Article

Primeiras Refeições: Serious Game to Improve Infant Feeding Knowledge

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Abstract

To address public health concerns surrounding infant nutrition misinformation, this study described the development of the serious game "Primeiras Refeições" and evaluated its effectiveness in improving knowledge on the topic among university students. A quasi-experimental, pre- and post-test study was conducted with 119 undergraduate students from diverse academic fields at a Brazilian university. Participants' knowledge was assessed via a 10-item questionnaire before and after an intervention with the 2D simulation game, developed in the Unity engine. A paired t-test revealed a statistically significant knowledge increase, with mean scores rising from 4.65 (±2.01) to 5.20 (±1.89) post-intervention (p < 0.01). The study's primary contribution is its focus on university students, future professionals, and caregivers, a demographic rarely targeted by nutrition games, which typically focus on children. Furthermore, the game's mechanics are novel, addressing practical skills like preparing age-appropriate food consistencies, a topic often neglected in similar digital interventions. The findings indicate that "Primeiras Refeições" is a promising educational tool to improve guidance on accurate infant nutrition, holding significant potential for public health education.

1. Introduction

Proper feeding of children under two years old is crucial for their development, as it can prevent nutritional deficiencies and childhood obesity while promoting healthy physical, psychological, and motor growth [1].

Exclusive breastfeeding until six months of age is a necessity for a child, and it brings many health benefits. However, from six months onwards, breast milk can no longer completely supply

the baby's nutritional necessities, which makes it essential to provide complementary feeding. Still, if that is done before that time or incorrectly, it could turn the child susceptible to infections, diarrhea, malnutrition, short and long-term development impairment, increased risk of developing food and respiratory allergies, among others [2].

Despite clear guidelines from health organizations, misinformation regarding artificial dairy feeding and the premature introduction of solid foods remains prevalent. Studies indicate that even health professionals may lack adequate training and hold misconceptions about infant feeding, highlighting a critical need for continuing education to ensure they can provide accurate guidance and promote key practices, such as exclusive breastfeeding up to six months of age and its continuation for two years or more [3, 4, 5, 6]. Addressing this educational challenge requires engaging pedagogical strategies. Innovative methodologies, particularly serious games, present a promising approach, as they have been shown to be effective, and in many cases superior to traditional methods, for improving knowledge and skills among health professionals [7, 8]. This makes them a valuable tool to not only transmit information but also to influence future professional conduct positively.

Building on the need for engaging pedagogical strategies, ludic approaches, including board, card, and digital games, have demonstrated considerable effectiveness in health education [9]. Digital games, in particular, are well-suited for this context as they leverage interactivity and immediate feedback to enhance learner engagement and knowledge retention [10, 11]. More specifically, serious games are designed with the primary purpose of education rather than entertainment, applying game mechanics to complex real-world topics [12]. This positions them as a suitable tool for professional training and makes developing a serious game a promising strategy for improving education on complementary infant feeding.

The importance of proper infant feeding extends throughout public health, making the adequate preparation of health professionals a crucial issue. As previously established, knowledge gaps in this area are common [4, 5, 6]. Furthermore, the general population has doubts regarding the appropriate consistency, preparation method, and appearance of food, and can be mistaken when weaning early due to misinformation [13, 14].

Digital games offer a playful and engaging medium to support learning, develop logical reasoning, and stimulate interest in the subject [15]. They are also integrated into people's lives, being present across multiple platforms and environments. Additionally, serious games can support the continuing education of healthcare professionals by introducing new technologies and fostering competencies in digital navigation and game mechanics. This facilitates knowledge exchange with experts from other fields, such as computing and game design, promoting an interprofessional and interdisciplinary learning experience, which also contributes to making the game more accurate in its content and ensuring higher overall quality [16].

The widespread adoption and cultural integration of digital games, including in Brazil, indicates a high level of digital literacy and receptiveness to game-based interventions among the university student population [17, 18]. This ubiquity makes games a viable and accessible platform for delivering educational content.

