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Gamification in nutrition education: the impact and the acceptance of digital game-based intervention for improving nutritional habits

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Abstract

As school-based nutrition education interventions have become increasingly popular in recent years, they have proven effective in raising children awareness and responsibility toward good eating habits as well as improving their knowledge, skills, and attitudes. The aim of this work is to evaluate whether a gamification approach, using a digital application developed in AdobeXD, could be an appropriate strategy for increasing attention span toward nutrition education messages when compared to a classical didactic approach. The study involved 126 children aged 7 to 8 years, divided into control group (lesson with nutrition expert supported by slides) and intervention group (interactive lesson via application). A questionnaire was then administered to all participants to assess the knowledge they gained regarding basic nutrition education concepts. An additional questionnaire was distributed to the intervention group for the prototype digital evaluation based on the Technology Acceptance Model (TAM) framework. The results show that the digital application has the potential to be an effective tool for producing significant improvements in nutrition knowledge. The greater rating on the usefulness of the content, rather than on other intrinsic features of the prototype, demonstrates that the use of a digital approach can play a key role in capturing new concepts of nutrition education.

Keywords Media in education · Elementary education · Teaching/learning strategies · Gamification · Improving classroom teaching

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Introduction

In recent decades, childhood overweight and obesity have become an alarming global issue, having significantly increased and causing relevant socio-economic and public health problems (Wang & Lobstein, 2006). If nutritional needs are not fulfilled, health issues will inevitably follow, with obesity being a major concern that is increasing day by day worldwide. In 2017, 38 million children under age 5 were overweight or obese (Abarca-Gómez, Abdeen, Hamid, Abu-Rmeileh, Acosta-Cazares, Acuin, Adams, Aekplakorn, Afsana, Aguilar-Salinas, et al., 2017). European rates are estimated to be over 20%, with the number of overweight children predicted to rise by almost 1.3 million annually (Kosti, Panagiotakos, et al., 2006; Jackson-Leach & Lobstein, 2006).

According to the World Health Organization (WHO), this phenomenon is often caused by unhealthy eating habits and lack of physical activity, which can increase the risk of noncommunicable diseases like cardiovascular complications, cancer, and diabetes (Suleiman-Martos, García-Lara, Martos-Cabrera, Albendín-García, Romero-Béjar, Cañadas-De la Fuente, and Gómez-Urquiza, 2021). Besides, obese children are also at a higher risk for social issues, low self-esteem, and becoming obese adults. Therefore, the severe impacts of pediatric overweight and obesity emphasize the importance of implementing programs and policies to prevent it.

Nutrition education, as defined by Food and Agriculture Organization (FAO), is "the process of promoting healthy eating habits and proper food handling in order to improve the nutritional status of individuals". It is considered an effective preventive tool that can help prevent disease by teaching people how to make informed choices about their diet. Nutrition education interventions in schools have been shown to be successful in increasing children's awareness, responsibility, and understanding of healthy eating habits. Schools are considered an ideal setting for nutrition education, as they provide a large audience of children who can receive consistent messages and ongoing support for healthy eating (Rosi, Brighenti, Finistrella, Ingrosso, Monti, Vanelli, Vitale, Volta, and Scazzina, 2016).

Nowadays, effective food education programs in schools utilize various approaches, including face-to-face lessons and workshops using both traditional teaching methods and technology (such as computers, tablets, and interactive whiteboards). In particular, in recent years, game-based nutrition learning has been proven to be an effective method for improving children's knowledge, behavior, and healthy eating habits. Accordingly, the implementation of gamification tools has been considered to make nutrition education more interactive and engaging, with the aim of fostering the achievement of desired goals (Rosi, Dall'Asta, Brighenti, Del Rio, Volta, Baroni, Nalin, Zelati, Sanna, and Scazzina, 2016; Ogunsile & Ogundele, 2016).

The role of digital gamification in learning

Gamification is based on the application of game mechanics during the teaching and learning process (Kurtzman, Day, Small, Lynch, Zhu, Wang, Rareshide, and

Patel, 2018). Due to the difficulty of inducing lifestyle changes in young people, gamification can be an effective method for creating change and improving adherence to healthy practices (Kostenius, Hallberg, and Lindqvist, 2018). Specifically, game features are used to obtain achievements, prizes, or rewards. This game dynamic correlates with learning-level benefits and increases interaction among participants, providing freedom and increased motivation.

Gamification has been successfully implemented in several areas of health and education, including nutrition education. (Roche, Wingo, Westfall, Azuero, Dempsey, and Willig, 2018; Suleiman-Martos, García-Lara, Martos-Cabrera, Albendín-García, Romero-Béjar, Cañadas-De la Fuente, and Gómez-Urquiza, 2021). In this context, gamification is characterized as a concept that is able to stimulate and motivate people to make better food decisions (Ögel Aydın & Argan, 2021). Specifically, numerous studies have shown a positive effect on dietary behavior change in children and adults (Ezezika, Oh, Edeagu, and Boyo, 2018; Holzmann, Schäfer, Groh, Plecher, Klinker, Schauberger, Hauner, and Holzapfel, 2019; Berger & Jung, 2021).

A major impetus in fostering gamification techniques has come from new technologies, which allow the use of more interactive tools to deliver abstract theoretical concepts and implement the learning process in an educational setting. Information and communication technologies (ICTs) represent a powerful strategy for promoting healthy lifestyles and improving public health, and appearing to be more effective than traditional printed materials in producing nutrition behavior change. In fact, ICTs have been found to be very useful for educational purposes, improving the interaction between students, teachers and curricular content. In particular, gamification methods have been found to be most effective in promoting healthy habits during childhood, and resources such as social networks, mobile devices and applications can be very useful in spreading these concepts (Rohde, Duensing, Dawczynski, Godemann, Lorkowski, Brombach, et al., 2019). Based on this evidence, the state of the art analysis performed in Sect. 2 focused on digital gamification approaches for nutrition education in school-age individuals.

Main contributions

Following the scenario described above, the aim of the present study is to evaluate whether a gamification approach via digital application could be able to improve the effectiveness of a nutrition education intervention compared to a classical didactic approach. In particular, the objective is to understand and quantify whether children interaction through a digital approach could support the learning of nutrition education concepts in elementary school.

