolescents, although further research is needed to evaluate their long-term effectiveness on dietary outcomes.

Across non-immersive serious games, several recurring design approaches can be identified, including narrative-driven quests (e.g., *Squire's Quest! II*, *Gustavo in Gnam's*

Planet), collections of mini-games targeting specific nutritional concepts (e.g., *Fit, Food, Fun*), avatar-care mechanics (e.g., *Alien Health Game*), and decision-making challenges focused on food selection (e.g., *FoodRateMaster* and *VitaVillage*). A number of these interventions also incorporated behavior change techniques such as goal setting, action planning, feedback, rewards, and self-monitoring, reflecting an increasing emphasis on theory-informed game design.

The evaluation approaches used across studies varied considerably. While some studies primarily assessed usability, acceptability, or engagement (e.g., *NutritionRush* and *Gustavo in Gnam's Planet*), others employed controlled or quasi-experimental designs to examine educational and behavioral outcomes. Previous research demonstrates that serious games can be effective in specific areas of nutrition education, particularly in improving nutritional knowledge, food-related attitudes, and, in some cases, actual dietary behaviors. For example, interventions such as the *FIT Game*, *Squire's Quest! II*, Mole's Veggie Adventures App, and *FoodRateMaster* demonstrated improvements in food-related behaviors or fruit and vegetable consumption, while other games, such as *Alien Health Game*, primarily improved short-term knowledge without producing measurable changes in eating behavior. Furthermore, only a small number of studies incorporated objective outcome measures beyond self-reported questionnaires.

Overall, the literature suggests that serious games can support nutrition education and, in some cases, contribute to healthier dietary behaviors. However, most interventions have been implemented on conventional digital platforms, such as web-based, mobile, or desktop applications, with limited use of immersive technologies. Moreover, relatively few studies combine immersive interaction, nutrition-specific decision-making, explicit behavior change techniques, and theory-driven design within a single intervention targeting children. This gap motivated the development of *NutriQuest VR*, which integrates these elements into an immersive educational experience designed to promote healthier food choices among young users. Unlike many previous studies that focused primarily on usability or short-term knowledge gains, *NutriQuest VR* was evaluated with members of the target population using pre- and post-intervention KIDMED 2.0 measures and recorded in-game performance. The evaluation therefore provides preliminary evidence regarding these specific outcomes.

3. Materials and Methods

This section describes the methodology followed for the development and evaluation of the *NutriQuest VR* game. The design development process of the *NutriQuest VR* game is presented, including different development stages, the theoretical foundations used to support and justify the design decisions, and the behavior change techniques incorporated into the game. Finally, the study hypotheses and the methodology adopted to evaluate the proposed application with the target population are presented.

3.1. NutriQuest VR Game

NutriQuest VR game was designed as a VR nutrition education game for children and adolescents, with the aim of promoting healthier lifestyle and improving nutritional behavior in order to prevent childhood obesity. Although the game can be experienced by a broad range of ages, its educational objectives and evaluation focus on school-aged children without requiring prior nutritional knowledge.

The design of the VR nutrition game was informed by established theoretical approaches in game design, which were used to support and justify key design decisions. Frameworks such as the mechanics–dynamics–aesthetics (MDA) model [39], Winn's design–play–experience (DPE) framework [40,41], Schell's elemental tetrad [42] served as reference

points for aligning gameplay mechanics, narrative elements, and user experience with the intended learning and behavior change objectives. These frameworks were used to guide the interpretation and justification of the development of the game in all its stages rather than being applied as strict development methodologies.

3.1.1. Designing the Story and Scenario of the Game

Players can learn about nutrition and improve their nutritional habits through practicing in simulating environments [43]. Therefore, choosing healthier food items compared to others could increase their knowledge about food health more naturally. The parameters we need to determine in order to incarnate the game include: (i) the categories and nutrition value of food items the players should choose between, (ii) the quantity of food items they choose as expressed in the game's main scene scenario and story.

Food Categories and Nutrition Value

Fruits and vegetables are considered to be among the most beneficial foods for the human body, as they are associated with a lower incidence of cardiovascular disease and obesity and function as antioxidants, phytoestrogens and anti-inflammatory agents [44]. In addition, as stated in modern dietary recommendations like U.S. Dietary Guidelines [45], a complete and balanced meal cannot consist only of fruits and vegetables but should also include elements like grains, dairy, protein foods and oils. Considering these two parameters, we defined the following food categories among which a player has to choose the healthier food items, based on U.S. Dietary Guidelines [45]: fruits, vegetables, proteins, cereal and starchy foods, dairy and substitutes, fats and oils, drinks. We also added a junk food category, which consists of snacks, sweets and fast food, to improve the game flow, as explained in the following subsection.

In order to assess objectively the nutrition value of food items, we employed Nutri-Score, a front-of-package nutrition label colored with five nutritional scales from dark green (healthier) to dark orange, which correspond to the letters from A (healthier) to E (less healthy) [46]. The Nutri-Score algorithm (2015) quantifies the nutritional quality of foods by balancing unfavorable (energy, saturated fat, sugars, and salt) and favorable components (fiber, protein, fruits, vegetables, nuts, legumes, specific oils) per 100 g or 100 mL. Scores range from −15 to +40, classifying products from A to E, with separate algorithms used for general foods, fats/oils, and beverages [47].

Based on the food categories and coloring in Nutri-Score, we created the following table of foods shown in Figure 1 colored as specified by the algorithm. Based on the food categories used in the game and the Nutri-Score classification, Figure 1 presents the food items grouped into their respective categories and colored according to their Nutri-Score classification. Foods shown in dark green correspond to Nutri-Score A, while light green, yellow, orange, and red correspond to Nutri-Scores B, C, D, and E, respectively.

Main Scene Scenario

The main scene of the game consists of eight rounds. In each round, six food items are presented: five items from a specific food category and one item from the junk food category. The player is required to select two items from the six available options. Each food gives points according to Nutri-Score. The core gameplay loop consists of selecting two food items, receiving points based on their Nutri-Score, and progressing to the next round, where new food choices are presented. The player therefore repeatedly makes dietary decisions, while trying to achieve a higher score and complete the food-collection task. The different food categories and the gradual increase in the complexity of the nutritional decisions provide progression throughout the gameplay. The number of food items that appear in each round and the number of food items the player could choose was decided

while testing the game during its development, based on the "flow experience model theory" of Mihaly Csikszentmihalyi [48], as shown in Figure 2. In this model, a player's interest balances anxiety and boredom by dealing with new challenges and developing new skills. In our case, the progression was designed to gradually increase the complexity of nutritional decisions. The main scene scenario follows the diagram of the flow experience model theory and is illustrated in Figure 3.

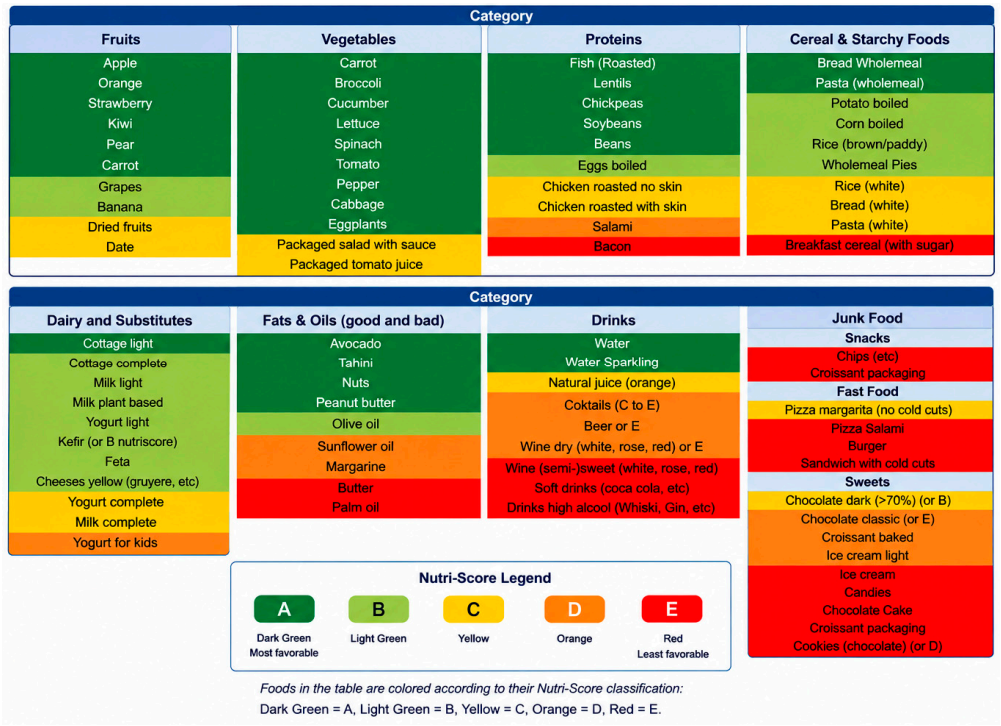


Figure 1. Food classification with Nutri-Score.

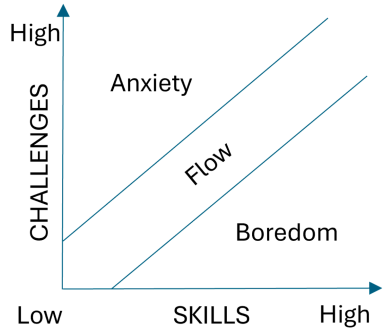


Figure 2. Flow experience model theory diagram (adapted from [48]).

