Research article

A mobile serious game about diabetes self-management: Design and evaluation

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ABSTRACT

Type 2 Diabetes Mellitus (T2DM) is a chronic condition that requires ongoing self-management and education. In recent years, there has been a growing interest in utilizing mobile serious games as a tool for patient education and engagement. This article presents the development of DiaPo, a mobile serious game designed to improve self-management education for patients with T2DM. DiaPo integrates gamification techniques to increase patient engagement and motivation while providing essential information about disease management. The development of DiaPo followed a structured design process, utilizing the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) educational system. This systematic approach allowed for the integration of best practices in educational game design and diabetes care. The development team consisted of experts in medical informatics, game design, and diabetes care, ensuring a multidisciplinary approach to the game's creation. The game's narrative focuses on a T2DM patient who earns positive points for making healthy lifestyle choices and negative points for poor ones. This gamified approach aims to reinforce positive behaviors and provide immediate feedback on negative ones. Interactive animations confirm or deny options selected by the player, further enhancing the learning experience. DiaPo offers a flexible and adaptable platform suitable for diverse audiences, promoting inclusiveness and accessibility in T2DM education. DiaPo represents a novel approach to self-management education for patients with T2DM, utilizing gamification techniques and a multidisciplinary design process to create an engaging and informative mobile serious game. By promoting inclusiveness and accessibility, DiaPo has the potential to empower patients with T2DM to take an active role in their disease management. As the field of mobile serious games continues to evolve, DiaPo stands as a promising tool for improving T2DM education and patient outcomes.

1. Introduction

The increasing prevalence of Type 2 Diabetes Mellitus (T2DM) globally has resulted in a significant burden on healthcare systems

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and individuals [1]. Self-management education is a critical component of T2DM care, empowering patients to take control of their condition and make informed decisions about their health [2]. However, traditional educational approaches may not always effectively promote sustained behavior change due to lack of engagement [3,4]. Consequently, there is a growing interest in utilizing technology, such as mobile serious games, to deliver self-management education in a more interactive and accessible manner [5–7].

This article is part of a PhD thesis in medical informatics focusing on the development of a mobile serious game (DiaPo) designed to educate T2DM patients about self-management. The aim of this research is to explore the potential of serious games as a tool for enhancing patient education and promoting behavior change in the context of T2DM.

The design of the serious game is informed by principles of user-centered design, behavior change theory, and evidence-based practices in diabetes education [8–10]. By integrating these elements, the game aims to provide an engaging and effective platform for delivering self-management education to T2DM patients [11,12]. Accessible on mobile devices, the game allows patients to engage with the educational content at their convenience, overcoming barriers of time and location [13,14].

In addition to leveraging technology, gamification will play a key role in the design of the serious game [15,16]. Gamification involves incorporating game-design elements and principles into non-game contexts to enhance engagement, motivation, and participation [17–21]. By incorporating gamification into the serious game, it aims to make the learning process more enjoyable and effective for T2DM patients through the use of rewards, challenges, and interactive activities to incentivize and motivate patients to actively participate in their self-management education [22].

The development of the serious game involves a multidisciplinary approach, bringing together expertise in medical informatics, game design, and diabetes care [23–25]. The process begins with a thorough needs assessment to identify the specific educational needs and preferences of T2DM patients [26,27]. This is followed by iterative design and development cycles, involving user feedback and usability testing to ensure that the game meets the needs and expectations of its intended audience [28–30].

The content of the serious game covers a range of topics relevant to T2DM self-management, including medication adherence, dietary choices, physical activity, blood glucose monitoring, and coping with psychosocial challenges. The game employs interactive features such as quizzes, challenges, and virtual rewards to encourage active engagement and knowledge retention. Additionally, the game incorporates personalized feedback and goal-setting mechanisms to support behavior change and self-efficacy.

Furthermore, the serious game is designed to be adaptable to individual patient needs and preferences, promoting inclusivity and accessibility in T2DM education.

In conclusion, the development of a serious game for educating T2DM patients about self-management represents an innovative approach to addressing the educational needs of this population. By leveraging the interactive and immersive nature of gaming technology, the serious game has the potential to enhance patient engagement, knowledge acquisition, and behavior change in T2DM care. This article will delve into the design process, theoretical underpinnings, and potential impact of the serious game within the context of T2DM education and patient empowerment.