The main hypotheses addressed in this study are two:

- to assess whether participants in a nutrition education intervention using a digital prototype (intervention group) could improve their knowledge to a greater extent

than participants in an intervention with a classical approach using traditional tools (control group);
- to assess how this digital approach may influence children intentions in putting what they have learned into practice, analyzing the connection between technology acceptance and the tangible impact it can have on users lives.

To this end, a randomized controlled trial was conducted on 126 children between the ages of 7 and 8, who represent the ideal target audience for such studies (Centro Nazionale per la Prevenzione delle malattie e la Promozione della Salute, 2019). Adobe XD[1] was identified for implementing the ad-hoc digital tool since it represents an advanced software for designing and prototyping user interfaces for applications. Specifically, it allows the creation of interactive prototypes that simulate the user experience, by adding transitions and animations and generating micro-interactions for various types of input. Moreover, the Technology Acceptance Model (TAM) has been adopted as a framework to measure user engagement. A novel adaptation of the TAM is proposed to study the acceptance of digital gamification in the learning process, with the aim to explore student intentions to adopt digital approaches in the specific context of nutrition education.

Related Work

As previously stated, gamification in nutrition education can lead to improvements in eating behavior among children and adolescents. An early experimental study testifying to this was carried out by Amaro et al. (2006) through the use of "Kalèdo", a board game on nutrition where a significant difference was seen in the post-intervention group regarding the increased use of healthy foods such as vegetables. The same experimental procedure was proposed by Zask et al. (2012), in which the authors designed a study using a control group and an intervention group where the former received no intervention while the intervention group used "Tooty Fruity Vegie", a game as a promotion program to increase fruit and vegetable intake and decrease unhealthy food intake using body mass index as a measure. Viggiano et al. (2015) found changes in waist circumference and BMI after intervention with gamification tool concerning healthy eating habits.

With the advent of new technologies and greater focus on the use of digital tools, more interactive approaches have been devised to guide information and implement the learning process, generally based on mobile and web-app applications. Several studies focused on the overall impact of gamification interventions on healthy eating practices. dos Santos Chagas et al. (2020) used the game "Rango Cards" and observed significant reductions in unhealthy eating habits and increased knowledge of the effects of fruit and vegetable consumption. Del Río et al. (2019) implemented an educational program based on ICT tools

[1] www.adobe.com/products/xd.html

and found significant improvements in nutritional knowledge and adherence to the Mediterranean diet among obese children.

The use of video games as interventions also yielded positive results. Lu et al. (2012) employed the health video game “Escape from Diab” to increase fruit and vegetable consumption, while Cullen et al. (2016) used the online video game “Squire’s Quest II” to promote fruit and vegetable intake during dinner. Both studies showed significant improvements in healthy eating behaviors compared to control groups. Additionally, Sharma et al. (2015) evaluated the impact of the computer game “Quest to Lava Mountain” on eating behaviors, physical activity, and psychosocial factors among children in Texas. The gamification approach resulted in a significant decrease in sugar consumption.

Both in terms of product developed and final goals, more similar to our study is the work of Froome et al. (2020), where the mobile app “Foodbot Factory” is used, and the authors found that it improved children’s nutritional knowledge. Similarly, Gan et al. (2019) developed the web platform “Healthy Foodie” and observed a statistically higher score in nutrition education knowledge among children in the intervention group compared to the control group. Overall, these studies highlight the effectiveness of gamification and digital tools in promoting nutritional knowledge and healthy eating behaviors among children, but not identifying what factors in the proposed methods may make students prefer the use of technology over classical teaching tools.

Several studies have investigated the acceptance and effectiveness of gamification and digital tools in various educational contexts. Rafique et al. (2020) focused on the acceptance of mobile library applications (MLAs) and found that perceived usefulness and ease of use were significant predictors of intention to use MLAs. Ab Rahman et al. (2019) explored the use of gamification in higher education and its impact on student engagement, using an improved version of the TAM as a measure. The findings highlighted the benefits of gamification in promoting student engagement. Another study conducted in Hungary investigated student behavior and performance while using the gamification platform “Kahoot!” It found that positive attitudes, good experiences, and ease of availability contributed to improved performance and intention to use the application (Varannai, Sasvári, and Urbanovics, 2017). Vanduhe et al. (2020) examined the factors influencing intentions of instructors to use gamification for training in universities. It enhanced the TAM with task technology fit, social motivations, and knowledge gain from using gamification. The findings emphasized the importance of perceived usefulness, attitudes, social recognition, and task technology fit in predicting continuance intentions to use gamified platforms for training.

These studies collectively contribute to the understanding of the acceptance and effectiveness of gamification and digital tools in educational settings, providing insights for decision-making and instructional design. However, to the best of our knowledge, there is no work in the literature that investigates nutrition education in elementary school with gamification approach while also assessing the technological acceptance component with an ad-hoc developed framework.

Table 1 Basic demographic data of the analyzed sample

	Control (n=60)	Gamification (n=66)	p-value
Age (years)	7.5 ± 0.5	7.7 ± 0.5	0.099
Grade (School)	2.3 ± 0.4	2.6 ± 0.5	< 0.001
Proportion in Grade 2	44 (73%)	27 (41%)	< 0.001
Male	32	29	0.377
Female	28	37	0.377
Child has attended previous nutrition education programs	18 (30%)	32 (48%)	0.862

Continuous data are presented as mean ± SD. Categorical data are presented as frequency (percentage). P-values are calculated by Chi-square test (categorical data) and unpaired t-test (continuous data)

Materials & Methods

This study seeks to assess the effectiveness of a gamification approach, employing a digital application created in AdobeXD, as a potential strategy to enhance attention span regarding nutrition education messages in comparison to a traditional didactic approach. Subsequent to this, questionnaires were dispensed to all participants to appraise the knowledge assimilated and measure the acceptance of technology through a proposed TAM framework. The present study was conducted in June 2022 at a summer center for elementary school children. Specifically, children aged 7 to 8 years old, corresponding to the second and third grade, were selected as participants. The sample was divided into a control group and an intervention group, with identification codes assigned to each participant to ensure anonymity. The control group was offered a nutrition education lecture with a nutrition expert, supported by a PowerPoint presentation. On the other hand, the intervention group utilized the digital application that covered the same nutrition education concepts as the control group. The effectiveness of the intervention was assessed using specially designed questionnaires administered at the beginning and end of the activity to both groups. These questionnaires aimed to evaluate the participants' acquisition of nutrition education concepts as well as measure the impact and acceptance of the digital prototype.