Game Story

To contextualize the food-selection tasks within a meaningful narrative, a simple story framework suitable for children was designed and deployed over three scenes, as stories are an important component of the overall experience [49]. Serious games that use narration can achieve greater immersion, engagement, motivation and learning [50]. Our main character appears in a kindergarten where they meet a child who is sick (introduction scene). In order for the player to heal the child, they must go to the street market and bring them some nutritious food (main scene). If the player manages to bring healthy food, the child will be healed. Otherwise, the child's health does not improve (final scene). The story provides the overall goal of the game, while the food-selection rounds constitute the core gameplay through which the player attempts to achieve this goal. This narrative device

is not designed to suggest that food can replace medical treatment or that nutrition alone can cure illness, but its purpose is to provide motivational context, emotional engagement, and a meaningful goal capable of sustaining children's interest throughout the experience. Furthermore, this storyline appears only briefly at the beginning and conclusion of the game. The combination of a narrative goal, repeated food-selection tasks, immediate score feedback, and progression across rounds provides the game structure through which the educational objectives are delivered. Summarizing, the interaction diagram of our game appears in Figure 4.

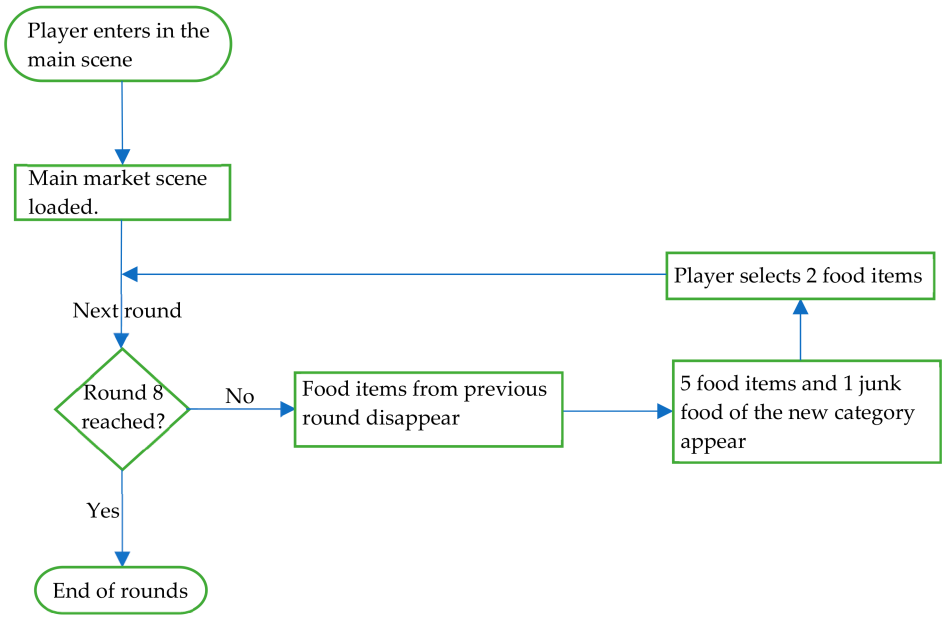


Figure 3. Main scene gameplay loop and progression across the eight food-selection rounds.

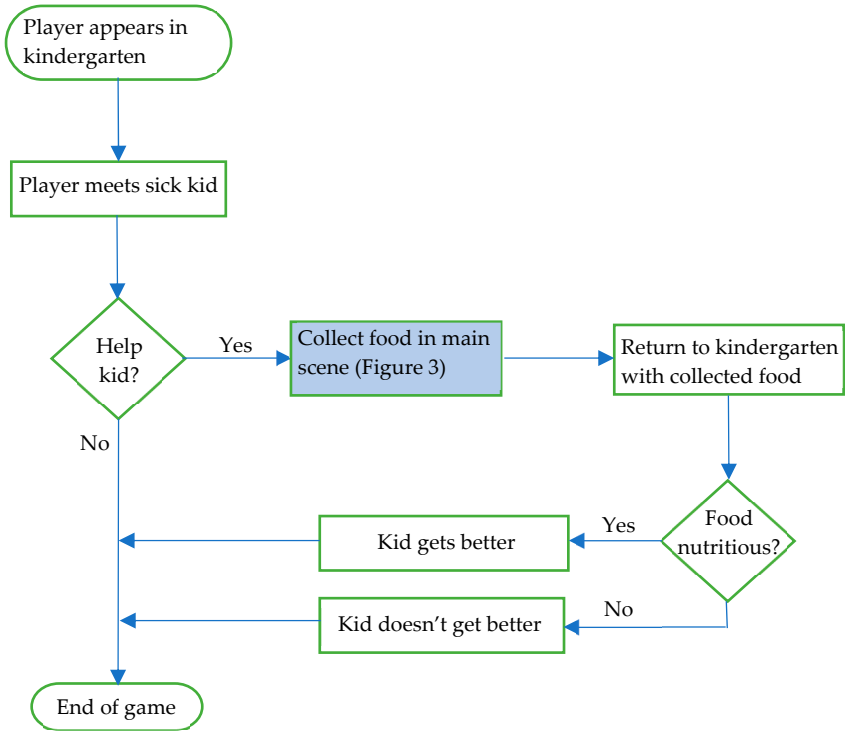


Figure 4. Game story and progression across the three scenes.

3.1.2. Designing the Mechanics of the Game

Mechanics in Kindergarten (Introduction Scene)

In the introduction scene, we determined the way a player moves in the VR environment and interacts with objects. These functions will follow the player throughout the game. As the application aims to encourage healthier food choices and support behavior change, we sought to minimize unnecessary cognitive load associated with movement and object interaction. That means that we did not provide any function that can help the player move, but the only way they can move is by taking steps in real world. Regarding object interaction, players do not use controllers; instead, food items are grabbed using hand tracking (motion capture) [51], as we wanted to achieve more immersive experience. This interaction method was also intended to support behavioral rehearsal by enabling players to perform food-selection actions in a manner that more closely resembles real-world behavior. The introduction scene also gives the player the opportunity, along with the integration into the story, to learn how to operate the application. For this reason, user interfaces (UIs) (Figure 5) with instructions appear, and when the player grabs the basket which will be used to collect the foods, the next scene is uploaded.

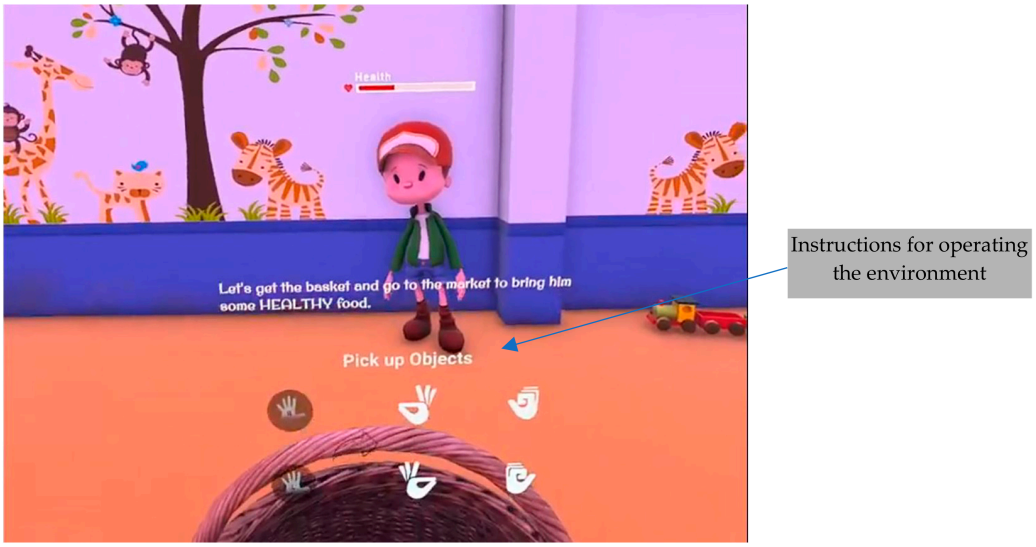


Figure 5. In the introduction scene, the player learns how to interact with objects through visual hands and UI instructions.

Mechanics in the Street Market (Main Scene)

The player must collect the two healthier food items every round and put them in the basket they took from the kindergarten. Every food item has a grade derived from Nutri-Score, as shown in Figure 6. Upon selection, the grade of the food item flies out of the basket (Figure 7) and is added to the total score of the current game session displayed in a table in the game world. When the player collects the two food items of the round, the numeric grade of each food item appears above each table (Figure 8). In this way, the player is informed about the Nutri-Score of each food item of the round. At the end of the eighth round, the player has collected all the food in his basket and is ready to return to kindergarten.

A	=	25
B	=	20
C	=	15
D	=	10
E	=	5

Figure 6. Nutri-Score to game grade matchup.



Figure 7. The player has just placed an apple in the basket, and its Nutri-Score value (25) is displayed above the basket as immediate feedback.



Figure 8. The Nutri-Score values of all food items are displayed for a few seconds at the end of each round, after the player has selected two food items from the current food category.

The design of the main scene aimed to present nutritional decision-making through simple and intuitive gameplay that could easily be understood by school-aged users without requiring prior nutritional knowledge. The interaction design was based on direct manipulation of virtual food items, while gameplay was organized into short rounds (Figure 3) requiring players to select two food items from six available alternatives. This structure was refined during iterative testing to maintain an appropriate balance between cognitive demand, gameplay and perceived challenge, thereby supporting the intended flow experience (Figure 2).

Mechanics for Returning to Kindergarten (Final Scene)

The player returns to kindergarten to see if the primary goal of the game, healing the child, has been achieved. In the beginning of the scene, the player sees a floating cloud displaying the total score that they achieved in the main scene, the food items they collected, and the child's health bar displayed above the child's head (Figure 9). Based on the total score, a corresponding animation is triggered, and the health bar gradually fills. The animations include a joyful dance, a happy reaction, a neutral movement cycle, a sad reaction and, in the worst outcome, the child fainting (it is almost impossible for this latter outcome take place).



Figure 9. In the return scene, the player has returned to kindergarten after collecting the food, and the total health score of collected foods appears.

