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Race Against Diabetes: development and validation of a serious game prototype for school-based health education

Corrida contra o diabetes: construção e validação de protótipo de jogo sério para educação em saúde no ambiente escolar

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Abstract: The global rise in the incidence of diabetes mellitus, particularly among children and adolescents, highlights the need for innovative educational strategies in school settings. Serious games have proven promising for improving self-care and preventing complications by combining playfulness with evidence-based content. This methodological study was conducted in two phases: the development of the digital prototype Race Against Diabetes and its validation with experts (n = 6) and the target population (n = 20, aged 11–14). The content adhered to the ADCES7 guidelines and those of the Brazilian Diabetes Society and was assessed using the CVC, I-CVI, S-CVI/AVE, binomial test, and a Likert-based usability scale. The game is a 2D title developed in Unity/C++, featuring five levels focused on collecting healthy foods and learning about self-care. It achieved an S-CVI/AVE of 0.87, with some items showing a minimum I-CVI of 0.66 ($p > 0.05$). Usability was rated as satisfactory (mean score: 9.3 ± 2.65), with participants highlighting motivation, clarity, and learning. Race Against Diabetes shows strong potential as a pedagogical tool in health education, promoting knowledge and self-care skills through interactive gameplay. The pixel art design, chosen by students, further enhances engagement. Expansion to other platforms and long-term clinical impact studies are recommended.

Keywords: Diabetes Mellitus, Educational Games, Self-Management, Health Education, Adolescents.

Resumo: O aumento global da incidência de Diabetes Mellitus, especialmente entre crianças e adolescentes, destaca a necessidade de estratégias educativas inovadoras no ambiente escolar. Jogos sérios têm se mostrado promissores para aprimorar o autocuidado e prevenir complicações, ao combinar ludicidade e conteúdo científico direcionado. Realizou-se pesquisa metodológica em duas fases: desenvolvimento do protótipo digital «Corrida contra o diabetes» e validação com especialistas (n=6) e público-alvo (n=20, 11–14 anos). O conteúdo seguiu as diretrizes ADCES7 e da Sociedade Brasileira de Diabetes, e foi aferido por CVC, I-CVI e S-CVI/AVE, além de teste binomial e usabilidade baseada em escala Likert. O jogo é um título 2D em Unity/C++, com cinco fases de coleta de alimentos saudáveis e informações sobre autocuidado. Obteve S-CVI/AVE de 0.87 e I-CVI mínimos de 0,66 em alguns itens, todos com $p>0.05$. A usabilidade foi avaliada como satisfatória (média 9,3±2.65), destacando motivação, clareza e aprendizagem. «Corrida contra o diabetes» demonstra viabilidade como ferramenta pedagógica em saúde, promovendo conhecimentos e habilidades de autocuidado de forma interativa. O design pixel art, escolhido pelos alunos, potencializa o engajamento. Recomenda-se expansão para outras plataformas e estudos de impacto clínico a longo prazo.

Palavras-chave: Diabetes mellitus, Jogos educativos, Autogerenciamento, Educação em saúde, Adolescentes.

1. Introduction

The rising incidence and prevalence of diabetes mellitus (DM) have made it a global public health concern, with significant financial, health, and quality-of-life implications (International Diabetes Federation, 2022). In 2022 alone, approximately 201,000 new cases of type 1 diabetes mellitus (T1DM) were diagnosed in individuals under the age of 20, placing Brazil third worldwide in childhood and adolescent T1DM cases (International Diabetes Federation, 2022). In this context, schools—where children and adolescents spend much of their time and undergo cognitive, social, and cultural development—are considered key environments for health promotion, particularly for disease prevention and management. However, when aligned with the traditional biomedical model, schools have had limited success in fostering behavioral changes that support a healthier lifestyle (Mourão, 2023).

Therefore, the school setting should serve as a space for providing information, fostering learning, and supporting both children and adolescents—whether or not they have a diabetes diagnosis—in preventing disease and promoting health. It also plays a critical role in ensuring continuity of care and self-management practices, which can positively influence students' health outcomes and overall quality of life (Lee et al., 2020).