To address the identified educational gap and contribute to resolving this public health dilemma, this study explores the use of a serious game to better prepare university students. Given the potential of game-based learning, this approach was deemed effective for the target audience. Therefore, the present study was designed with two primary objectives. First, to describe the technical development process of the serious game "Primeiras Refeições." The second was to evaluate the game's effectiveness by comparing knowledge on infant feeding before and after the intervention.

This paper is organized into five main sections. The first section reviews the relevant literature, presenting the theoretical foundations and key concepts that guide the study. The second section

describes the research methodology, including the design, participants, data collection instruments, and analytical procedures. The third section presents the results, emphasizing the main findings and patterns identified. The fourth section discusses these findings in relation to previous research, exploring their theoretical and practical implications. Finally, the conclusion summarizes the key insights, acknowledges the study's limitations, and offers directions for future research, outlining the overall contributions of the work.

2. Methods and Material

2.1   Ethical Considerations

The presented research was prepared in accordance with Brazilian National Health Council resolution Nº 466/2012, which deals with human research, forwarded and approved by the Ethics and Research Committee with approval number 5.843.784 in January 2023. University students from the classes were invited to participate in the research, and those who agreed signed an informed consent form. Participation was voluntary and subject to prior consent, obtained digitally through a free and informed consent form embedded as the first page of the initial questionnaire.

2.2   Game Development

The game called "Primeiras Refeições" was developed in the Technological Development and Innovation Initiation Scholarship Program - PIBITI CNPq with the project entitled "It looks like it, but it isn't, feeding children under two years of age" in the years 2021 and 2022. A multidisciplinary team was involved to ensure both pedagogical quality and technical expertise. The team consisted of a game and lead designer, who is a nutritionist, a programmer specialized in the C# language, a digital illustrator with experience in game production, and a nutritionist specialized in Maternal and Child Nutrition.

The development followed the methodology proposed by Chandler [19], known as the Basic Game Production Cycle, which is structured into four cyclical stages: Pre-production, Production, Testing, and Post-production. This pyramid-shaped model emphasizes the importance of careful planning and allows adjustments throughout the development process.

The first stage, Pre-production, encompasses preliminary studies related to the project, including market research and skill acquisition. It is the phase in which the core idea of the game is developed, scope and theme are defined, requirements such as time and budget are established, and a roadmap for completion is created. Overall, pre-production serves as the foundation for project planning, reducing the likelihood of errors during later stages.

Following pre-production, the Production stage involves the effective development of the game. This includes the creation and implementation of game and level design, visual and audio assets, and the programming of gameplay mechanics.

Conducted either after or simultaneously with production, the Testing stage aims to detect and correct errors. It also serves to ensure that execution remains consistent with the plans defined in pre-production, functioning as a validation step for the overall process. If, during this stage, it becomes evident that the initial plan is not being followed, the process returns to the pre-production phase to realign the project's direction.

Finally, the Post-production stage corresponds to the closing and evaluation of the project. Following delivery or release, the team conducts retrospective analyses (post-mortem) to identify key strengths and challenges experienced during development. This stage provides insights into which strategies were effective, which shortcomings could have been avoided, and what improvements may be applied to future projects. Consequently, post-production represents a

collective learning opportunity that enhances team expertise and contributes to the refinement of methodologies and processes in subsequent developments.

2.3   Study Design and Participants

A quasi-experimental study with a pre-test/post-test design was conducted at the largest private higher education institution in the central region of Rio Grande do Sul, Brazil. To minimize educational bias, the sample was composed of university students; to ensure heterogeneity of prior knowledge, these students were recruited from diverse academic fields. From the total student population (3152), a sample size of 229 participants was calculated for a 95% confidence level with a 5% margin of error. A proportional stratified sampling method was employed, using the four main areas of knowledge defined by the university (Health Sciences, Technological Sciences, Social Sciences, and Human Sciences) as strata. The required number of students per area is presented in Table 1. This method was chosen to ensure the sample would reflect the actual distribution of students across the different academic fields within the institution, thus justifying the proportional imbalance observed in the collected sample.