Participants and inclusion and exclusion criteria

A randomized controlled trial was designed, which involved a study sample including children, an intervention structured as a digital playful game component (gamification approach), data collected on the effect of the intervention on knowledge of proper eating habits and acceptance of the digital prototype as an educational tool. The study sample consisted of second- and third-grade elementary school students, aged between 7 and 8 years, as these age ranges have been commonly used in similar research studies (Rosi, Brighenti, Finistrella, Ingrosso, Monti, Vanelli, Vitale, Volta, and Scazzina, 2016; Rohde, Duensing, Dawczynski, Godemann, Lorkowski, Brombach, et al., 2019; Del Río, González-González,

(a) Control group lessons, (b) intervention group lessons.

Fig. 1 **a** Control group lessons and **b** intervention group lessons

Martín-González, Navarro-Adelantado, Toledo-Delgado, and García-Peñalvo, 2019). A written informed consent was obtained from parent or representative of all the participants. Exclusion criteria for participation included children's lack of verbal consent and absence on either the pre- or post-intervention measurement occasions. The basic characteristics of the participants are described in Table 1.

Intervention

A total of 126 children participated in the study, with 60 children assigned to the control group and 66 assigned to the intervention group. The control group received a nutrition education lesson using a traditional didactic approach, which involved a nutrition expert presenting slides (Fig. 1a). On the other hand, the intervention group engaged in an interactive activity using a custom-made application developed with Adobe XD specifically for this study (Fig. 1b).

The concepts of nutrition education

With the aim of improving children's eating habits, the components of the educational program were based on pivotal topics of nutrition education related to daily diet. Key points and core concepts were identified based on analysis of "OKkio alla SALUTE" data, nutrition education guidelines, and existing studies. The following points were considered:

- Importance of breakfast: breakfast was emphasized as the first meal of the day, providing essential energy intake and influencing cognitive performance, overall diet quality, nutrition status, cardiometabolic risk, and body weight. A balanced breakfast composition including cereals, semi-skimmed milk, and fruit was recommended (O'Neil, Byrd-Bredbenner, Hayes, Jana, Klinger, and Stephenson-Martin, 2014);

- Proper distribution of calories: it was advised to divide daily energy into three main meals and two snacks to avoid prolonged fasting, overconsumption, and to maintain metabolic parameters and body weight stability (Bellisle, Rolland-Cachera, Deheeger, and Guilloud-Bataille, 1988). Recommendations included allocating 20% of daily calories to breakfast, 40% to lunch, 30% to dinner, and 5% to each snack;
- Health condition: the study highlighted the importance of maintaining energy balance from an early age to prevent obesity. Children should understand that being healthy involves consuming the right amount of food in balance with daily activities (Guyenet & Schwartz, 2012);
- Healthy food vs. junk food: the negative effects of consuming ultra-processed junk foods, which are high in simple sugars, saturated fat, sodium, and low in nutrients, were emphasized. The study highlighted the risks associated with increased consumption of these products, particularly for the cardiovascular system (Khandpur, Neri, Monteiro, Mazur, Frelut, Boyland, Weghuber, and Thivel, 2020);
- Macronutrients and micronutrients: children should be educated about macronutrients (carbohydrates, fiber, fat, and protein) and micronutrients (vitamins and minerals). The functions and sources of each macronutrient were explained, highlighting the importance of a varied diet from different food groups;
- The Food Pyramid and the Healthy Plate: the food pyramid based on the Mediterranean diet was introduced to guide children in understanding which foods to consume daily, weekly, or occasionally (D'Alessandro, Lampignano, and De Pergola, 2019). The healthy plate concept was presented to illustrate the composition of a balanced meal, including sources of carbohydrates, protein, vegetables, and fruits, with extra virgin olive oil as a recommended addition.

"The story of Sofy": a story-based Adobe XD application

The interactive lesson for the digital gamification approach was based on a custom-made Adobe XD application (or rather, prototype). Adobe XD (Adobe Inc., 2023) is a software tool included in the Adobe Creative Cloud platform, specifically designed for User Experience (UX) and User Interface (UI) design. The application features two main modes: "Design" and "Prototype". The "Design" mode enables the definition of the UI elements, while the "Prototype" mode allows for the creation of an interactive user experience. In our study, we primarily utilized Adobe XD for the capability to generate high-fidelity interactive prototype. The prototype is instrumental in simulating and evaluating the desired digital experience. The tool was specifically designed for the desired educational activity, providing explanations of nutritional concepts, engaging children through active participation in the educational game, and fostering a sense of connection with the protagonist. The ludic elements are represented by sounds, animations, and the possibility of interactivity through buttons and micro-interactions.

Fig. 2 Some final screens of the digital prototype "The Story of Sofy"

Based on the fundamental concepts of nutrition education discussed earlier, the digital prototype presents the "Story of Sofy", a initially lazy child with incorrect eating habits (Fig. 2). As the story progresses, Sofy recognizes her errors and undergoes a transformative journey towards adopting proper nutritional practices. Within the narrative, Sofy grapples with the significance of main meals, the importance of not skipping breakfast, and the need for suitable snacks that support daily activities. She also gains knowledge about fundamental nutrition concepts, including distinguishing between "junk foods" and healthier options. Moreover, Sofy becomes familiar with the food pyramid, which guides her on selecting foods for regular (e.g., daily) or occasional (e.g., weekly) consumption based on essential food groups. The protagonist further learns to differentiate between macronutrients (carbohydrates, proteins, fats) and micronutrients (vitamins and minerals), culminating in an understanding of how to compose a nutritious dish with the right balance of these components. The significance of water intake and physical activity is also emphasized. This transformative journey shapes the eating habits of Sofy, facilitating the students learning process by allowing them to identify with the story's protagonist. This allows to avoid a more didactic and theoretical approach based on rote knowledge.