3.1.3. Complete Game Showcase

To illustrate a complete interaction showcasing the design and mechanics of the game scenes previously described, we uploaded a video at "https://www.youtube.com/watch?v=pE8jeovuOR4. (accessed on 12 July 2026)". The video was actually recorded through MetaQuest (Meta Platforms, Inc., Menlo Park, CA, USA). In the rest of the paragraph, time points refer to the uploaded video. The player starts the game (0:07), and the introduction scene at the kindergarten appears (0:14), where the kid's situation is explained and the basket is introduced (0:26), encouraging the player to collect healthy food. By choosing to help, the player gets used to game operations (0:38), grabs the basket (0:43) and enters in the main scene (0:48). The first round of food items appears with labels hovering over them (1:04), the player chooses an apple (1:10), points associated to its Nutri-Score appear when dropped in the basket (1:14), and then a kiwi is selected (1:19), while total points are displayed on a board (1:23). After choosing two food items, the player moves to the second round (1:37) and interacts similarly until the end of the eight rounds. The player finishes grabbing food items (4:19) and has a score of 215. Then, the player returns to the kindergarten, where all collected food items are displayed (4:27) and the score associated with their nutritious value is displayed once more (4:31).

3.1.4. Technology

Regarding the technology and software used in the development of the game, the primary tool was the Unity Game Engine (https://unity.com/, accessed on 12 July 2026),

which offers excellent capabilities for creating VR applications. Within Unity, every 3D asset of the game world was imported, and the entirety of the game's interactions was implemented.

Most assets were sourced from the Unity Asset Store (https://assetstore.unity.com/, accessed on 12 July 2026), the official online marketplace for Unity developers. Food items were obtained from 3D assets platforms like Sketchfab (https://sketchfab.com/, accessed on 12 July 2026) and CGTrader (https://www.cgtrader.com/, accessed on 12 July 2026). Some 3D objects were created or modified using Cinema4d (https://www.maxon.net/en/cinema-4d, accessed on 12 July 2026).

The sounds of the game were sourced in Freesound (https://freesound.org/, accessed on 12 July 2026), a collaborative online platform for sharing sound files under Creative Commons licenses, and were edited using Filmora (https://filmora.wondershare.com/, accessed on 12 July 2026), a software tool for audio and video editing.

3.1.5. Theoretical Foundations Corresponding to *NutriQuest VR* Game

In this section, the relationship between theoretical frameworks, their implementation in *NutriQuest VR* and the intended experiential behavior outcomes is presented. Table 1 summarizes these relationships.

Table 1. Application of theoretical foundations in the design of *NutriQuest VR*.

Theory/Framework	Implementation in the *NutriQuest VR* Game
Flow theory	Gameplay progresses from food categories with easily distinguishable quality (e.g., fruits and vegetables) to increasingly challenging nutritional decisions. As players become more familiar with the Nutri-Score system, the gameplay maintains an appropriate balance between challenge and skill.
MDA	Mechanics such as food selection, score accumulation, and immediate Nutri-Score feedback generate repeated comparison and decision-making dynamics, promoting feelings of competence, curiosity, and accomplishment while supporting an engaging learning experience.
DPE	Players interact directly with virtual food items using natural hand movements through motion tracking. They physically inspect, grasp, and place food items into the shopping basket, creating an embodied learning experience that promotes active participation and immersion.
Schell's tetrad	Schell's tetrad was used to ensure coherence between the narrative, gameplay mechanics, visual presentation, and technological implementation of the application. The narrative centers on helping a child recover through healthier food choices, while mechanics require players to evaluate and select foods based on their nutritional value. Visual feedback, such as health-related animations, reinforces player actions and strengthens emotional engagement with the task.

3.1.6. Behavior Change Techniques

In this section, we describe the behavior change techniques incorporated into the development of the *NutriQuest VR* game. The identification and classification of these techniques follow the behavior change technique taxonomy (v1) (BCTTv1) [52], a standardized and widely applied framework for reporting and analyzing components of behavior change interventions [52]. Based on the game's structure, narrative, interaction mechanics, and feedback system, the following BCTs were embedded into the gameplay experience to support healthier food choices and enhance engagement, as shown in Table 2.

Table 2. Behavior change techniques used in game according to BCTTv1.

BCT Code	BCT Name	Application in the VR Nutrition Game
2.2	Feedback on behavior	Each time a player puts a food item in the basket, immediate feedback is triggered, which informs the player about the nutritional value of the food based on Nutri-Score. In this way, each selection allows players to associate each food selection with its nutritional quality and supports learning through immediate behavioral feedback.
2.7	Feedback on outcome(s) of behavior	Rather than providing feedback on specific actions of the players, the game also communicates the total consequences of the player's decisions. This situation provides the story and the purpose of the game, that is, to gradually improve the child's health. After each completed shopping session, the game illustrates the overall outcome of healthier food choices, thus helping players understand the overall consequences of their decisions.
7.1	Prompts/cues	Visual prompts are provided through the stable table which depicts the total Nutri-Score and exists in the game environment, while the Nutri-Scores of all food items are revealed at the end of each round to reinforce nutritional comparisons and guide future selections. Together, these visual cues encourage players to consider food nutritional quality when making subsequent decisions.
8.1	Behavioral practice/rehearsal	Players repeatedly practice nutritional decision-making during the eight gameplay rounds. More specifically, players evaluate foods of different food categories, providing repeated opportunities to rehearse healthier food-selection decisions across different food categories
8.7	Graded tasks	The game gradually increases the cognitive difficulty of nutritional decisions by progressively introducing more challenging rounds. This progression enables players to build confidence before facing more difficult tasks.

3.2. Evaluation Methodology

Following the development of the *NutriQuest VR* game, an empirical pilot study was designed and conducted to evaluate its effectiveness. This section presents the methodology adopted for the study, including study hypotheses, participant characteristics, study procedure, expected results, and statistical analysis design.

3.2.1. Aim and Hypotheses

The aim of this evaluation is to investigate whether participation in the *NutriQuest VR* intervention improves children's dietary behavior. Based on this objective, the following hypotheses were formulated:

H1. *Participation in the NutriQuest VR game intervention will lead to a significant improvement in children's dietary behavior.*

H2. *Higher in-game performance will be positively associated with healthier dietary behavior.*

H3. *Repeated participation in the NutriQuest VR intervention will lead to significant improvement in participants' in-game performance, as reflected by their game total scores.*

3.2.2. Study Design

The basic evaluation tool employed by the study procedure was the KIDMED 2.0 questionnaire, which measures adherence to the Mediterranean diet through 16 items, including 12 positively scored items and 4 negatively scored items [53]. The questionnaire has been validated for assessing adherence to the Mediterranean diet in children and adolescents. However, it remains a questionnaire-based measure and does not provide an objective assessment of food intake. The study was conducted using a single group as pre-test/post-test intervention design. The current preliminary study was designed to assess how this serious VR game can result in behavior change in an educational setting. Further research measuring user experience with appropriate tools, such as SUS and MEEGA+KIDS, is needed to evaluate comprehensively the game, as described in the Perspectives subsection, along with objective measurements such as BMI and biomarkers.

3.2.3. Participants

The empirical evaluation was conducted at the junior high school of Poros (Attica, Greece). A total of 34 students initially enrolled in the study, while 33 completed the entire process and were included in the final analysis. Among the participants, 25 students were boys and eight were girls. Regarding the age of the participants, eight students were 12 years old, eighteen were 13 years old, three were 14 years old, and four were 15 years old.

Participation was voluntary and required written informed consent from the participants' parents or legal guardians.

3.2.4. Study Implementation

The initial step was the approval of the study protocol for the period between 12 March and 8 May 2026. Students who expressed interest in participating received a parental consent form including the KIDMED 2.0 questionnaire. After returning the consent signed and the questionnaire completed, each participant received a unique anonymous identification number and was ready to start the experimental process with the VR devices. The overall study design and evaluation procedure are illustrated in Figure 10.

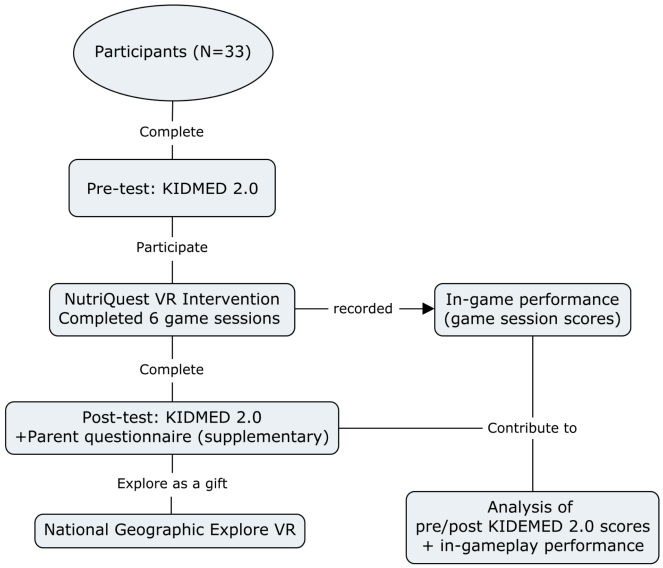


Figure 10. Overall study design and evaluation procedure of the *NutriQuest VR* intervention.

The intervention was conducted during regular school hours in a dedicated VR school classroom. The *NutriQuest VR* game was executed and controlled by the researcher on

a laptop and displayed to the students through Meta Quest 2 head-mounted display. Participants completed one gameplay session per day, lasting approximately 5–10 min, over five consecutive school days whenever possible. Only the first day, students completed two consecutive sessions to become familiar with the VR environment and interaction mechanics. In total, each participant completed six gameplay sessions as part of the same intervention. The application recorded one total game score for each participant in each session, resulting in six session-level scores per participant. Although each session comprised eight food-selection rounds, separate round-level and food-category-specific scores were not retained in the analytical dataset. The Session 1 and Session 6 total scores were used for the prespecified H3 comparison, while the complete six-session series was examined in an additional exploratory trajectory analysis. During each intervention session, two participants were present in the VR room simultaneously. After completing the gameplay session, each participant was replaced by another student, allowing the intervention to continue throughout the teaching period.