The selection of courses and classes within each stratum followed a simple random sampling method. A proportional draw was used to select more classes from the larger academic areas. The resulting sampled courses were: Journalism and Advertising (Social Sciences); Design, Digital Games, and Computer Science (Technological Sciences); Nutrition, Medicine, Psychology, and Pharmacy (Health Sciences); and History (Human Sciences).
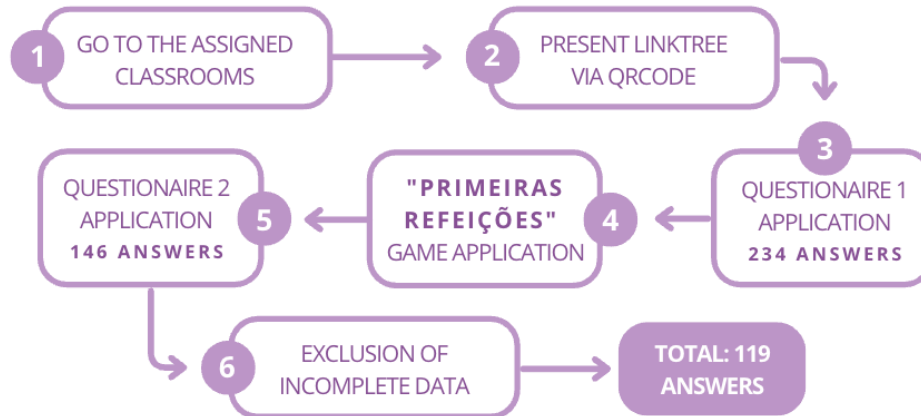
Table 1. Sample of students by area.

	Total number of students	% students per area	Students required for sampling
Social Sciences	736	23%	52
Technological Sciences	538	18%	41
Health Sciences	1778	56%	129
Human Sciences	100	3%	7
TOTAL	3152	100%	229

Inclusion criteria were being an enrolled undergraduate student, being present in the classroom on the day of data collection, and completing both the pre-test and post-test questionnaires. Students with special needs that would prevent interaction with the mobile game, such as visual impairment, were excluded.

2.4   Data Collection Procedure

The primary instrument was a questionnaire developed on Google Forms. It consisted of ten closed-ended questions designed to assess specific knowledge related to breastfeeding and complementary feeding, based on the official Food Guide for Brazilian Children Under Two Years [1]. To enable a before-and-after comparison of knowledge acquired through gameplay, the questionnaire also collected personal data such as name, gender, course, semester, and email. The same questionnaire was administered as a pre-test before playing the game and as a post-test after participants played the game.

After obtaining authorization from course coordinators, researchers visited the selected classrooms. The procedure, which lasted approximately 20 minutes, involved providing participants with access to a Linktree via a QR Code containing three sequential items: Questionnaire 1 (pre-test), the game "Primeiras Refeições" (on the Itch.io platform), which participants played, and Questionnaire 2 (post-test). This entire procedure is summarized in Figure 1.

Figure 1. Methodological workflow illustrating the application of the game and questionnaires

Initially, 234 students answered the first questionnaire, and 146 students completed the second questionnaire after the gameplay intervention. Consequently, only the data from students who completed both questionnaires were considered, resulting in a final valid sample of 119 participants for the paired analysis.

2.5   Statistical Analysis

The collected data were stored in an Excel spreadsheet and analyzed using the Statistical Package for the Social Sciences (SPSS), version 23.0. To evaluate the distribution of variables, the Kolmogorov-Smirnov test was applied, and to describe the nominal and ordinal qualitative variables, absolute and relative frequencies, and continuous quantitative frequencies, the mean and standard deviation were used. The difference between the average scores before and after the game, and the average difference between courses in the health area and other areas, were both confirmed by the t-test. It was considered a significance level of 5% ($p<0.05$).