Proposed Technology Acceptance Model framework

In order to analyze user behavior and assess the level of acceptance towards the proposed technology, we employed the Technology Acceptance Model (TAM). TAM is an information systems theory introduced by Davis et al. (1989) and is based on the Theory of Reasoned Action (TRA). The TRA states that user behavior is influenced by the intention to perform it, which, in turn, is determined by a person's attitude and subjective norm regarding the behavior. Expanding on this theory, TAM posits that perceived ease of use (PEU) and perceived usefulness (PU) are crucial factors in predicting technology adoption, as they directly impact users' willingness to adapt to the technology. PEU refers to the belief that using a particular system is effortless, while PU refers to the belief that using the system will enhance user performance.

According to TAM, PEU and PU are influenced by external variables and collectively shape the intentions of users. The model incorporates two additional constructs: usage attitude, which reflects a user's perception of the desirability of using a specific information systems application, and behavioral intention to use, which gauges the likelihood of an individual actually using the application. TAM has gained widespread application across various contexts in recent decades (Xia, Zhang, and Zhang, 2018; Ferrara, Pierdicca, Balestra, Mignani, Frontoni, and Cavicchi, 2021), including the evaluation of gamification applications, as discussed in Sect. 2. Specifically, in the realm of human health, TAM has been utilized to assess how the gamification of health apps can provide users with a motivating and engaging experience to encourage the adoption of wearable devices for a healthier lifestyle (Spil, Sunyaev, Thiebes, and Van Baalen, 2017). Furthermore, TAM has proven useful in measuring the impact of digital gamification strategies in education and training (Vanduhe, Nat, and Hasan, 2020).

Based on the characteristics of the prototype, an evaluation was first conducted using seven questions to provide a summary assessment, as reported in Sect. 3.4. Additionally, six influencing factors were identified, namely Graphic aspects, Content clarity, Content originality, Usability, Acquired notions, and Story structure. The TAM was employed to examine the relationship between these factors and the two moderator variables, PEU and PU. The objective was to evaluate their impact on children's attitudes and intentions towards adopting other nutrition education apps, continued usage of the proposed app, and adherence to the acquired nutrition education concepts. To this end, six research hypotheses (H) were formulated:

- H.1: the characteristics of the prototype have an effect on PU;
- H.2: the features of the prototype have an effect on PEU;
- H.3: the features of the prototype positively influence the attitude towards continued app usage;
- H.4: the features of the prototype positively influence the intention to adopt other nutrition education apps;
- H.5: the characteristics of the prototype have a positive effect on the intention to comply with acquired nutrition education concepts;
- H.6: the attitude towards continued use of the prototype positively impacts the intention to comply with acquired nutrition education notions.

In summary, these were formulated to examine the effects of various prototype characteristics and features on children attitudes, intentions, and compliance with nutrition education concepts. By focusing on alternative hypotheses, we aim to uncover specific influences and relationships that may exist within the context of our study.

For each factor, its influence on three attitudes/intentions was analyzed according to the scheme shown in Fig. 3.

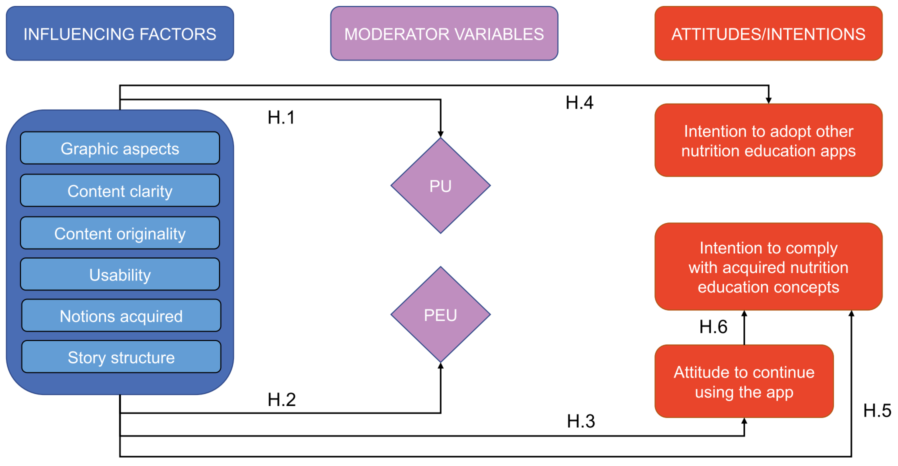

Fig. 3 Methodological framework for the digital evaluation of the prototype with TAM model. PU: Perceived Usefulness; PEU: Perceived Ease of Use

Data collection

Questionnaire "The importance of healthy habits"

The intervention group and control group both received a questionnaire administered through smartphones, tablets, and PCs before and after the intervention. In the classroom, nutrition education experts were present to provide clarification or address any questions regarding the questionnaire. The questionnaire was designed to evaluate participants' understanding of fundamental nutrition education concepts (see appendix A, Table 9). It consisted of 10 questions, with 9 being multiple-choice and the remaining one being a true/false question with 8 items. To assess the participants' level of nutritional knowledge, a cultural-nutritional Awareness Factor (AF) score was calculated by summing the scores assigned to each response (Rosi, Dall'Asta, Brighenti, Del Rio, Volta, Baroni, Nalin, Zelati, Sanna, and Scazzina, 2016). The AF score could range from 0 to a maximum of 26. For multiple-choice questions, incorrect answers received 0 points, while correct answers were awarded 2 points. True/false items were assigned 0 points for incorrect answers and 1 point for correct answers. The questionnaire was administered via Google Forms.

Questionnaires for digital prototype evaluation

The intervention group proceeded with the digital evaluation of the prototype using the TAM framework, as designed. According to a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), the first questionnaire assessed partecipants' levels of agreement or disagreement with the following seven questions:

1. Is the graphic design pleasing and appealing?
2. Do you feel the content is clearly displayed?
3. Do you feel the content is original?
4. Is the app easy to use?
5. Did the app help you discover nutrition education notions?
6. Do you feel that the app could replace a traditional lecture?
7. Do you feel that you could use a nutrition education app frequently?