One week after completing the intervention, participants completed the KIDMED 2.0 questionnaire again. In addition, students completed a study-specific nutrition behavior questionnaire together with their parents or legal guardians. Its purpose was to collect supplementary exploratory information regarding parents' perceptions of food-related changes. Because the questionnaire has not been formally validated, it was not treated as a measure of Mediterranean diet adherence and was not used to test the primary study hypotheses. All collected data were anonymized prior to analysis. Questionnaire responses were digitized using Google Forms, exported to Microsoft Excel, and subsequently analyzed using IBM SPSS Statistics 29.0.2.0. The questionnaire items are presented in Table 3.

Table 3. The supplementary parent/guardian questionnaire.

Question	**Response Scale**
Section 1. Please indicate the extent to which you have observed an increase in your child's consumption and/or willingness to consume the following food categories during the past weeks.	**0 = no increase; 1, 2, 3, 4 = very significant increase**
Vegetables	0–4
Fruits	0–4
Fish and seafood	0–4
Lean meat (e.g., skinless chicken, lean beef)	0–4
Legumes	0–4
Low-fat dairy products	0–4
Healthy fats (e.g., nuts, avocado, olive oil)	0–4
Water (still or sparkling)	0–4
Question	**Response scale**
Section 2. Please indicate the extent to which you have observed that your child intends or is willing to reduce the consumption of the following food categories now or in the near future.	**0 = No reduction, 1, 2, 3, 4 = Very significant reduction**
Processed meats (e.g., ham, sausages, salami)	0–4
Foods high in sugar (e.g., sweets, biscuits, chocolate)	0–4
Foods high in salt (e.g., potato chips, salty snacks)	0–4
Sugar-sweetened beverages (e.g., soft drinks, packaged fruit juices, energy drinks)	0–4
Fast food (e.g., gyros, processed-meat pizza, fast-food sandwiches)	0–4

To encourage completion of the intervention, participants who successfully completed all study sessions were offered to navigate through an additional educational VR experience using National Geographic Explore VR "https://www.meta.com/experiences/national-geographic-explore-vr/2046607608728563/ (accessed on 12 July 2026)", allowing them to virtually visit Machu Picchu and Antarctica.

The overall study design and evaluation procedure are illustrated in Figure 10.

3.2.5. Statistical Analysis Design

The distributions of continuous variables were examined using normal P–P plots and histograms with superimposed normal curves. These assessments were used to evaluate the suitability of the planned statistical analyses. Continuous variables are calculated as mean ± standard deviation (SD), together with minimum, maximum, and 25th/50th/75th percentile values, while categorical variables (sex, age, KIDMED 2.0 score categories before and after the intervention) are calculated as absolute and relative (%) frequencies.

Children's adherence to the Mediterranean diet are assessed using the KIDMED 2.0 index, both before and after the intervention. Based on the total KIDMED 2.0 score, participants are classified into three categories: low adherence to the Mediterranean diet (score ≤ 3), medium adherence (low and medium adherence indicate a need to improve dietary habits towards the Mediterranean pattern (score 4–7), and high/optimal adherence to the Mediterranean diet (score ≥ 8). This categorization is applied separately to the pre- and post-intervention KIDMED 2.0 Score.

Changes in children's KIDMED 2.0 score before and after the intervention are evaluated using the paired-samples *t*-test. Effect sizes for the paired comparisons are calculated using Cohen's *d* and Hedges' correction, together with their 95% confidence intervals, using the pooled standard deviation of the mean difference as the standardizer. To evaluate H2, Pearson's correlation coefficient was used to examine the association between participants' average game total score and their pre- and post-intervention KIDMED 2.0 scores. Age and sex were summarized descriptively and were not included in the primary correlation analysis, as they were not part of the predefined study hypotheses.

In response to the need for a more detailed interpretation of the observed change in KIDMED 2.0 scores, an additional exploratory item-level analysis was conducted. For each of the 16 KIDMED 2.0 items, the number and percentage of participants showing the health-promoting response were calculated before and after the intervention. Changes were expressed as percentage-point differences between the two assessment time points. In addition, individual transitions between the three KIDMED 2.0 adherence categories (low, medium, and high/optimal adherence) were examined by comparing each participant's pre- and post-intervention classification. These analyses were descriptive and exploratory and were not treated as additional confirmatory hypothesis tests.

As a supplementary analysis related to H2, participants' average game total scores were compared across the low-, medium-, and high-adherence KIDMED 2.0 categories. Because the total sample was relatively small (n = 33) and categorization resulted in smaller and potentially unequal subgroups, the non-parametric Kruskal–Wallis test was used separately for the pre- and post-intervention KIDMED 2.0 categories. Effect size was expressed as epsilon-squared ($\varepsilon^2 = H/(n-1)$).

Reported *p*-values are based on two-sided tests, with statistical significance set at $\alpha = 5\%$. All statistical analyses are performed using IBM SPSS Statistics software (IBM Corp., Armonk, NY, USA).

As an additional exploratory analysis, total game scores from all six gameplay sessions were summarized descriptively and compared using the Friedman test for related samples, with Kendall's W reported as the effect-size measure. Exploratory adjacent-session compar-

isons were performed using Wilcoxon signed-rank tests with Holm adjustment for multiple comparisons. Participant-level patterns were visualized using individual trajectory curves and a participant-by-session heatmap.

4. Results

This section presents the results of the empirical evaluation. Statistical analyses were performed using IBM SPSS Statistics, and the findings are reported in the following subsections.

4.1. Paired-Samples t-Test (KIDMED 2.0 Score Pre vs. Post)

A paired-samples *t*-test showed a statistically significant increase in children's KIDMED_2_Score following the intervention (pre: M = 5.67, SD = 2.901; post: M = 6.55, SD = 2.895; t(32) = −2.634, $p = 0.013$, Cohen's $d = -0.459$, 95% CI [−0.814, −0.096]).

The analysis examined whether children's adherence to the Mediterranean diet (KIDMED_2_Score) changed following the intervention by comparing their scores before and after participation. A statistically significant increase in KIDMED_2_Score was observed following the intervention (from a mean score of 5.67 to 6.55), with a moderate effect size (Cohen's $d = -0.459$). These findings indicate a statistically significant within-participant increase in reported Mediterranean diet adherence after the intervention.

Item-Level Changes in KIDMED 2.0 and Adherence-Category Transitions

To further explore the statistically significant increase observed in the overall KIDMED 2.0 score, an item-level descriptive analysis was performed for the 16 questionnaire items. Table 4 presents the number and percentage of participants showing the health-promoting response before and after the intervention.

Table 4. Item-level changes in health-promoting KIDMED 2.0 responses before and after the intervention.

Item	Health-Promoting Dietary Behavior	Pre, n (%)	Post, n (%)	Change, Percentage Points
1	≥2 servings of fruit per day	16 (48.5)	22 (66.7)	+18.2
2	≥1 serving of vegetables per day	19 (57.6)	21 (63.6)	+6.1
3	Legumes/lean meat/fish/eggs at lunch and dinner	28 (84.8)	22 (66.7)	−18.2
4	>50% of foods of plant origin	21 (63.6)	27 (81.8)	+18.2
5	Fresh/minimally processed meat, eggs and/or fish	24 (72.7)	29 (87.9)	+15.2
6	Avoidance of pre-cooked/fast food ≥1 time/week	20 (60.6)	17 (51.5)	−9.1
7	≥3 servings of legumes per week	13 (39.4)	16 (48.5)	+9.1
8	Food usually baked, grilled, or boiled at home	30 (90.9)	32 (97.0)	+6.1
9	Whole-grain cereal products	11 (33.3)	11 (33.3)	0.0
10	Nuts ≥3 times/week	10 (30.3)	14 (42.4)	+12.1
11	Virgin olive oil used at home	32 (97.0)	29 (87.9)	−9.1
12	Avoidance of commercial soft drinks/juices/shakes	10 (30.3)	15 (45.5)	+15.2
13	Natural/minimally processed dairy products	27 (81.8)	26 (78.8)	−3.0
14	Avoidance of processed/sugary breakfast foods	23 (69.7)	26 (78.8)	+9.1
15	Unprocessed/minimally processed breakfast foods	19 (57.6)	23 (69.7)	+12.1
16	Avoidance of industrial pastries/sweets/snacks	16 (48.5)	18 (54.5)	+6.1

For negatively scored KIDMED 2.0 items (Items 6, 12, 14, and 16), the health-promoting response corresponds to the absence of the less healthy behavior. Positive percentage-point values indicate improvement in the direction of greater Mediterranean diet adherence.

The largest positive changes were observed for consuming two or more servings of fruit per day, which increased from 16/33 participants (48.5%) before the intervention to

22/33 (66.7%) after the intervention (+18.2 percentage points), and for consuming a diet in which more than half of the foods were of plant origin, which increased from 21/33 (63.6%) to 27/33 (81.8%) (+18.2 percentage points).

Other notable positive changes were observed for the consumption of fresh or minimally processed meat, eggs, and/or fish, which increased from 24/33 (72.7%) to 29/33 (87.9%) (+15.2 percentage points), and for avoidance of commercial soft drinks, juices, and/or shakes, which increased from 10/33 (30.3%) to 15/33 (45.5%) (+15.2 percentage points). Positive changes were also observed for nut consumption at least three times per week (+12.1 percentage points) and consumption of an unprocessed or minimally processed breakfast (+12.1 percentage points).