3. Results

3.1   Game Development Results

Following the application of the chosen methodology [19], the pre-production stage resulted in a clear project plan. The educational theme was defined as breastfeeding and complementary feeding, based on the official Brazilian Food Guide [1]. The project scope was established with a 12-month completion timeline, and the budget was structured based on hourly costs for each team member and separate allocations for software and sound assets. The game's genre was defined as a simulation and resource management game inspired by Tamagotchi (1996), to be developed in Portuguese for Web and Android platforms.

The production stage resulted in the creation of the final game assets and code. The game was developed in the Unity engine using the C# language and the Visual Studio environment. Sound effects with acquired rights were purchased and integrated, along with other game elements. All art

is entirely 2D (Figure 2), illustrated in Procreate and subsequently vectorized in Adobe Illustrator to maintain quality upon importation into Unity. A notable design choice was making the baby character purple. This decision was a result of budget and scope considerations, avoiding the cost and time of creating assets for multiple races and genders while reducing the sense of exclusion.
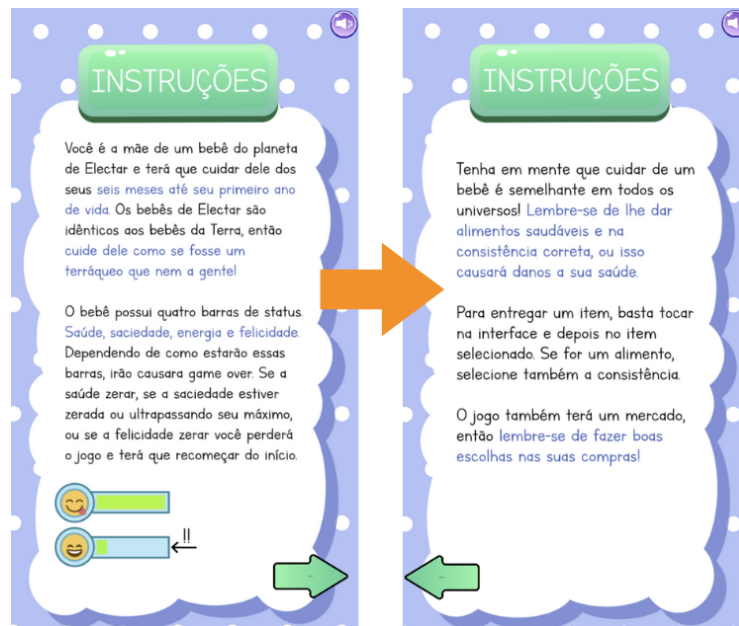

Figure 2. Screenshot of the game interface showing the baby character and its status indicators. The screen displays available money, age ("idade: 6 meses"), and phase ("fase 1"). On the left, icons represent satiety, happiness, energy, and health levels. At the bottom, interactive buttons allow actions such as "falar" (talk), "alimentar" (feed), "entregar" (deliver), and "dormir" (sleep).

The final game features a start screen (Figure 3) with options to begin, view instructions explaining the interface icons (Figure 4), and see the credits. A "see more" button was included to allow for future content additions. A key gameplay feature resulting from the design process is the in-game market (Figure 5). At the end of each phase (representing a month of the baby's life), the player receives a fixed amount of in-game currency to spend in the market, adding a layer of resource management and decision-making.

Figure 3. Screenshot of the menu interface showing the initial actions that can be taken by the player. From top to bottom, they are: 'Start', 'Instructions', and 'Credits'.

Figure 4. Screenshot of the 'Instructions' interface, explaining the game story, mechanics, visual elements and main goal to the players.

Figure 5. Screenshot of the game interface, showing the 'market', and the items available to purchase with the in-game currency. Both on the top shelf and on the bottom shelves, there are up to 14 food items to choose from, while on the white shelf on the right, there are 3 toy options.

The focus of the game mechanics was the promotion of breastfeeding and how important this process is for the baby, the appropriate consistency of food for each age (Figure 6), encouraging the disuse of infant formula and ultra-processed foods rich in sugar and fats, and promoting habits that improve the child's behavior, such as playing and communicating with them during meals. All game content was based on the Food Guide for Brazilian children under two years of age [1].