A second questionnaire was used to analyze the influence of the six identified factors on three intentions/attitudes. Also in this case, each item was assessed using a Likert scale ranging from 1 to 5. Similarly, participants were once again administered the questionnaires via Google Forms.

Statistical analyses

The two-way analysis of variance (ANOVA) test was employed to examine variations in nutrition knowledge among and within groups prior to and following the standard nutrition lesson as well as the lesson with gamification. To evaluate differences pre- and post-interventions and between the two treatments, the post hoc Tukey test was utilized (Table 2). Within each group, the paired t-test was utilized to compare the average AF scores before and after the intervention. Furthermore, the unpaired t-test was employed to explore potential discrepancies in AF scores between genders within each group, both before and after the intervention (Table 3). Separate assessments of 2nd graders and 3rd graders were performed using ANOVA and post hoc Tukey test (Table 4). Statistical significance was determined by a p-value < 0.05 for all tests. Python programming language libraries such as Numpy, Scipy, and Seaborn were employed for data analysis.

Results

Analysis of the questionnaire "The importance of healthy habits"

A total of 126 questionnaires were examined, with 60 belonging to the control group and 66 to the intervention group using digital gamification. Pre-intervention nutrition knowledge scores (baseline, BL) is relatively low in both groups, as shown in the box-plot in Fig. 4. However, after the intervention (PI), there is a notable and statistically significant improvement in the nutrition knowledge scores for both groups.

AF scores for each group are presented in Table 2 as mean ± standard deviation. These values confirm a similar increase in nutritional knowledge for both groups: +5.1 AF score for control group (from 15.8 ± 4.5 to 20.9 ± 3.9), +5.3 AF score for gamification group (from 17.2 ± 4.4 to 22.5 ± 3.2). However, the ANOVA analysis revealed that there is no statistically significant difference in the increase of nutritional knowledge between the two groups ($p = 0.809$). Further analysis using the post hoc Tukey test indicates a significant difference within each group, comparing

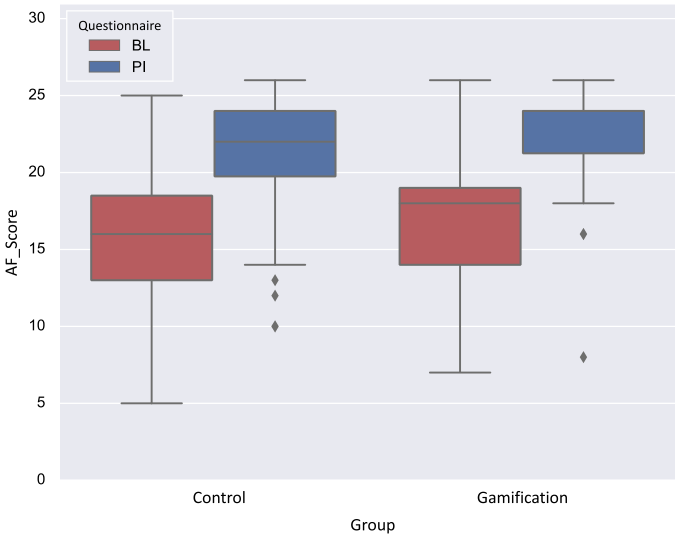

Fig. 4 Boxplot graph showing the distribution of awareness factor (AF) results by group (Control/Gamification) and questionnaire (pre-intervention [BL] and post-intervention [PI]). The median value is shown for each box

Table 2 Results of the questionnaire for the evaluation of nutrition education content

	Control (n=60)		Gamification (n=66)		
	BL	PI	BL	PI	p-value
AF score (max 26)	$15.8 \pm 4.5^{A,c}$	$20.9 \pm 3.9^{A,d}$	$17.2 \pm 4.4^{B,c}$	$22.5 \pm 3.2^{B,d}$	0.809

Awareness factor (AF) values are expressed as mean (mean) ± standard deviation (SD). P-value was determined by the two-way ANOVA test. Uppercase and lowercase letters indicate statistically significant and nonsignificant differences within and between groups, respectively, assessed by post hoc Tukey test. Significance is accepted for $p < 0.05$

Table 3 Questionnaire results for evaluation of nutrition education content expressed by gender

Group	Users	Frequency	BL	PI	p-Value
Control	Male	32	15.6 ± 3.9^{a}	20.4 ± 4.5^{b}	0.645^{a}
	Female	28	16.1 ± 5.2^{a}	21.5 ± 3.3^{b}	0.279^{b}
	Total	60	15.8 ± 4.5^{C}	20.9 ± 3.9^{C}	$< 0.001^{C}$
Gamification	Male	29	17.9 ± 3.9^{d}	22.7 ± 2.6^{e}	0.227^{d}
	Female	37	16.6 ± 4.7^{d}	22.4 ± 3.6^{e}	0.603^{e}
	Total	66	17.2 ± 4.4^{F}	22.5 ± 3.2^{F}	$< 0.001^{F}$

Awareness factor (AF) values are expressed as mean (mean) ± standard deviation (SD). Lower case letters a,b,d,e indicate non-significant difference between genders within each group (unpaired t-test). Capital letters C,F indicate significant differences within each group without regard to gender (paired t-test). Significance was accepted for $p < 0.05$

Table 4 Questionnaire results for the evaluation of nutrition education content expressed by class

	Control		Gamification		p-value
	BL	PI	BL	PI	
2nd grade	$14.7 \pm 4.2^{A,C}$	$20.1 \pm 4.0^{A,d}$	$17.1 \pm 4.4^{B,C}$	$21.8 \pm 3.9^{B,d}$	0.554
3nd grade	$18.7 \pm 4.3^{A,c}$	$23.1 \pm 3.0^{A,d}$	$17.3 \pm 4.5^{B,c}$	$23.0 \pm 2.5^{B,d}$	0.329

Awareness factor (AF) values are expressed as mean (mean) ± standard deviation (SD). P-value was determined by the two-way ANOVA test performed between groups for each class. Uppercase and lowercase letters indicate statistically significant and nonsignificant differences within and between groups assessed by post hoc Tukey test, respectively. Significance is accepted for $p < 0.05$

BL and PI scores ($p = 0.001$ A,B), but no significant difference is found between the groups either before ($p = 0.237$ c) or after the intervention ($p = 0.119$ d).