Against this backdrop, the use of educational technologies through collaborations between the education and health sectors, as well as multidisciplinary approaches to diabetes, has become a promising strategy to help children and adolescents learn about the condition. These tools can improve quality of life, reduce complication rates, and lower healthcare costs (Cobas et al., 2022). Serious games have increasingly been used in both education and healthcare as collaborative teaching strategies that promote students' skill development, autonomy, and competency building (Maskeliūnas et al., 2020). Clark C. Abt (1987) was the first to define serious games as those that go beyond entertainment, incorporating a clearly defined educational purpose. These games are designed with specific learning objectives and are used across various contexts, including schools, healthcare settings, professional training, and the simulation of real-life situations. While inherently playful, their core goal is to promote learning, enhance competencies, and foster critical thinking. As such, serious games function as tools for pedagogical and social interventions (Abt, 1987).

Serious games stand out as an educational technology in both school and healthcare settings, especially for children and adolescents. These games move beyond entertainment by delivering targeted, health-focused content and are used in teaching and learning processes to develop cognitive, psychomotor, and behavioral skills (Lima & Otero, 2024). The authors also emphasize that in pediatric contexts, serious games support treatment adherence for chronic conditions, reduce anxiety during medical interventions, and promote psychomotor development. In addition, Novák (2023) argues that involving children and adolescents in the development of a game about T1DM increases acceptance and engagement by making the content more accessible and better adapted to the specific needs of this population.

In health education, serious games have shown positive results, particularly when used in school-based educational campaigns, as they improve health literacy and

promote healthy behaviors among children and adolescents (Ancona et al., 2024). According to Liu et al. (2024), these games also encourage physical activity, especially when incorporated into ongoing interventions. Thus, serious games have proven to be valuable educational tools for addressing challenges in public health and education.

At both elementary and higher education levels, serious games have contributed to the development of cognitive, emotional, and social competencies. Studies indicate that when children and adolescents engage with well-structured serious games, they enhance critical thinking, creativity, and autonomy (Papanastasiou, Drigas & Skianis, 2022). In higher education, such games are used to foster meaningful learning on complex subjects (Celestini, 2020).

In health education, serious games are also used for professional training and patient care. Evidence shows that these tools increase students' confidence and health literacy, in contrast to traditional methods (Maheu-Cadotte et al., 2020). In pediatric contexts, they contribute to improved treatment acceptance, better mental health, and psychomotor development (Lima & Otero, 2024). As such, serious games are promising educational technologies that integrate health, education, and digital innovation.

Given this context, developing diabetes-focused games is expected to provide young people with knowledge about the disease, including its causes, symptoms, complications, treatment, and self-care practices. These tools can help promote health, prevent complications, encourage self-care, and improve quality of life. Reducing diabetes-related complications is particularly urgent, as they impose significant costs on Brazil's public health system. This study aimed to describe the development and validation of a serious game as an educational technology for diabetes education targeting children and adolescents.

2. Method

This was a methodological study conducted in two phases: (1) development of the digital game and (2) validation of the digital game with experts and the target population.

2.1. Development of the digital game

The game development process began with a needs assessment of the target audience, conducted through a field study at Municipal School Professora Maria Gondim dos Santos, located in Fortaleza (Ceará, Brazil).

A convenience sample of 20 students was selected, comprising five from each grade level (6th through 9th grades) of lower secondary school. As noted by Rehman et al. (2021), sample size may vary depending on the study objective. Small groups are effective in exploratory analyses, particularly when data are collected through observations and interviews. This sampling approach has also been applied in the validation of educational technologies to obtain direct feedback from the target audience (Mondellini et al., 2023). Initially, students were invited to participate and were provided with an Informed Consent Form (ICF) for children and adolescents, as well as an Assent Form for parents or legal guardians. A semi-structured questionnaire

was then administered, consisting of sociodemographic data and 12 questions related to diabetes.

The data collected were analyzed qualitatively and used in the actual game development phase. The participants' prior knowledge, perceived needs, and preferences regarding features considered appealing in a digital game served as the foundation for designing the serious game (Savi et al., 2010; Dabbs et al., 2009). The scientific content on diabetes was based on the seven self-care behaviors proposed by the American Association of Diabetes Educators (AADE) (Kolb, 2021) and the Guidelines of the Brazilian Diabetes Society (2022).