Figure 6. Screenshot of the game interface showing the baby character during feeding time. The top section again displays money, age, and phase. The label "Hora do Almoço!" ("Lunch time!") introduces food choices, with icons for different ingredients (meat, carrot, potato, pumpkin) and three consistency options for the meal.

The testing stage revealed relevant findings related to the project's management and technical workflow. Some bugs were identified, the most significant being the loss of project progress due to issues with the initial version control system, Unity Collab. This finding directly informed the post-mortem analysis in the final stage. Two key lessons were learned from the development process: technically, the decision was made to abandon Unity Collab in favor of storing the project in Bitbucket via the Sourcetree platform for superior version control. Methodologically, the post-mortem highlighted the critical importance of joint decision-making and maintaining open communication channels within the interdisciplinary team to quickly resolve issues and align on project goals.

As a final outcome, the completed game, titled "Primeiras Refeições," was made available on the Itch.io platform. The software was also officially registered with the National Institute of Industrial Property (INPI) under the number BR512022001799-7.

3.2 Results On Knowledge

The final sample consisted of 119 students, of which 51 were enrolled in Health Sciences courses and 68 in non-health-related fields. The detailed distribution was as follows: 19 students (16%) from Nutrition, 13 (10.9%) from Medicine, 11 (9.2%) from Psychology, and 8 (6.7%) from Pharmacy. In the other areas, the distribution included 18 students (15.1%) from Design, 15 (12.6%) from Journalism, 13 (10.9%) from Computer Science, 11 (9.2%) from Advertising, 9 (7.6%) from Digital Games, and 2 (1.7%) from History.

Regarding gender, 63 participants (52.9%) were identified as female, 54 (45.4%) as male, and 2 (1.7%) preferred not to declare. The students were typically in the third semester of their studies (P25-1st- P75-5th).

When asked whether they had prior knowledge about feeding children under two years of age, 20 (16.8%) reported "yes," 58 (48.7%) reported "partially," and 41 (34.5%) reported "no." Regarding the sources of this knowledge (n = 88), the most commonly reported were "Personal experience" 23 (26.1%) and "Discipline in the course" 21 (23.9%), followed by "Other" 22

(25.0%), "Social media" 15 (17.0%), "Websites" 5 (5.7%), and "Magazines" 2 (2.3%). Some participants who reported not having prior knowledge still indicated having accessed information on the topic from one or more of the listed sources.

The analysis of the questionnaires, as described in Table 2, revealed an increase in students' knowledge following the intervention. In Questionnaire 1, the average number of correct answers was 4.65 (46.5% correctness rate), with a total of 556 correct answers, comprising 299 from students in the health area and 257 from other areas. In Questionnaire 2, the average increased to 5.20 (52.0% correctness rate), with a total of 626 correct answers, evenly distributed with 313 from the health area and 313 from other areas.

Table 2. Frequency of correct answers before and after playing Primeiras Refeições.

Questions	Questionnaire 1 (n%)	Questionnaire 2 (n%)	% of improvement
In general, at how many months of a child's life should complementary feeding start?	73 (61,3)	96 (80,7)	31,5
At how many months should meat start to be offered to the child?	34 (28,6)	43 (36,1)	26,5
For an 8-month-old child, what is the appropriate consistency for the dish?	72 (60,5)	79 (66,4)	9,7
Which of the options below provides the best development for the child?	66 (55,5)	67 (56,3)	1,5
Which of these activities are the most suitable for supporting a healthy child development?	63 (52,9)	73 (61,3)	11,1
If possible, how long can the baby be breastfed?	32 (26,9)	31 (26,1)	-3,22
Which of these are NOT benefits of exclusive breastfeeding up to six months?	17 (14,3)	19 (16)	11,7
Once the child starts eating, at least how many types of food are recommended to have on the plate?	57 (47,9)	62 (52,1)	8,7
Select the best foods for your child from 6 months onwards.	59 (49,6)	78 (65,5)	32,2
How many times should breastfeeding be offered during the day?	83 (69,7)	78 (65,5)	-7

Note: The values are presented in number (%) and % of improvement between the correct answers in questionnaires 1 and 2.