These findings are also supported by the paired t-test, which compared the mean AF scores before and after the intervention within each group ($p < 0.001$ C,F), as summarized in Table 3. Additionally, no significant differences are observed between genders within each group, both before and after the educational intervention.

After categorizing the participants into their respective grades, the results of the ANOVA analysis reveals no significant difference in the improvement of nutritional knowledge between the two groups. This lack of statistical significance is observed for both 2nd graders ($p = 0.554$) and 3rd graders ($p = 0.329$), as indicated in Table 4. However, when conducting the post hoc Tukey test, significant differences are found within each group between BL and PI assessments for both 2nd and 3rd graders. Additionally, significant differences are observed between the pre-intervention groups within the 2nd grade participants.

To determine the specific areas of improvement in nutritional knowledge following the interventions, we analyzed the frequency of correct responses for each question. Figure 5 clearly illustrates that the intervention utilizing digital gamification surpassed a 90% correct response rate for 11 out of 17 questions.

Table 5 provides a comprehensive assessment of the accuracy of responses for each question in both the control group and the intervention group with gamification. The results reveal the following:

- in 14 out of 17 questions, the intervention group utilizing digital gamification achieved a higher percentage of correct answers;
- in 10 out of 17 questions, the intervention group utilizing digital gamification exhibited a greater percentage increase in correct answers.

Although both groups demonstrated notable improvements in their nutritional knowledge, specific questions showed remarkable advancements. The control group witnessed a more than 100 percent increase in correct responses for questions Q4 and Q8, while the intervention group observed the same significant improvement for questions Q3 and Q7.

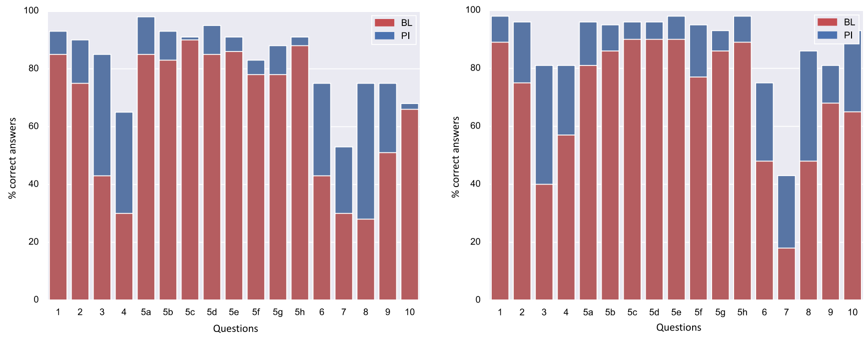

Fig. 5 Barplot chart showing the detailed rating of percentage correct answers for each question on the questionnaire in the **a** control group and **b** digital gamification group before (BL) and after intervention (PI)

Analysis of questionnaires for digital prototype evaluation

The assessment of the prototype acceptance involved analyzing the 66 questionnaires from the intervention group that participated in the digital gamification approach. The results, presented in Table 6, indicate a high likability score of 27.8 ± 4.2 out of a maximum of 35 points. Notably, females obtained the highest score (28.7 ± 4.1) compared to males (26.7 ± 4.1), and participants in 3rd grade

Table 5 Detailed evaluation of correct responses between the control group and participants who used the prototype. Results presented as frequency (percentage). Diff %: relative percentage difference. In italic the highest percentage value of correct PI responses for each question; in bold the highest relative percentage value for each question

Questions	Control (n=60)			Gamification (n=66)		
	BL	PI	Diff %	BL	PI	Diff %
Q1	51 (85)	56 (93)	9%	59 (89)	*65 (98)*	**10%**
Q2	45 (75)	54 (90)	20%	50 (75)	*64 (96)*	**28%**
Q3	26 (43)	*51 (85)*	96%	27 (40)	54 (81)	**100%**
Q4	18 (30)	39 (65)	**116%**	38 (57)	*54 (81)*	42%
Q5_a	51 (85)	*59 (98)*	15%	54 (81)	64 (96)	**18%**
Q5_b	50 (83)	56 (93)	**12%**	57 (86)	*63 (95)*	10%
Q5_c	54 (90)	55 (92)	1%	60 (90)	*64 (96)*	**6%**
Q5_d	51 (85)	57 (95)	**11%**	60 (90)	*64 (96)*	6%
Q5_e	52 (86)	55 (92)	5%	60 (90)	*65 (98)*	**8%**
Q5_f	47 (78)	50 (83)	6%	51 (77)	*63 (95)*	**23%**
Q5_g	47 (78)	53 (88)	**12%**	57 (86)	*62 (93)*	8%
Q5_h	53 (88)	55 (92)	3%	59 (89)	*65 (98)*	**10%**
Q6	26 (43)	45 (75)	**73%**	32 (48)	50(75)	56%
Q7	18 (30)	*32 (53)*	77%	12 (18)	29(43)	**141%**
Q8	17 (28)	45 (75)	**164%**	32 (48)	*57 (86)*	78%
Q9	31 (52)	45 (75)	**45%**	45 (68)	*54 (81)*	20%
Q10	40 (67)	41 (68)	2%	43 (65)	*62 (93)*	**44%**

(29.6 ± 3.6) expressed higher liking than those in 2nd grade (25.7 ± 4.0). The boxplot in Fig. 6 illustrates that 3rd grade females achieved the highest likability, whereas 2nd grade males recorded the lowest score.