Moving forward, further research and evaluation will be conducted to assess the effectiveness of the serious game in promoting behavior change and improving health outcomes for T2DM patients. This will involve gathering feedback from patients who have used the game, as well as conducting clinical studies to measure its impact on self-management behaviors and health-related outcomes.

In summary, the integration of gamification into the design of a serious game for T2DM education represents a promising avenue for enhancing patient engagement and promoting positive behavior change [20,31,32]. By leveraging technology and game-design principles, this innovative approach has the potential to revolutionize the delivery of self-management education for T2DM patients, ultimately improving their quality of life and reducing the burden of this chronic condition on healthcare systems.

2. Material and methods

2.1. Study design

Our study's approach is flexible and multidisciplinary, merging the realms of medicine, computer science, and design. Our goal is to develop an educational game that encourages self-management among individuals with Type 2 Diabetes Mellitus (T2DM). The game is intended to be inclusive and appropriate for various age groups, spanning from young individuals to the elderly. From conception to execution and assessment, we will meticulously shape the game to tackle essential aspects of T2DM management. While our primary focus is on adults, the game's adaptability makes it beneficial for a wider audience.

2.2. Theoretical framework

The research project was structured into three distinct phases, each serving a specific purpose in addressing the educational needs of individuals living with Type 2 Diabetes Mellitus (T2DM). The initial phase involved a comprehensive analysis aimed at identifying the specific educational requirements of this patient population. Through this process, valuable insights were gained regarding the informational gaps and challenges faced by patients in effectively managing their condition. This foundational knowledge then served as the basis for the second phase, which focused on the development of an educational serious game tailored to the unique needs of individuals with T2DM. The resulting digital game was meticulously designed to deliver essential information and guidance, with the ultimate goal of empowering users to better self-manage their condition. By addressing the identified educational needs through an innovative and engaging platform, the aim was to provide individuals with a means to enhance their understanding and management of T2DM. The third and final stage of the research involved the evaluation of the game, incorporating feedback from both users and experts. This evaluation process was crucial in assessing the effectiveness and usability of the educational serious game, ensuring that it

truly meets the needs of individuals living with T2DM and contributes to their overall well-being.

2.3. First phase: need assessment

During the needs assessment phase, a comprehensive five-step process was employed to identify the information needs of individuals with type 2 diabetes. The initial step involved conducting a thorough review to ascertain these needs, taking into account the perspectives of both patients and healthcare providers. This review encompassed an examination of articles and diabetes clinical guidelines sourced from reputable entities such as the Ministry of Health, established diabetes scientific associations, and educational websites overseen by diabetes scientific associations. Subsequently, the identified informational needs of type 2 diabetes patients were collated and categorized, with an emphasis on unifying terminology and organizing them into a multi-level structure termed the knowledge-based message library. This hierarchical structure featured overarching general topics at higher levels and more specific sub-topics at lower levels. Each individual message within this structure was assigned a unique code and contained care recommendations and verified facts designed to augment patient knowledge and awareness.

After identifying the informational needs of type 2 diabetes patients, we proceeded to develop a questionnaire aimed at addressing these needs. The questionnaire consisted of ten approved subject headings, each accompanied by explanations for the content it encompassed. Patients were then asked to rate the importance and priority of each item using a 4-point Likert scale. This method allowed us to systematically gather and analyze the patients' perspectives on the relevance of the identified informational needs.

Subsequently, the questionnaire was distributed to a sample of ten patients. The purpose of this exercise was to extract and prioritize the information needs of type 2 diabetes patients based on their feedback. Items that scored more than 75 % in terms of importance and priority were considered as the key informational needs of diabetic patients. This rigorous selection process resulted in the identification of 157 educational messages that were deemed to have high importance and priority.

These educational messages, covering a wide range of topics relevant to managing type 2 diabetes, were then incorporated into an educational game. By integrating these crucial informational needs into an engaging and interactive format, we aimed to provide patients with a novel and effective means of learning about their condition. This approach not only addresses the informational needs of diabetic patients but also seeks to enhance their overall understanding and management of type 2 diabetes.