A paired t-test confirmed that this increase in the mean score of correct answers between the pre-test and the post-test was statistically significant ($p < 0.01$), as detailed in Table 3.

Table 3. Average of correct answers before and after playing Primeiras Refeições

	Average 1	Average 2	p
Total matches*	4,67±2,01	5,26±1,89	<0,01#
Healthcare are matches**	5,86±1,84	6,14±1,83	<0,01#
Other areas matches**	3,78±1,65	4,60±1,67	<0,01#

*Note: Values presented as mean±standard deviation. *T-test for paired samples. **T-test for independent samples. #p<0.05.*

4. Discussion

4.1 Principal Results

The game and level design were centered on the player experience, leveraging an experiential learning cycle where players learn through trial and error. This allows them to actively identify harmful and beneficial actions for the baby. Foods such as flavored yogurts, baby formula bottles, and processed juices are examples of foods that are unsuitable for children under two years of age, causing the player to lose status points. Fresh foods such as broccoli, meat and beans are foods that increase this score if offered in the appropriate consistency for the age. These score-lowering foods are unsuitable, and score-increasing foods are suitable for children in real life. By immersing the player in this direct feedback loop, the serious game encourages engagement and facilitates active learning, where knowledge is constructed through action and consequence, rather than passive reception [20].

Although a maximum time for the intervention was allotted, the practical gameplay duration varied among students. This variation depended on the specific class context, such as the subject being taught, the classroom dynamics, and the flexible time frame provided by the professor within the lesson plan. The finding of a short-term knowledge increase in the present study is consistent with other research in this field. For example, a study on the game "Feed the Alien!" [21] also found that brief gameplay sessions improved children's immediate recall of nutritional facts (specifically, the names of macronutrients). However, the authors reported that this effect was not sustained at a 2-week follow-up, and the game did not significantly impact other measures like healthier food choices or actual food intake. This suggests that while serious games are effective at introducing concepts, achieving long-term knowledge retention and behavioral change may require more prolonged or repeated interventions than what a short study can provide.

Regarding the students' prior knowledge, only 20 (16.8%) stated that they had extensive knowledge about nutrition for children under two years of age. The most common sources of knowledge mentioned were "Discipline in the course" and "From own experience". Although students who have already had a subject in their classes and individuals with experience in raising a child should already have some knowledge about breastfeeding and complementary feeding, this wasn't contemplated in the research. However, students in the health area had a higher average number of correct answers in both Questionnaire 1 (5.86±1.84) and Questionnaire 2 (6.14±1.83) compared to other areas. Other studies also show an improvement in students' short-term knowledge of nutritional awareness after playing a game. However, the target audience for these studies was elementary school children [9][21][22]. These results indicate the importance of consolidating a basic knowledge of infant nutrition during academic training and encouraging the search for updated information based on scientific evidence, participation in education and

professional development programs as a form of continuing education. Based on the education of these professionals, nutrition education must be promoted for parents and guardians so that the child can grow and develop healthily [1].

Analyzing the students' knowledge scores, the primary finding is the overall improvement after playing "Primeiras Refeições." However, a more nuanced look at the data reveals a key outcome: while students from the health area consistently achieved higher scores, the greatest learning gain was observed among students from other areas. This suggests that the serious game was particularly effective for the audience with the lowest baseline knowledge on the subject, demonstrating its potential as a leveling educational tool. This outcome can be contextualized by comparing it to studies with more intensive methodologies. For example, a study with children [10] reported that the number of correct answers tripled after the intervention. In that case, however, the participants were actively involved in creating the game's mechanics, which constitutes a much longer and more immersive educational process. Considering the present study involved a short, single-session intervention, the observed knowledge gain is noteworthy, especially for the non-health student population.