Table 6 Results of the digital prototype evaluation questionnaire

Group	Frequency	Score
Male	29	26.7 ± 4.1
Female	37	28.7 ± 4.1
2nd grade	27	25.7 ± 4.0
3rd grade	39	29.6 ± 3.6
Total	66	27.8 ± 4.2

Score values (min 7 - max 35) are expressed as mean ± standard deviation (SD)

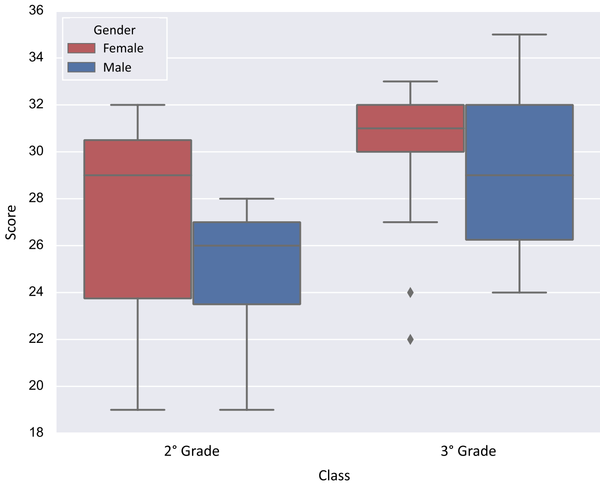

Fig. 6 Boxplot graph showing the distribution of prototype liking results by class and gender. The median value is shown for each box

Table 7 Results of the prototype summary evaluation questionnaire separated for each question, expressed as mean ± standard deviation (SD)

Questions	Score
1) Is the graphic design pleasing and appealing?	3.9 ± 1.1
2) Do you think the contents are clearly displayed?	4.1 ± 1.1
3) Do you think the content is original?	3.9 ± 1.0
4) Is the app easy to use?	4.0 ± 1.0
5) Did the app help you discover novel notions of nutrition education?	4.3 ± 0.9
6) Do you think the app can replace a traditional lecture?	3.6 ± 1.3
7) Do you think you could use a nutrition education app frequently?	3.8 ± 1.0

Score value ranges from a minimum of 1 to a maximum of 5

Fig. 7 Barplot chart showing the detailed rating of scores (in percentage) assigned to each question in the digital prototype evaluation questionnaire

To examine the influential factors of the prototype on the final evaluation, we analyzed the ratings assigned to each question. A comprehensive assessment of the scores for each question is presented in Table 7, depicting a range of values from a minimum average score of 3.6 (Q6) to a maximum score of 4.3 (Q5) out of 5. Figure 7 illustrates the findings through a bar plot, revealing that a majority of participants awarded a score of 4 (indicating agreement) or 5 (indicating strong agreement), especially for the initial five questions. Notably, question Q5 garnered the highest score, with a maximum peak of score 5 (60%). Conversely, the maximum peak of score 1 (representing strong disagreement) was observed for question Q6 (8%).

Table 8 presents the findings of the second questionnaire regarding users' acceptance of the prototype and its influence on their intentions to continue using

Table 8 Prototype user acceptance results for nutrition education, expressed as mean ± standard deviation (SD)

Influencing factors	Your intention to continue using the app would be positively affected by:	Your intention to download and use other nutrition education apps would be positively influenced by:	Your intention in complying with acquired nutrition education concepts would be positively influenced by:
Graphic aspects	4.0 ± 1.1	3.9 ± 1.1	3.6 ± 1.0
Content clarity	4.0 ± 0.9	3.8 ± 1.3	3.8 ± 1.1
Content originality	4.0 ± 1.3	3.8 ± 0.9	3.9 ± 0.9
Usability	3.5 ± 1.3	3.6 ± 1.3	3.4 ± 1.1
Acquired notions	**4.2 ± 0.8**	**4.0 ± 0.9**	**4.2 ± 0.9**
Story structure	3.7 ± 1.1	3.7 ± 1.2	3.6 ± 1.0

In bold is the highest mean score value for each intention. Score value ranges from a minimum of 1 to a maximum of 5 the prototype, adopt other nutrition education apps, and adhere to the acquired nutrition education concepts. The "Acquired notions" factor emerges as the most significant factor for each intention, consistently scoring above 4.0. Conversely, the "Usability" factor receives the lowest scores, with a minimum value of 3.4 related to the intention in complying with acquired nutrition education notions.

Discussions

Based on the analysis of the results, it is possible to evaluate the effectiveness of nutrition education interventions, employing either a traditional or digital gamification approach, in enhancing participants' understanding of proper eating habits. As indicated in Table 2, both interventions resulted in improved AF scores. The control group exhibited an increase of +5.1 AF (19.6%), progressing from 60.8% to 80.4% of the maximum AF score, while the digital gamification group showed a boost of +5.3 AF (20.4%), advancing from 66.1% to 86.5% of the maximum AF score. These results indicate a significant difference between pre- and post-intervention scores within each group, with the digital gamification approach yielding higher AF scores in absolute terms. This observation is further supported when examining individual question outcomes, as demonstrated in Table 5. The gamification approach not only led to a greater impact in absolute value but also resulted in a higher percentage increase in the number of correct responses.

However, the statistical analysis comparing the control group and the digital gamification group revealed that the use of the prototype did not lead to a statistically significant increase in AF when compared to the control intervention (as shown in Tables 2 and 3). This suggests that the impact of the prototype, in comparison to the standard lesson, was roughly equal. There are several possible reasons for this outcome. One factor could be attributed to the fact that the prototype, originally intended for independent use by the child, was instead utilized by a nutrition expert and projected to the children through an interactive whiteboard due to Covid-19 restrictions still in place at the time of data collection. This indirect utilization by the children may have diminished the effectiveness of the intervention, as indicated by the digital evaluation questionnaire where the usability factor received the lowest mean score among all user intentions (see Table 8).

In terms of gender differences, no significant variances were observed between genders within each group, both before and after the educational intervention (refer to Table 3). However, the intervention group showed the greatest increase in females (+5.8 AF). This finding aligns with the results of the digital evaluation, where females demonstrated the highest liking score, as depicted in Table 6 and Fig. 6. Even when dividing the overall sample into different grade levels, specifically 2nd graders and 3rd graders, there were no statistically significant differences in the increase in nutritional knowledge between the control and intervention groups. However, the post hoc Tukey test has identified a statistically significant difference between the pre-intervention groups in the 2nd grade (see Table 4). One potential explanation for this finding is that a considerable proportion of students in the intervention group had previously received nutrition education classes (48

%), as indicated in Table 1. Consequently, the study had a limitation in terms of sample heterogeneity regarding prior knowledge, since the summer center children came from various schools. Nonetheless, the utilization of a digital gamification approach resulted in a noteworthy increase of +4.7 AF among the participants.