Not all KIDMED 2.0 components improved. The proportion of participants reporting the health-promoting response for the item concerning consumption of legumes, lean meat, fish, and/or eggs at both lunch and dinner decreased from 28/33 (84.8%) to 22/33 (66.7%) (−18.2 percentage points). Smaller decreases were also observed for avoidance of pre-cooked or fast food (−9.1 percentage points), use of virgin olive oil at home (−9.1 percentage points), and consumption of natural or minimally processed dairy products (−3.0 percentage points). Thus, the overall improvement in KIDMED 2.0 score reflected changes across several dietary behaviors rather than uniform improvement across all questionnaire components.

Individual changes in KIDMED 2.0 adherence category were also examined. Of the 33 participants, seven (21.2%) moved to a higher adherence category after the intervention, 22 (66.7%) remained in the same category, and four (12.1%) moved to a lower adherence category. Specifically, four participants moved from low to medium adherence and three from medium to high adherence. In contrast, two participants moved from medium to low adherence and two moved from high to medium adherence.

4.2. In-Game Performance Across the Six Gameplay Sessions

As shown in Table 5, a paired-samples *t*-test showed a statistically significant increase in total game score from Session 1 (M = 300.15, SD = 22.378) to Session 6 (M = 327.27, SD = 17.279), t(32) = −7.294, $p < 0.001$, Cohen's $d = -1.270$, 95% CI [−1.725, −0.803]. The negative values reflect the subtraction order (Session 1 minus Session 6).

Table 5. Paired-samples *t*-test results for changes in Mediterranean diet and in-game performance (H1 and H3).

Hypothesis	Outcome	First Measurement, M ± SD	Final Measurement, M ± SD	T (df)	*p*	Cohen's *d*	95% CI for *d*
H1	KIDMED 2.0 score	5.67 ± 2.901	6.55 ± 2.895	−2.634 (32)	0.013	−0.459	[−0.814, −0.096]
H3	Game total score	300.15 ± 22.378	327.27 ± 17.279	−7.294 (32)	<0.001	−1.270	[−1.725, −0.803]

Note. H1 compares pre-and-post-intervention KIDMED 2.0 scores. H3 compares total game scores from the first and sixth gameplay sessions. Negative t and Cohen's *d* values reflect the subtraction order (first measurement–final measurement); the final measurement was higher for both outcomes.

The analysis examined whether there was a change in the total score between the initial and final assessments. The comparison revealed a statistically significant increase in scores, with a large effect size (Cohen's $d > 1.2$), indicating a strong and consistent improvement in participants' performance throughout the intervention.

Group mean total game scores increased overall across the six gameplay sessions: Session 1, M = 300.15 (SD = 22.38); Session 2, M = 310.91 (SD = 23.63); Session 3, M = 317.42 (SD = 17.55); Session 4, M = 324.09 (SD = 20.67); Session 5, M = 325.15 (SD = 15.44); and

Session 6, M = 327.27 (SD = 17.28). The Friedman test indicated an overall difference across sessions, $\chi^2(5) = 46.350$, $p < 0.001$, Kendall's W = 0.281.

The largest numerical mean gain occurred between Sessions 1 and 2 (+10.76 points), followed by Sessions 3 and 4 (+6.67 points) and Sessions 2 and 3 (+6.52 points). Mean changes were smaller between Sessions 4 and 5 (+1.06 points) and Sessions 5 and 6 (+2.12 points), suggesting a leveling of group mean performance after Session 4. None of the exploratory adjacent-session comparisons remained statistically significant after Holm adjustment (all adjusted $p \geq 0.202$), indicating that the overall change was cumulative rather than a uniform statistically significant increase between every consecutive pair of sessions.

The prespecified comparison between the first and final sessions remained statistically significant. The mean Session 6 total game score was significantly higher than the mean Session 1 total game score, t(32) = −7.294, $p < 0.001$, Cohen's $d_z = -1.270$, 95% CI [−1.725, −0.803]. The negative signs reflect the subtraction order used in the analysis (Session 1 minus Session 6). At the participant level, 27 children (81.8%) had a higher score in Session 6, three (9.1%) had the same score, and three (9.1%) had a lower score. Individual participant trajectories are presented in Figure 11, and the corresponding heatmap is provided in Supplementary Figure S1.

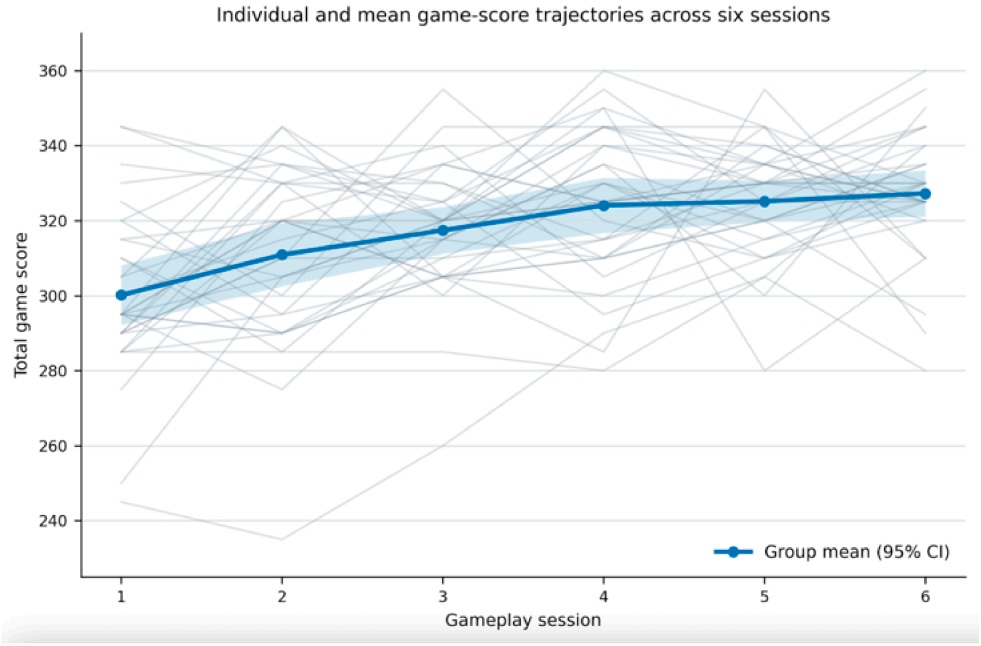


Figure 11. Participant-level total game-score trajectories across the six gameplay sessions. Gray lines represent individual participants; the blue line and shaded area represent the group mean and 95% confidence interval.

4.3. Association Between In-Game Performance and Dietary Behavior

To evaluate H2, Pearson's correlation coefficients were calculated between participants' average game total score and their KIDMED 2.0 scores. As shown in Table 6, average game performance was not significantly associated with pre-intervention KIDMED 2.0 score (r = 0.092, $p = 0.610$) or post-intervention KIDMED 2.0 score (r = 0.159, $p = 0.377$). A statistically significant positive correlation was observed between pre- and post-intervention KIDMED 2.0 scores (r = 0.781, $p < 0.001$). Therefore, although participants demonstrated an overall improvement in dietary adherence following the intervention, participants with higher in-game performance did not necessarily report higher adherence to the Mediterranean diet. H2 was therefore not supported.

Table 6. Pearson correlations between in-game performance and KIDMED 2.0 scores.

Variables	r	*p*	Interpretation
Average game score—pre-intervention, KIDMED 2.0	0.092	0.610	Not significant
Average game score—post-intervention, KIDMED 2.0	0.159	0.377	Not significant
Pre-intervention KIDMED 2.0—post-intervention, KIDMED 2.0	0.781	<0.001	Significant positive correlation

Note: Pearson's correlation coefficient was used to evaluate H2. Average in-game performance was not significantly associated with either pre- or post-intervention KIDMED 2.0 scores. Pre- and post-intervention KIDMED 2.0 scores were strongly and positively correlated.

4.4. Game Performance Across KIDMED 2.0 Adherence Categories

As a supplementary analysis of H2, participants' average game total scores were compared across the low-, medium-, and high-adherence KIDMED 2.0 categories (Table 7). No statistically significant difference was found across the pre-intervention adherence categories, $H(2) = 0.005$, $p = 0.997$, $\varepsilon^2 < 0.001$. Mean ranks were 17.19, 17.00, and 16.85 for the low-, medium-, and high-adherence groups, respectively.

Table 7. Comparison of average performance across KIDMED 2.0 adherence categories.

KIDMED Classification	H (df)	*p*	ε^2	Interpretation
Pre-intervention	0.005 (2)	0.997	<0.001	Not significant
Post-intervention	1.608 (2)	0.448	0.050	Not significant

Note. Kruskal–Wallis tests compared participants' average game total scores the low-, medium-, and high-adherence KIDMED 2.0 categories. Effect size is reported as epsilon-squared (ε^2). Neither comparison reached statistical significance.

Similarly, no statistically significant difference was observed across the post-intervention adherence categories, $H(2) = 1.608$, $p = 0.448$, $\varepsilon^2 = 0.050$. Mean ranks were 13.17, 16.73, and 19.25 for the low-, medium-, and high-adherence groups, respectively. These findings provide no statistically significant evidence that average in-game performance differed according to participants' level of Mediterranean diet adherence.

4.5. Supplementary Parent/Guardian-Reported Dietary Changes

The supplementary parent/guardian questionnaire was analyzed descriptively. The supplementary questionnaire score (ScoreP) had a mean of 8.1 (SD = 5.9). Because the questionnaire was developed specifically for the present study and has not been formally validated, ScoreP cannot be interpreted using the KIDMED 2.0 adherence cut-offs or as a measure of Mediterranean diet adherence. These results provide only exploratory descriptive information regarding parents' perceptions and should not be interpreted as independent evidence of changes in children's dietary behavior.