The questions with the greatest increase in correct answers were: "In general, at how many months of the child's life should complementary feeding be started?" "At how many months should meat start to be offered to the child?" and "Select the best foods for your child from 6 months onwards." With an improvement of 32.2% in correct answers, these results were significant. These three inquiries are discussed a lot in the game, since during the gameplay, the player starts feeding a child from the age of six months, and meat can be offered from that age as something healthy. Furthermore, the appropriate and inappropriate food options represented in the game could be defined positively or negatively, depending on the context. This shows that even if played for a short amount of time, the game managed to bring insight through the association between the game and real life.

On the other hand, some issues that were also addressed within the game, such as breastfeeding and the minimum number of foods on the child's plate, had a less significant improvement or even a 7% decrease in the proportion of correct answers. The question "For an 8-month-old child, what is the appropriate consistency of the dish?" had an improvement of 9.7% correct answers, which is a less significant result than other issues. The consistency of the dish brought up on throughout the game, however, most university students were unable to reach the child's eighth month due to the time allowed for the exercise having run out, and/or not being able to reach this stage due to game overs and having to answer Questionnaire 2. Therefore, there was no time to convey the knowledge on this topic for it to be truly effective. These results may indicate that the game time was unable to transmit certain learnings or that the explanation of these items was not clear enough within the game. It shows that the game may have probably been more effective in some aspects of education about children's nutrition than in others.

4.2 Limitations

Some limitations of this study should be acknowledged. First, the sample was drawn from a single private university in Southern Brazil, which may limit the generalizability of the findings to other populations. Second, due to the proportional stratified sampling that reflected the institution's enrollment, the academic areas were unbalanced. This methodological choice prevents meaningful statistical comparisons of knowledge gain between students from different fields (e.g., Health vs. Human Sciences).

Although the primary objective was not to compare different educational methods but rather to assess the game's effectiveness on its own, two main limitations from a study design perspective are apparent. The study lacked a control or comparison group (e.g., a group receiving the

information via a traditional lecture or text). Therefore, while the study concludes that knowledge increased after the intervention, it cannot establish that the serious game is more effective than other educational methods. Furthermore, the assessment did not include a long-term follow-up test, so the findings are limited to short-term knowledge retention, and no conclusions can be drawn about the persistence of this knowledge over time.

Finally, procedural limitations included a high attrition rate, as many students who answered the first questionnaire did not complete the second, which could introduce selection bias. Additionally, the variable time-on-task for gameplay, dictated by classroom dynamics, may have influenced the learning outcomes. These limitations offer important directions for future research.

5. Conclusions

This study aimed to describe the development of the serious game "Primeiras Refeições" and evaluate its effectiveness as a tool for improving knowledge of infant nutrition among university students. The results demonstrated that even a short intervention with the game led to a statistically significant increase in students' knowledge. Notably, the greatest learning gains were observed among students from non-health-related fields, indicating that the game is particularly impactful for audiences with a lower baseline knowledge.

The primary contribution of this work to the state of the art is its focus on university students, a critical and underresearched demographic in the field of nutrition-based serious games, which has predominantly targeted children. The findings have significant implications for higher education, suggesting that serious games are a viable and effective tool for the academic training of future professionals from diverse fields. By equipping these students with essential, evidence-based knowledge, such interventions can play a role in promoting broader and more accurate public health education.

Acknowledging the study's limitations provides clear directions for future research. To further validate the game's efficacy, future studies should incorporate a control group to compare its effectiveness against traditional teaching methods, such as lectures or readings. A long-term follow-up assessment is also essential to determine the retention of the acquired knowledge over time. Finally, future work could involve adapting and testing "Primeiras Refeições" with its ultimate target audiences, such as parents, caregivers, and community health workers, to assess its impact beyond the academic environment.

Acknowledgments

Conflicts of interest

The authors declare that they have no conflicts of interest.

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