The game prototype was developed by a multidisciplinary team of professionals from the fields of health, education, information systems, and serious game development. The game was designed as computer-based software using simulations and iterative testing to improve functionality and ensure smooth gameplay. Development followed the four-phase process outlined by Chandler (2012): preproduction, production, testing, and post-production.

In the preproduction phase, the game concept, requirements, and planning were established. The production phase involved the development of programming, visual assets, audio components, and code, thereby building on the initial prototype. This stage also included the implementation of the preproduction report, which identified issues to be addressed (Chandler, 2012; Cruz-Cunha, 2013). Students participated in selecting the visual design elements, the game's title, and the main character's name. After this stage, the code was released for testing.

In the testing phase, the interface and programming were finalized, and alpha, beta, and gold versions were developed. In the alpha version, the development team tested functionality. The beta version addressed issues identified during alpha testing. The final gold version was submitted for expert validation in the field of diabetes (Chandler, 2012; Cruz-Cunha, 2013; Novak, 2012, 2024). Finally, during the post-production phase, a usability evaluation was conducted with the target audience.

2.2. Validation of the digital game by experts and the target audience

To assess content and face validity, eleven diabetes experts were invited to participate, of whom six completed the questionnaire. According to Pasquali (2013), six is an adequate number for this stage. Expert selection followed the criteria proposed by Jasper (1994). Searches on the Lattes Platform were conducted to confirm that the selection criteria had been met. Formal invitations were sent via email, and upon acceptance, participants were provided with the Informed Consent Form (ICF), an expert characterization form, screenshots of the game, and a link to the evaluation instrument via an online form.

The evaluation tool, adapted from Francisco (2019), included 14 questions distributed across three domains: content, language, and appearance. Each item had four response options on a Likert scale: (4) Strongly agree, (3) Agree, (2) Disagree, and (1) Strongly disagree. An open field was also provided for comments and suggestions aimed at improving the serious game. The original instrument consisted of 10 questions and had been developed to evaluate and validate a memory game on

leprosy. The adaptation consisted of replacing the term leprosy with diabetes and adding questions related to design, illustrations, and color choices in the game.

Data analysis was based on the Content Validity Coefficient (CVC), which measures the degree of agreement among experts. The CVC indicates the proportion of items rated as 3 or 4 by the panel of judges. Suggestions and proposed changes were reviewed and, when relevant, implemented (Polit & Beck, 2019).

For the analysis of the experts' responses, the Item-level Content Validity Index (I-CVI) and the Scale-level Content Validity Index using the Average Calculation Method (S-CVI/AVE) were calculated, with a minimum acceptable threshold of 0.78 (Polit & Beck, 2019). The exact binomial test was also performed, appropriate for small samples, considering a p-value greater than 0.05 and an agreement rate of 0.8 among the judges. Data were analyzed using Jamovi software (version 2.6). Usability was then assessed to evaluate the human–computer interaction, aiming to improve task performance, user comfort, and operability, thereby ensuring the quality of the interaction and software functionality (Castro et al., 2015). This phase was conducted at Professora Maria Gondim dos Santos School during science classes taught by the researcher, in Fortaleza, Ceará, Brazil, in November 2023.

The researcher's laptop was used to run the game. Initially, the opening screen was displayed, showing three command buttons: «Play» to start the first level of the game, «How to Play» to access the tutorial screen (game rules), and «Exit» to end the game. Next, participants were instructed to first access the tutorial and then start the game. After playing, each student completed the evaluation instrument. The game was tested by 20 children and adolescents aged 11 to 14, enrolled in lower secondary education and selected through convenience sampling. This moment proved highly enriching, as students showed strong engagement while playfully learning about health.

Usability was assessed individually using an evaluation instrument designed to determine whether the game fulfilled its intended goals of playability and learning construction. The instrument was based on the educational game evaluation model proposed by Savi et al. (2010) and contained nine questions. Scores ranged from 1 to 5 (unsatisfactory) and 6 to 10 (satisfactory). The criteria assessed included student motivation to use the educational game, the relationship between learning and fun, the quality of the game's illustrations, and the likelihood of students recommending it to peers. Suggestions provided during the usability evaluation may be incorporated into future versions of the educational technology, with support from an IT professional.