5. Discussion

In this section, the findings of the empirical evaluation are discussed in relation to the study hypotheses and the previous literature. The study was based on the *NutriQuest VR* game, a VR serious game developed to promote healthier eating behaviors. In particular, the study investigates whether repeated engagement with this VR application can promote healthier dietary habits and whether these changes are associated with participants' performance in the game. Finally, the limitations of the present study are discussed, and directions for future research are proposed.

Regarding H1, the findings indicated that participants who played the *NutriQuest VR* game demonstrated in a statistically significant improvement in their dietary behavior, as

reflected by the increase in KIDMED 2.0 scores. This improvement suggests that repeated exposure to nutritional decision-making within the VR environment may have positively influenced participants' nutritional habits. These findings are broadly consistent with previous research on nutrition-focused serious games, which has reported improvements in nutritional knowledge, food-related attitudes, and, in some cases, dietary behaviors among children. The present findings extend this evidence by showing a significant improvement in KIDMED 2.0 scores following repeated exposure to an immersive VR serious game. This suggests that VR-based interaction may provide an additional context in which repeated nutritional decision-making can be incorporated into a behavior change intervention.

The additional item-level analysis provides a more detailed interpretation of this overall change. The largest positive shifts were observed in fruit consumption and in the proportion of participants reporting that more than half of their dietary intake consisted of plant-based foods. Improvements were also observed in the selection of fresh or minimally processed protein foods, avoidance of commercial sugar-containing beverages, nut consumption, and healthier breakfast choices. These findings suggest that the increase in the overall KIDMED 2.0 score was distributed across several dietary behaviors rather than being driven by a single questionnaire component.

At the same time, not all dietary behaviors improved. Some KIDMED 2.0 items showed little change or a reduction in the proportion of participants reporting the health-promoting response. This heterogeneous pattern highlights the importance of interpreting the total KIDMED score together with its individual components and suggests that some dietary behaviors may be more responsive to short educational interventions than others.

Furthermore, 21.2% of participants moved to a higher Mediterranean diet adherence category, whereas 12.1% moved to a lower category and 66.7% remained within the same category. These category transitions provide additional descriptive evidence of individual-level change but should be interpreted cautiously. Given the single-group pre–post design and the absence of a control group, the observed changes cannot be attributed exclusively to the *NutriQuest VR* intervention.

H2 was not supported by the present findings. Although results have shown significant improvement to participants' dietary habits after the intervention, no statistically significant association was found between average game performance and KIDMED 2.0. scores. Likewise, students classified into different levels of Mediterranean diet adherence did not differ significantly in their average game session total scores. These findings indicate that better in-game performance was not directly associated with healthier dietary behavior in the present sample. Several factors may have contributed to this outcome, including aspects of the intervention or the game itself; however, the present study does not allow firm conclusions regarding the underlying reasons. To our knowledge, few previous studies have specifically examined the relationship between in-game performance and dietary behavior, making direct comparisons difficult. The absence of a significant association in the present study suggests that improved performance within the game does not necessarily translate directly into healthier dietary behavior. This distinction is important, as learning to perform the nutritional decision-making task within a game may represent a different outcome from broader changes in dietary behavior.

The findings for H3 showed an overall improvement in in-game performance across the six gameplay sessions. The largest numerical mean gain occurred early in the intervention, whereas smaller changes after Session 4 indicated a leveling of group mean performance. Participant-level trajectories nevertheless showed variability, and the exploratory comparisons between adjacent sessions were not statistically significant after correction for multiple testing. These findings suggest that the observed improvement developed cumulatively across repeated gameplay rather than through a uniform statistically

significant increase after every session. The observed change reflects performance within the game environment and should not, on its own, be interpreted as evidence of corresponding changes in real-world dietary behavior. Future evaluations should retain round-level selections and food-category-specific scores to permit the examination of category-specific learning curves and error patterns.

The supplementary parent/guardian questionnaire provided exploratory descriptive information regarding parents' perceptions of changes in their children's food-related behavior following the intervention. Because this study-specific questionnaire has not been formally validated and does not measure KIDMED 2.0 adherence, its findings should not be interpreted as evidence of high adherence to the Mediterranean diet.

Finally, in comparative Table 8, we contextualize the magnitude of the changes observed in *NutriQuest VR* relative to previous nutrition-focused serious-game studies. The table presents the study design, sample, outcome, principal quantitative result, and Cohen's *d* where this was reported or could be calculated from the published summary statistics.

Table 8. Comparison of effect sizes reported in selected nutrition-focused serious-game studies and the present *NutriQuest VR* study.

Study	Design and Sample	Principal Outcome	Main Quantitative Result	Cohen's *d*
Foodbot Factory [31]	Randomized controlled pilot study; intervention n = 39, control n = 34	Overall nutrition knowledge	Intervention: 10.3 to 13.5; control: 10.2 to 10.4; $p < 0.001$	0.88 *
Fit, Food, Fun [33]	Quasi-experimental school-based pilot study; gameplay group n = 39 at baseline	Overall nutrition knowledge	Proportion of correct responses increased from 0.31 to 0.42; $p = 0.001$	NR
VitaVillage [32]	Quasi-experimental school comparison; intervention n = 75, control n = 94	Overall nutrition knowledge	Mean change: +2.3 points in the intervention group versus +0.7 in the control group; $p = 0.035$	0.35
Squire's Quest! II [35]	Four-group randomized study; n = 400; all groups received the game with different planning conditions	Meal-specific fruit and vegetable intake	Vegetable group-by-time effect at dinner ($p = 0.01$); fruit intake increased at breakfast ($p = 0.009$), lunch ($p = 0.01$), and snack occasions ($p < 0.001$)	NR †
NutriQuest VR	Single-group pre–post pilot study; n = 33	Reported Mediterranean diet adherence	KIDMED 2.0: 5.67 to 6.55; $p = 0.013$	0.459 ‡
NutriQuest VR	Single-group repeated-session pilot study; n = 33	In-game performance	Total game score: 300.15 to 327.27; $p < 0.001$	1.270 ‡

NR = not reported. Effect sizes relate to different outcomes and study designs and should not be interpreted as directly equivalent estimates of intervention effectiveness. * For *Foodbot Factory*, Cohen's *d* was calculated from the published post-intervention group means and standard deviations using the pooled standard deviation; it was not reported in the original publication. † *Squire's Quest! II* reported an a priori Cohen's *d* of 0.17 for sample-size planning, but this was not an observed intervention effect. ‡ Absolute Cohen's *d* values are presented for *NutriQuest VR* to facilitate comparison of magnitude; the negative signs in the original analyses resulted from the subtraction order.

As shown in Table 8, the within-participant change in reported Mediterranean diet adherence observed for *NutriQuest VR* was moderate in magnitude ($|d| = 0.459$). This effect was of the same general order as the effect reported for overall nutrition knowledge in *VitaVillage* ($d = 0.35$) and smaller than the post-intervention between-group effect calculated from the published *Foodbot Factory* results ($d = 0.88$). However, these values are not directly comparable because they represent different outcomes and were obtained using different study designs. In particular, the large effect observed for *NutriQuest VR* in-game performance ($|d| = 1.270$) reflects learning and performance within the game environment rather than a dietary outcome. Accordingly, the comparison positions the present findings within the broader serious-game literature but does not establish the superiority of *NutriQuest VR* over the other interventions.

Limitations

The present study has several limitations that should be considered when interpreting the findings.

First, conducting studies, particularly those involving students, requires extensive administrative and ethical approval procedures. Such studies involving minors are subject to strict regulations while obtaining the necessary permissions from educational authorities, the university ethics committee, the school administration, and parents or legal guardians required considerable preparation before the intervention could begin. Therefore, such processes require a lot of time and energy.

A second limitation concerns the implementation of the intervention within the school environment. Although the study was designed to provide repeated daily gameplay sessions, maintaining the planned schedule was challenging due to the normal operation of the school. Activities such as examinations, school excursions, extracurricular events, student absences, and the Easter holiday period were difficult events to manage.

Another limitation concerns the single-group pre-test/post-test design of the study and the absence of a control group. This design does not allow the observed changes in KIDMED 2.0 scores to be attributed exclusively to the VR intervention. Other external or contextual factors may have contributed to the observed changes.

In addition, the relatively small sample (n = 33), recruitment from a single school, and gender imbalance (25 boys and eight girls) limit the precision and generalizability of the findings. The sample also provided limited sensitivity to smaller associations and subgroup differences, and no gender-specific conclusions can be drawn. The findings should therefore be considered preliminary and require confirmation in larger, controlled, multi-site, and more gender-balanced samples.

The absence of objective and additional contextual measures to complement the KIDMED 2.0 questionnaire can also be considered a limitation. Using the validated KIDMED 2.0 questionnaire was appropriate for the scope of the present intervention and allowed dietary behavior to be assessed in a structured and feasible manner among the participating children. As shown in related work, similar nutrition-related game-based interventions have also evaluated their outcomes primarily through questionnaire-based or self-reported measures. Accordingly, the observed changes in KIDMED 2.0 scores should be interpreted as changes in reported Mediterranean diet adherence rather than as objectively verified changes in food intake or anthropometric status. However, objective measures, such as dietary intake records and anthropometric measurements (e.g., height, weight, and BMI), could provide additional evidence regarding the observed changes. Moreover, the study did not collect socioeconomic or educational variables such as household income, parental education, or school performance. Consequently, their potential associations with dietary behavior and intervention response could not be examined. Future studies should consider including these variables, together with larger samples, to allow more comprehensive analyses. Similarly, the study did not include standardized measures of usability, engagement, VR presence, or cybersickness. Consequently, the user experience, degree of presence, and tolerability of the VR application could not be formally evaluated. Future evaluations should incorporate validated instruments such as the SUS, MEEGA+KIDS, GEQ, and SSQ.