With regard to children's acceptance of the digital gamification prototype, the results indicate that the acceptance of the tool is primarily influenced by the usefulness ("Acquired notions") and the originality and clarity of the information provided. The intention to continue using the application, explore other nutrition education apps, and adhere to the acquired knowledge are all mostly influenced by these factors (refer to Table 8). Consequently, the analysis reveals that the characteristics of the prototype primarily impact the PU (H.1). The emphasis placed on the content's usefulness, rather than the visual aspects or other intrinsic features like the story structure, underscores the crucial role of new technologies and a digital approach in effectively conveying nutrition education concepts, extending beyond mere gaming purposes.

The discussion on the moderator variable PEU (H.2) should be addressed separately. While a high score was achieved in Q4, "Is the app easy to use?" (Table 7), the influence factor associated with "Usability" received the lowest scores compared to all other intentions (Table 8). This discrepancy may be attributed to the lack of direct user interaction with the prototype, as mentioned earlier. Furthermore, the absence of active participation from the children resulted in a greater disparity of responses in Q6, "Do you think the app can replace a traditional lesson?". Some participants explicitly expressed how the lesson felt too "static" compared to a traditional lesson with a teacher.

Overall, the positive attitude towards using the app, influenced by a combination of influencing factors and moderating variables, played a specific role in shaping the intention to adhere to the acquired concepts of nutrition education (H.5).

Thus, the proposed TAM framework aimed to identify the elements that had a greatest impact on the success of the learning experience based on digital gamification. However, only the actual impact of intrinsic influencing factors belonging to the prototype was analysed. As a future work, the framework could be modified by incorporating the evaluation of factors directly related to the comparison between digital and traditional approaches. This adjustment will allow to identify specific elements that emerge as key drivers also with respect to traditional learning.

Conclusion

The purpose of the present study was to evaluate whether a digital gamification approach could support the learning of nutrition education concepts in elementary school and whether it might be able to improve its effectiveness over a classical teaching approach. Additionally, the study aimed to investigate how the intervention influenced participants' understanding of healthy eating habits and their acceptance of the digital prototype as an effective educational tool, utilizing a novel Technology Acceptance Model (TAM) framework specifically designed for this study.

Based on the analysis of data collected from 126 children aged 7 to 8 years, the findings demonstrate that the prototype developed with AdobeXD software has the potential to effectively engage children in learning about nutrition education concepts, leading to significant improvements in their overall knowledge. However, the study did not find a significant difference compared to a standard nutrition education intervention. Several factors may have contributed to this outcome, including the limitations of the study design, such as the inability of children to directly use the prototype due to Covid-19 restrictions. Moreover, the study was conducted in a summer center rather than a school setting, resulting in a lack of uniform prior knowledge among the participants, as they came from different schools.

To further advance this research, future studies should evaluate the prototype in a school environment for two primary reasons: firstly, to ensure a sample with consistent prior nutritional knowledge, and secondly, because classroom settings are more conducive to attentiveness and comprehension of new concepts compared to leisure-oriented contexts like summer centers. Additionally, allowing users to independently interact with the digital prototype using devices like smartphones or tablets would provide a more autonomous and immersive learning experience for the children.

Appendix A Questionnaire "The importance of healthy habits"

Table 9 Questionnaire and scores "The importance of healthy habits" to determine the cultural-nutritional awareness factor (AF)

Questions	Answers (Score)
Q1) What happens if we don't have breakfast?	·Nothing, we snack anyway (0)
	·We lack energy and concentration to start the day (2)
	·We can better enjoy a super snack (0)
Q2) What gives you the most energy to get through the day?	·Have breakfast with yogurt, cereal and a fresh fruit (2)
	·Have breakfast with a packaged snack (0)
	·Don't have breakfast but have a snack (0)
Q3) How many meals do we have to have each day?	·5, including 3 main ones (breakfast, lunch and dinner) and 2 snacks (2)
	·Only breakfast, lunch and dinner (0)
	·Breakfast, lunch, dinner and snack at school (0)
Q4) We stay healthy when:	·We eat more food than we consume (0)
	·What we eat is equal to what we consume (2)
	·We eat less than we consume (0)
Q5) It is a junk food:	
a. French fries	·True (1) ·False (0)
b. Hot-dog	·True (1) ·False (0)
c. Banana	·True (0) ·False (1)
d. Coca-cola	·True (1) ·False (0)

Table 9 (continued)

Questions	Answers (Score)
e. Salad	·True (0) ·False (1)
f. Pasta with tomato	·True (0) ·False (1)
g. Sweets	·True (1) ·False (0)
h. Peas	·True (0) ·False (1)
Q6) What is the purpose of the Food Pyramid?	·Helps us understand, starting from the bottom, what foods to consume every day, in the week and every so often (2)
	·Helps us understand, starting from the top, which foods to consume every day, in the week, and every so often (0)
	·Represents a complete meal (0)
Q7) What is the purpose of the Healthy Plate?	·It tells us what foods and how often we should eat them each day in the week (0)
	·It serves to compose the meal of lunch and dinner (2)
	·It is used to learn about foods (0)
Q8) Where are the carbohydrates found?	·Meat (0)
	·Fish (0)
	·Bread (2)
Q9) Eggs, milk, legumes, meat and fish provide mostly:	·Carbohydrates (0)
	·Proteins (2)
	·Fats (0)
Q10) Why is it important to drink water?	·Because it contains sugar which give us energy for the day (0)
	·Because it contains minerals that are important for our body to function well (2)
	·To swallow food better (0)

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Data Availibility Statement The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethical statement We affirm that this manuscript is the product of our original work, incorporating feedback from reviewers. This manuscript does not include any research findings previously published or authored by others. We are the sole authors of this manuscript, and we accept full legal responsibility for the accuracy and integrity of this statement.

Consent to participate Written informed consent obtained from all the participants.

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