The Research Ethics Committee of the State University of Ceará (UECE) approved the study under number 6.272.309 and CAEE 68625323.7.0000.5534.

3. Results

3.1. Development of the digital game

During the needs assessment stage, it was found that most students defined diabetes as a disease that increases blood sugar levels and were unfamiliar with its symptoms,

causes, treatment, complications, and prevention. This information was used during the development phase to design an interactive, fun, and educational game set in everyday scenarios.

In the conceptual phase, the decision was made to create a digital serious game, designed to educate, train, and promote behavior change by presenting specific content in a playful and engaging way (Lima & Otero, 2024). The game design outlines all the components of the game, including gameplay, design, interface, characters, levels, and all features to be used throughout the experience. It provides a detailed description of the gameplay.

Following multidisciplinary team meetings and a literature review conducted during the planning stages, a storyline was developed based on environments from the daily lives of the target audience, to encourage positive decision-making to stay healthy and maintain blood glucose within target levels. Racing Against Diabetes (Corrida contra o Diabetes) is an original proposal, entirely conceptualized and developed by the authors based on educational objectives defined for the target audience. It is a standalone game created from scratch and categorized as a serious game for health education in the school setting. Its visual and functional elements were inspired by styles commonly found on open-source digital game platforms, which were consulted solely for exploratory analysis of aesthetics, design, and style in order to identify usability practices, accessible mechanics, and visual elements suitable for children and adolescents. However, it is important to emphasize that Race Against Diabetes features its own storyline, educational objectives, gameplay mechanics, and distinctive resources, and should not be regarded as an adaptation or modification of any pre-existing game.

The development of the Game Design Document was guided by the following components:

- Mechanics: This is a movement and item-collection game. The main character, named Dimi, moves through the environment to collect healthy foods while avoiding the villain (sugar). The gameplay includes a scoring system and interactive variables. The energy bar (representing blood glucose) must remain full by collecting healthy items. Collecting unhealthy items does not add points and also slows down Dimi's speed. If the energy bar becomes empty, the round ends. During each timed level, the player must achieve the required score and keep the energy bar above the minimum threshold before the countdown reaches zero. Contact with the villain temporarily reduces Dimi's speed. When pressing the «Z» key, informational speech bubbles appear, and the player interacts with characters who share information about diabetes and the seven self-care behaviors. An interactive soundtrack, along with reward and alert sounds, is triggered during collection, reinforcing desired behaviors. The game features five levels in which the main character (Dimi) runs through different environments. Movement is controlled using the «W» (up), «S» (down), «A» (left), and «D» (right) keys.

- Narrative: The game developed in this study is titled Race Against Diabetes, and the main character, Dimi, was named using the first syllables of diabetes mellitus. The target audience selected both the game's title and the main character's name during the first phase of the study. The game's narrative also includes seven friends who serve as supporting characters and one villain representing sugar

(hyperglycemia). Familiar everyday settings were chosen for the game scenes to resonate with the target audience. Dimi runs through various urban environments collecting healthy foods to refill his energy bar (glucose) while fleeing from the villain. Along the way, friends appear and interact with him, teaching him about the seven diabetes self-care behaviors. The goal is to foster learning around self-care, self-management, and diabetes control.

- Game strategy: The game was developed in 2D using the Unity game engine and programmed in C++, one of today's most widely used programming languages. Unity is a popular engine for developing 2D and 3D games, offering a robust and stable ecosystem that is highly compatible with various operating systems (Windows, macOS, Linux), thus ensuring broad accessibility for schools and end users. Its user-friendly interface also facilitates object, scene, and script management, which proved essential for rapid and iterative prototyping, particularly valuable in educational projects requiring ongoing testing with the target audience (Kohli et al., 2024). Unity is widely adopted by developers and features extensive repositories of assets and tools, providing continuous support and speeding up development. The use of C++ in combination with Unity's modular architecture enabled the creation of sophisticated game logic, allowing control of variables such as time, score, interactions, penalties, and individual player progress. It also made it easier to integrate pixel art graphics—an artistic style chosen for its strong visual appeal among children and adolescents (Aleksić & Simeunović, 2024). Lastly, Unity is recognized for performing well even on lower-end machines, ensuring the game can be played on school computers without requiring high processing capacity (Singh & Kaur, 2022; Gazis & Katsiri, 2023).