A further limitation concerns the parent/guardian questionnaire, which was developed specifically for the present study and has not undergone formal psychometric validation. Consequently, its findings were considered only as exploratory descriptive information and should be interpreted with caution. For the same reason, the parent-derived score (ScoreP) was not included in the correlation analyses with the KIDMED 2.0 scores.

A final limitation that also concerns the questionnaires relates to the possibility of response bias in both questionnaires. The parent questionnaire was completed in collaboration with the children, which may have influenced parents' responses through discussion or shared decision-making. Similarly, although students were instructed to complete the KIDMED 2.0 questionnaire independently, parental influence cannot be entirely excluded, as parents are typically responsible for food purchasing and meal preparation within the household and may have assisted their children during completion. Therefore, some degree of response bias may have been present in both assessment tools.

6. Conclusions

This paper presented the design, implementation, and pilot empirical evaluation of the *NutriQuest VR* game, an immersive VR serious game developed to promote healthier dietary behaviors among children. By combining VR technology, established game design frameworks, and behavior change techniques, the proposed application aimed to provide an engaging learning experience that encourages healthier nutritional decision-making.

The preliminary empirical evaluation demonstrated a statistically significant increase in participants' reported adherence to the Mediterranean diet following the intervention, as measured by the KIDMED 2.0 questionnaire, while repeated gameplay was associated with improved in-game performance. Participants also showed significant improvements in their in-game performance across gameplay sessions, indicating increased familiarity with identifying healthier food choices based on the Nutri-Score system. Although no significant relationship was found between game performance and dietary adherence, these findings highlight the educational potential of the proposed intervention while also suggesting that improvements in nutritional behavior cannot be explained solely by players' performance within the game. The present study was designed as a behavior change intervention and evaluated only the VR version of the game. Therefore, the specific contribution of VR immersion cannot be isolated from the potential contributions of the educational content and game mechanics. Moreover, aspects of user experience were not evaluated, nor were objective measurements (other than measurement of in-game performance) carried out; doing so would allow one to comprehensively assess the value of the *NutriQuest VR* game.

Given the single-group design, causal or VR-specific effects cannot be established. Larger multicenter randomized controlled trials incorporating control and non-immersive comparison groups, objective measures, UX assessment, and longer-term follow-up are therefore required.

Perspectives

In order to overcome the presented limitations, future research should investigate user experience and the long-term effects of the *NutriQuest VR* game on children's dietary behaviors, as well as the extent to which the observed behavioral improvements were driven by the game design itself or by the immersive characteristics of VR. In this direction, more versions of the game are currently being implemented in other platforms (mobile and desktop) and a broader study protocol is designed and headed for approval by the ethics committee and the regional school directorate. The approval of the expansion of the study in more schools is easier now that the preliminary study has been carried out successfully in one school.

This broad research will include:

- Larger and more gender-balanced groups from diverse schools;
- The introduction of a control group for comparing measurements with and without the use of the game;

- Comparison of different versions of the game such as those on desktop computers, mobile devices, or augmented reality environments, while preserving identical game mechanics and educational content;
- Measurement of UX with SUS as in our previous research [54];
- BMI measurement and wearable devices in addition to questionnaires as described in our previous research [55].

We estimate that this broader study will provide a better understanding of the specific role of immersive technologies in promoting healthier dietary behaviors and help identify the most effective technological approach for nutrition education.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/informatics13090153/s1, Figure S1: Heatmap of total game scores for each participant (P01–P33) across the six gameplay sessions. Cell values indicate total session scores.

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Abbreviations

The following abbreviations are used in this manuscript:

VR	Virtual reality
UI	User interface
BCTTv1	Behavior change technique taxonomy v1

References

1. World Health Organization Regional Office for Europe. Childhood Obesity and Overweight Remain a Major Concern Across the Region, New WHO Report Finds. Available online: https://www.who.int/europe/news/item/04-11-2025-childhood-obesity-and-overweight-remain-a-major-concern-across-the-region--new-who-report-finds (accessed on 12 July 2026).
2. UNICEF. Obesity Exceeds Underweight for the First Time Among School-Age Children and Adolescents. Available online: https://www.unicef.org/press-releases/obesity-exceeds-underweight-first-time-among-school-age-children-and-adolescents (accessed on 12 July 2026).
3. Harvard, T.H. Chan School of Public Health. Rising Childhood Obesity Exceptionally Concerning, Says Expert. Available online: https://hsph.harvard.edu/news/rising-childhood-obesity-exceptionally-concerning-says-expert/ (accessed on 12 July 2026).
4. Centers for Disease Control and Prevention. Childhood Obesity Facts. Available online: https://www.cdc.gov/obesity/childhood-obesity-facts/childhood-obesity-facts.html (accessed on 12 July 2026).
5. World Health Organization Regional Office for Europe. Obesity and Overweight. Available online: https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight. (accessed on 12 July 2026).
6. Masood, B.; Moorthy, M. Causes of obesity: A review. *Clin. Med.* **2023**, *23*, 284–291. [CrossRef] [PubMed]

7. Greenhalgh, T. How to improve success of technology projects in health and social care. *Public Health Res. Pract.* **2018**, *28*, e2831815. [CrossRef] [PubMed]
8. Park, M.J.; Kim, D.J.; Lee, U.; Na, E.J.; Jeon, H.J. A Literature overview of virtual reality (VR) in treatment of psychiatric disorders: Recent advances and limitations. *Front. Psychiatry* **2019**, *10*, 505. [CrossRef] [PubMed]
9. Liu, Y.; Yue, K.; Yue, L.; Yang, S.; Gao, H.; Sha, H. How to Construct Behavioral Patterns in Immersive Learning Environments: A Framework, Systematic Review, and Research Agenda. *Electronics* **2025**, *14*, 1278. [CrossRef]
10. Mystakidis, S.; Berki, E.; Valtanen, J.-P. Deep and Meaningful E-Learning with Social Virtual Reality Environments in Higher Education: A Systematic Literature Review. *Appl. Sci.* **2021**, *11*, 2412. [CrossRef]
11. Bowman, S.L. Immersion and Shared Imagination in Role-Playing Games. In *Role-Playing Game Studies*; Routledge: New York, NY, USA, 2018; pp. 379–394. Available online: https://www.taylorfrancis.com/chapters/edit/10.4324/9781315637532-22/immersion-shared-imagination-role-playing-games-sarah-lynne-bowman (accessed on 12 July 2026).
12. Mystakidis, S. Combat Tanking in Education—The TANC Model for Playful Distance Learning in Social Virtual Reality. *Int. J. Gaming Comput. Mediat. Simul.* **2021**, *13*, 28–47. [CrossRef]
13. Damaševičius, R.; Maskeliūnas, R.; Blažauskas, T. Serious games and gamification in healthcare: A meta-review. *Information* **2023**, *14*, 105. [CrossRef]
14. Dörner, R.; Göbel, S.; Effelsberg, W.; Wiemeyer, J. *Serious Games*; Springer: Cham, Switzerland, 2016; Volume 247. Available online: https://link.springer.com/chapter/10.1007/978-3-319-40612-1_1#Sec1 (accessed on 12 July 2026).
15. Connolly, T.M.; Boyle, E.A.; MacArthur, E.; Hainey, T.; Boyle, J.M. A systematic literature review of empirical evidence on computer games and serious games. *Comput. Educ.* **2012**, *59*, 661–686. [CrossRef]
16. Alvarez, J.; Michaud, L. Serious Games: Advergaming, Edugaming, Training and More. 2008. Available online: https://hal.science/hal-04677055v1 (accessed on 12 July 2026).
17. Di Natale, A.F.; Repetto, C.; Riva, G.; Villani, D. Immersive virtual reality in K-12 and higher education: A 10-year systematic review of empirical research. *Br. J. Educ. Technol.* **2020**, *51*, 2006–2033. [CrossRef]
18. Checa, D.; Bustillo, A. A review of immersive virtual reality serious games to enhance learning and training. *Multimed. Tools Appl.* **2020**, *79*, 5501–5527. Available online: https://link.springer.com/article/10.1007/s11042-019-08348-9 (accessed on 12 July 2026). [CrossRef]
19. Yigitbas, E.; Mazur, J. Augmented and virtual reality for diet and nutritional education: A systematic literature review. In *Proceedings of the 17th International Conference on PErvasive Technologies Related to Assistive Environments, New York, NY, USA, 10–13 June 2024*; ACM: New York, NY, USA, 2024; pp. 88–97. [CrossRef]
20. Hou, C.I.; Wang, J.H.; Shiao, K.S.; Cheng, C. Harnessing Virtual Reality to Influence Attitudes Toward Beef Consumption: The Role of Empathy in Dietary Interventions. *Foods* **2024**, *13*, 3750. [CrossRef] [PubMed]
21. Glympi, A.; Odegi, D.; Zandian, M.; Södersten, P.; Bergh, C.; Langlet, B. Eating Behavior and Satiety with Virtual Reality Meals Compared with Real Meals: Randomized Crossover Study. *JMIR Serious Games* **2023**, *11*, e44348. [CrossRef] [PubMed]
22. Zhang, H.; Ho, J.C. VR diet museum: A virtual experience designed for better learning and reflection on eating habits and its effects. In *International Conference on ArtsIT, Interactivity and Game Creation*; Springer Nature: Cham, Switzerland, 2022; pp. 253–268. [CrossRef]
23. Fogg, B.J. *Fogg Behavior Model*; Behavior Design Laboratory, Stanford University: Stanford, CA, USA, 2019. Available online: https://public.websites.umich.edu/ jmondisa/TK/KATA_Files/FBM.pdf (accessed on 12 July 2026).
24. Arnold, P.; Khot, R.A.; Mueller, F.F. You Better Eat to Survive" Exploring Cooperative Eating in Virtual Reality Games. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction, Stockholm, Sweden, 18–21 March 2018*; ACM: New York, NY, USA, 2018; pp. 398–408. Available online: https://dl.acm.org/doi/pdf/10.1145/3173225.3173238 (accessed on 12 July 2026).
25. Salomidis, K.; Styliaras, G.; Apergi, K.; Malisova, O. Hydration VR Game: Promoting Awareness on Hydration. In Proceedings of the Sixteenth International Conference on Information, Intelligence, Systems and Applications (IISA 2025), Mytilene, Greece, 10–12 July 2025.
26. Wienrich, C.; Döllinger, N.; Hein, R. Behavioral framework of immersive technologies (BehaveFIT): How and why virtual reality can support behavioral change processes. *Front. Virtual Real.* **2021**, *2*, 627194. [CrossRef]
27. Plechatá, A.; Morton, T.; Perez-Cueto, F.J.; Makransky, G. A randomized trial testing the effectiveness of virtual reality as a tool for pro-environmental dietary change. *Sci. Rep.* **2022**, *12*, 14315. [CrossRef] [PubMed]
28. Moore, S.; Lau, A.C.H.; Greatbatch, S.; Lamb, J.; Pine, K.; Tacheva, B.; Parkinson, B.; Pachaly, P.; Pachaly, B. Formative evaluation of a nutrition label education intervention using computer gamification to promote learning among school students. *Health Educ. J.* **2026**, *85*, 29–39. [CrossRef]
29. Vepsäläinen, H.; Skaffari, E.; Wojtkowska, K.; Barlińska, J.; Kinnunen, S.; Makkonen, R.; Heikkilä, M.; Lehtovirta, M.; Ray, C.; Suhonen, E.; et al. A Mobile App to Increase Fruit and Vegetable Acceptance Among Finnish and Polish Preschoolers: Randomized Trial. *JMIR Mhealth Uhealth* **2022**, *10*, e30352. [CrossRef] [PubMed]