- Gameplay: The game consists of five levels in which points are awarded for each healthy food item collected. This point system acts as a reward and incentive to promote healthy habits and long-term behavior change. In the top corner of the screen, an energy bar (glucose) fills up as healthy items are collected and must be kept full to maintain controlled energy levels. Players advance to the next level upon reaching 200 points within the allotted time. Around ends in failure if the energy bar runs out or if the required 200 points are not reached before time expires. Additional information about the seven self-care behaviors in diabetes is presented through the interaction button to promote meaningful learning.

- Design: A 2D pixel art style was chosen for its emotional appeal, creating a sense of empathy through characters and visual elements that resonate with players. This feature supports meaningful learning (Bao, 2022; Aleksić & Simeunović, 2024). The graphic elements, created by a professional designer, were presented to researchers and participants, who provided feedback and suggestions. The soundtrack was selected to enhance the game's dynamics and align with the expectations and interests of the target audience. Race Against Diabetes stands out from other diabetes-related games due to its genre, design, presentation approach, and the way it delivers content. The game fosters agility and motor coordination as players collect food and reinforces the idea that only healthy foods earn points, which is crucial for glucose control. The 2D pixel model was chosen to build this serious game, featuring simple and engaging illustrations commonly used in games enjoyed by the target audience (Aleksić & Simeunović, 2024). The visuals are playful and appealing, reflecting everyday life for children and adolescents. Game scenes were based on daily settings relevant to the target audience. Some of these

represent self-care behaviors and feature a vibrant, colorful, and playful palette. In terms of text, distinct colors were used for the main character and villain, differing from those assigned to the supporting characters. The start screen of Race Against Diabetes displays one of the game environments and includes three command buttons: «Play» to start the first level, «How to Play» for the game instructions, and «Exit» to stop playing.

Figure 1. Start menu «Race Against Diabetes».

3.2. Validation of the digital game with experts and the target audience

During the validation phase, six experts—all women and nurses—participated, with a mean age of 43.5 ± 9.3 years and an average of 21.1 ± 9.2 years since graduation. All reported holding both a graduate certificate and a master's degree; half (3) had completed a PhD, and one was currently pursuing doctoral studies. They had professional experience in clinical care, teaching, and diabetes research, with an average of 17.8 ± 6.9 years in the field.

The serious game Race Against Diabetes achieved a satisfactory overall content validity index (S-CVI/AVE = 0.87), with the highest scores in the content domain, followed by language and appearance. The items «the illustrations stimulate students' interest» and «the text colors are appropriate and facilitate reading» received the lowest individual ratings (I-CVI = 0.66), possibly due to the experts' limited familiarity with the pixel art style. All items had p-values > 0.05.

The suggestions made by the experts were incorporated to enhance the game's clarity and functionality for teaching and learning, including sentence restructuring for better comprehension, standardizing the word «diabetes» in the masculine form, using the abbreviations DM1 and DM2, adding periods to all sentences, and replacing «YOU LOST» with «Not this time» when the game objectives are not achieved.

Table 1. Validation of the digital game Race Against Diabetes. Fortaleza, CE, Brazil, 2023.

Validation of the digital game	CVI	p-value*
Content	0.97	
The game's content is appropriate for the target audience.	0.83	0.738
The content presents the topic of diabetes in a clear and straightforward manner.	1	1.000
The content is suitable for children and adolescents.	1	1.000
It helps answer questions about the topic.	1	1.000
It enhances knowledge in this field.	1	1.000
It encourages reflection on the topic.	1	1.000
Language	0.87	
The language used is easy for children and adolescents to understand.	1	1.000
The illustrations stimulate students' interest.	0.66	0.345
The language supports student learning.	1	1.000
The game rules are clear and easy to understand.	0.83	0.738
Aparência	0.83	
The text colors are appropriate and make reading easier.	0.66	0.345
The visual design is suitable and engaging for children and adolescents.	1	1.000
The shapes and colors of the illustrations are well-suited to this type of material.	0.83	0.738
The illustrations are appropriate for the type of material and the target audience.	0.83	0.738
Overall CVI	0.87	

p-value* binomial test

Following expert evaluation, the target audience assessed the game in a usability test and rated it as satisfactory (mean score = 9.3 ± 2.65). The domains of motivation, clarity, satisfaction, and learning all received excellent scores, ranging from 9.1 to 9.6. Based on the positive feedback from the target audience and the widespread appeal of the pixel art style among children and adolescents, the team decided to maintain the colorful and visually engaging design.

4. Discussion

Race Against Diabetes is a fun and engaging game designed to educate players about diabetes. This serious game, developed for diabetes education, was conceived as a pedagogical strategy to enhance attention span, foster problem-solving skills, creativity, and motivation, and encourage social interaction among students (Maskeliūnas et al., 2020). Video games promote learning playfully, increasing children's and adolescents' interest in and motivation for learning.

The seven self-care behaviors in diabetes comprise a robust framework for diabetes education and self-management support aimed at behavior change and improved clinical outcomes. Proposed by the Association of Diabetes Care and Education Specialists (ADCES7) (Kolb, 2021), these behaviors—healthy coping, healthy eating, being active, taking medication, monitoring, reducing risks, and problem-solving—demonstrate that improvements in learning, behavior, clinical outcomes, and

the effective use of technology can enhance both health outcomes and quality of life for people with diabetes. For this reason, the framework was used as a foundation in the game's development.

According to Makhlysheva (2013), the goals of serious games for diabetes are based on three pillars: nutrition, self-management, and physical activity. The game developed in this study, Race Against Diabetes, primarily focused on nutrition and information-sharing about diabetes. This focus was selected because students in school settings tend to choose unbalanced, ultra-processed foods and fast food. These eating habits often contribute to poorer outcomes in type 1 diabetes and increase the risk of obesity and type 2 diabetes in children and adolescents.

Race Against Diabetes is innovative in its format as a digital game, adopting a pixel art design similar to games created solely for entertainment, such as Minecraft, Stardew Valley, Terraria, and Dave the Diver, among others, commonly played by children and adolescents. This visual style evokes emotional responses in players, fostering greater engagement, interaction, concentration, and attraction to the game (Aleksić & Simeunović, 2024; Bao, 2022). This characteristic supports the meaningful learning proposed by the game, which features engaging and playful illustrations commonly used in entertainment games and closely tied to the everyday lives of children and adolescents.

The pixel art design style, although classic, remains widely used by digital game developers due to its practicality and aesthetic appeal. Pixels are points of light that form the visual structure of characters and scenarios in games (Silber, 2016).

Developing an educational game requires detailed planning, including script definition, gameplay elements, game phases, and graphic design, to ensure functionality (Machado et al., 2009). Therefore, the involvement of experts in health, education, and information technology, as well as the participation of the target audience, was essential. This collaboration has enabled the creation of a technology that is aligned with the target audience's real-life context, demonstrating strong usability and acceptability.

Behavioral changes among people with diabetes that result from the use of serious games stem from progressive learning and improved health literacy, as individuals gain knowledge about the disease and incorporate self-care and self-management practices (Oliveira, 2021). Thus, the game is expected to support the development of new skills and competencies in people with diabetes, contributing to better health outcomes and quality of life.

5. Conclusion

This study had some limitations, including the small number of experts who returned the evaluation instrument, the inability to provide them with access to the serious game for gameplay testing, and the restricted availability of the game on other platforms, limiting access for a broader audience of children and adolescents.

The educational serious game Race Against Diabetes offers an innovative approach to health learning. As an interactive and motivating tool, it elicits an

emotional response in players and aims to promote behavior change toward healthier living.

This research describes the development of the serious game Race Against Diabetes, which followed a rigorous methodological process and demonstrated satisfactory evidence of content and face validity, as well as positive usability ratings from the target audience. The game shows strong potential to support meaningful learning about diabetes mellitus by promoting the dissemination of information and encouraging the acquisition of knowledge, attitudes, and practices playfully related to health.

The game can be used both in and outside of the school setting, in public or private education systems. Furthermore, this study underscores the need for increased investment and collaboration between the health and education sectors, along with follow-up studies to assess outcomes such as knowledge, self-care behaviors, and clinical outcomes.

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