30. Baranyi, R.; Steyrer, B.; Lechner, L.; Agbektas, N.; Lederer, G.; Grechenig, N. NutritionRush—A serious game to support people with the awareness of their nutrition intake. In Proceedings of the 2017 IEEE 5th International Conference on Serious Games and Applications for Health (SeGAH), Perth, Australia, 19–22 April 2017. [CrossRef]
31. Froome, M.H.; Townson, C.; Rhodes, S.; Arellano, F.; Sage, B.; Savaglio, L.A.; Brown, R.; Hughes, M.J.; Karpalos, J.; Arcand, B. The Effectiveness of the Foodbot Factory Mobile Serious Game on Increasing Nutrition Knowledge in Children. *Nutrients* **2020**, *12*, 3413. [CrossRef] [PubMed]
32. Vlieger, D.N.; Sainsbury, L.; Smith, S.; Riley, N.; Miller, A.; Collins, C. O30 Development and Preliminary Testing of VitaVillage: A Serious Game Used for Nutrition Education. *J. Nutr. Educ. Behav.* **2020**, *53*, S14–S15. [CrossRef]
33. Holzmann, L.S.; Schäfer, H.; Groh, G.; Plecher, A.D.; Klinker, G.; Schauberger, G.; Hauner, H.; Holzpfel, C. Short-Term Effects of the Serious Game "Fit, Food, Fun" on Nutritional Knowledge: A Pilot Study among Children and Adolescents. *Nutrients* **2019**, *11*, 2031. [CrossRef] [PubMed]
34. Wengreen, J.H.; Joyner, D.; Kimball, S.S.; Schwartz, S.; Madden, J. A Randomized Controlled Trial Evaluating the FIT Game's Efficacy in Increasing Fruit and Vegetable Consumption. *Nutrients* **2021**, *13*, 2646. [CrossRef] [PubMed]
35. Cullen, K.W.; Liu, Y.; Thompson, D.I. Meal-specific dietary changes from squires quest! II: A serious video game intervention. *J. Nutr. Educ. Behav.* **2016**, *48*, 326–330. [CrossRef] [PubMed]
36. Espinosa-Curiel, I.E.; Pozas-Bogarin, E.E.; Lozano-Salas, J.L.; Martínez-Miranda, J.; Delgado-Pérez, E.E.; Estrada-Zamarron, L.S. Nutritional education and promotion of healthy eating behaviors among Mexican children through video games: Design and pilot test of FoodRateMaster. *JMIR Serious Games* **2020**, *8*, e16431. [CrossRef] [PubMed]
37. Hermans, J.C.R.; Broek, D.V.N.; Nederkoorn, C.; Otten, R.; Ruiter, M.L.E.; Glensberg, J.C.M. Feed the alien! The effects of a nutrition instruction game on children's nutritional knowledge and food intake. *Games Health J.* **2018**, *7*, 164–174. [CrossRef] [PubMed]
38. Marchetti, D.; Fraticelli, F.; Polcini, F.; Lato, R.; Pintaudi, B.; Nicolucci, A.; Fulcheri, M.; Mohn, A.; Chiarelli, F.; Vieste, D.G.; et al. Preventing Adolescents' Diabesity: Design, Development, and First Evaluation of "Gustavo in Gnam's Planet". *Games Health J.* **2015**, *4*, 344–351. [CrossRef] [PubMed]
39. Hunicke, R.; LeBlanc, M.; Zubek, R. MDA: A formal approach to game design and game research. *Proc. AAAI Workshop Chall. Game AI* **2004**, *4*, 1722. Available online: https://cdn.aaai.org/Workshops/2004/WS-04-04/WS04-04-001.pdf (accessed on 12 July 2026).
40. Winn, B.M. The design, play, and experience framework. In *Handbook of Research on Effective Electronic Gaming in Education*; IGI Global Scientific Publishing: Hershey, PA, USA, 2009; pp. 1010–1024. [CrossRef]
41. Silva, F.G. Practical methodology for the design of educational serious games. *Information* **2019**, *11*, 14. Available online: https://www.mdpi.com/2078-2489/11/1/14#B21-information-11-00014 (accessed on 12 July 2026). [CrossRef]
42. Schell, J. *The Art of Game Design: A Book of Lenses*; CRC Press: Boca Raton, FL, USA, 2008. [CrossRef]
43. Liao, L.L.; Lee, C.K.; Lai, I.J.; Chang, L.C. Preliminary effectiveness of VR-enhanced nutrition education for promoting healthy diets among college students. *Nutr. J.* **2025**, *24*, 125. [CrossRef] [PubMed]
44. Slavin, J.L.; Lloyd, B. Health benefits of fruits and vegetables. *Adv. Nutr.* **2012**, *3*, 506–516. [CrossRef] [PubMed]
45. The U.S. Departments of Agriculture (USDA) and Health and Human Services (HHS) jointly develop the Dietary Guidelines for Americans, Which Provide Evidence-Based Recommendations on Food and Beverage Choices to Promote Health, Meet Nutrient Needs, and Prevent Chronic Disease (USDA & HHS, n.d.). Available online: https://www.dietaryguidelines.gov/ (accessed on 12 July 2026).
46. Hercberg, S.; Touvier, M.; Salas-Salvado, J.; Llanaj, E. The Nutri-Score nutrition label: A public health tool based on rigorous scientific evidence aiming to improve the nutritional status of the population. *Int. J. Vitam. Nutr. Res.* **2021**, *92*, 147–157. [CrossRef] [PubMed]
47. Merz, B.; Temme, E.; Alexiou, H.; Beulens, J.W.J.; Buyken, A.E.; Bohn, T.; Ducrot, P.; Falquet, M.-N.; García Solano, M.; Haidar, H.; et al. Nutri-score 2023 update. *Nat. Food* **2024**, *5*, 102–110. Available online: https://www.nature.com/articles/s43016-024-00920-3 (accessed on 12 July 2026). [CrossRef] [PubMed]
48. Csikszentmihalyi, M.; Csikzentmihaly, M. *Flow: The Psychology of Optimal Experience*; Harper & Row: New York, NY, USA, 1990; Volume 1990, p. 1. [CrossRef]
49. Linderoth, J. Creating stories for a composite form: Video game design as Frame Orchestration. *J. Gaming Virtual Worlds* **2015**, *7*, 279–298. [CrossRef] [PubMed]
50. Naul, E.; Liu, M. Why story matters: A review of narrative in serious games. *J. Educ. Comput. Res.* **2020**, *58*, 687–707. [CrossRef]
51. Jörg, S.; Ye, Y.; Mueller, F.; Neff, M.; Zordan, V. Virtual hands in VR: Motion capture, synthesis, and perception. In *SIGGRAPH Asia 2020 Courses*; Association for Computing Machinery: New York, NY, USA, 2020; pp. 1–32. [CrossRef]
52. Michie, S.; Richardson, M.; Johnston, M.; Abraham, C.; Francis, J.; Hardeman, W.; Eccles, M.P.; Cane, J.; Wood, C.E. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. *Ann. Behav. Med.* **2013**, *46*, 81–95. [CrossRef] [PubMed]

53. López-Gajardo, M.A.; Leo, F.M.; Sánchez-Miguel, P.A.; López-Gajardo, D.; Soulas, C.; Tapia-Serrano, M.A. KIDMED 2.0, An update of the KIDMED questionnaire: Evaluation of the psychometric properties in youth. *Front. Nutr.* **2022**, *9*, 945721. [CrossRef] [PubMed]
54. Dimou, V.; Styliaras, G.D.; Salomidis, K. AR-Based Food Traceability as a Means for Sustainable Development. *Sustainability* **2024**, *16*, 3037. [CrossRef]
55. Apergi, K.; Styliaras, G.D.; Tsirogiannis, G.; Beligiannis, G.N.; Malisova, O. A Scoping Review of AI-Driven mHealth Systems for Precision Hydration: Integrating Food and Beverage Water Content for Personalized Recommendations. *Multimodal Technol. Interact.* **2025**, *9*, 112. [CrossRef]

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