In conclusion, the development of the questionnaire and the subsequent extraction and prioritization of informational needs have been instrumental in shaping the content of the educational game. By focusing on the specific needs and priorities of type 2 diabetes patients, we have been able to create a resource that is tailored to their requirements and designed to facilitate meaningful learning experiences. We believe that this approach will contribute to empowering patients with the knowledge and skills necessary to effectively manage their condition and improve their overall well-being.

Finally, our review study on digital health interventions and their impact on type 2 diabetes has provided valuable insights into the requirements and design features of interventions and digital games. Through a comprehensive approach, we have systematically extracted and prioritized the information needs of type 2 diabetes patients. This ensures that our educational game is tailored to effectively address the specific needs of this patient population. Moving forward, we will use this knowledge to develop a digital health intervention that has the potential to make a significant impact on the management and treatment of type 2 diabetes. Our findings will also contribute to the growing body of research on digital health interventions for chronic disease management, providing a foundation for future studies and developments in this important area of healthcare.

2.4. Second phase: design and implementation of digital game

In the second phase of the project, the emphasis transitioned to the development and execution of a digital game designed for educational purposes. This phase began with thorough planning of educational material and information-based communications, guaranteeing their harmony with the educational goals. Following this, the essential authorizations were pursued to integrate this material into the digital game, ensuring adherence to pertinent standards and regulations.

During the design phase of the educational game, three key stages were undertaken to ensure a comprehensive and effective approach. The first stage involved the development of the game scenario, which required careful conceptualization of the game's narrative, setting, and overall structure. This stage was crucial in determining how the educational content would be seamlessly integrated into the game in a manner that would engage and maximize its impact on the target audience. This required meticulous attention to detail and a thorough understanding of the educational objectives in order to create a game that would effectively convey the intended content to the players [33,34].

After setting up the game scenario, the design phase advanced to the development of the game's visual and interactive elements. This encompassed the creation of graphical components, user interface, and overall aesthetics to deliver an engaging and visually captivating experience for the players. Furthermore, great attention was given to crafting interactive features that would promote learning through meaningful interactions and challenges, enhancing the overall educational value of the game [22,35].

During the final stage of the design phase, the focus shifted towards programming the game. This crucial step involved bringing to life all the conceptualized elements and designs through coding and technical implementation. It was essential for the design and development teams to work closely together during this stage to ensure the seamless integration of educational content into the gameplay mechanics. Furthermore, it was imperative to guarantee that the overall functionality of the game met the specified requirements. This collaborative effort was vital in ensuring that the educational objectives were effectively incorporated into the final product, ultimately enhancing the overall user experience.

Throughout the various stages of development, a strong emphasis was placed on ensuring that the game design was aligned with the

educational objectives, with the goal of creating a gameplay experience that not only engaged players but also facilitated meaningful learning. The iterative nature of the design process enabled continuous refinement and improvement, as feedback from relevant stakeholders was incorporated to enhance the educational effectiveness and overall quality of the digital game.

In conclusion, the second phase of the project encompassed a thorough process of developing and integrating a digital game with educational material. Every step, from detailed content curation to careful design and technical execution, was carried out meticulously to produce an immersive and influential educational experience through digital gaming.

2.5. Developing the game scenario

In the process of developing the game scenario, we began by collecting and approving headlines and educational messages. These were then shaped into a game scenario following the principles of game scenario design and expert opinions [36–42]. The game was specifically tailored to address the important issue of diabetes self-management education. To enhance the game's engagement and effectiveness, we utilized the sukr framework, which is designed for the gamification of educational content [43,44].

The game's storyline revolves around a type 2 diabetes patient who earns positive points for making correct choices related to their drug consumption, diet, physical activity, and more. Conversely, they receive negative points for incorrect choices, and can visualize the effects of their decisions through leaderboards, points, and badges. Additionally, users receive feedback on their choices.

To further engage users and encourage them to answer all questions, we designed a character for each educational topic. Through animation, these characters confirm or deny selected options (good or bad/true or false) and provide feedback to the user. For instance, if a user is asked about regular use of blood sugar control drugs and chooses not to take them, an animated medicine icon in the form of a capsule will illustrate the negative consequences of not taking medication regularly or correctly.

Users have the option to answer questions an unlimited number of times and receive different feedback, or answer the questions only once. Upon re-entering the game, they will proceed directly to the knowledge-oriented message section to review the messages. Furthermore, if a user is interested in a particular message within any of the six axes, they can save the desired message in their profile by selecting the "like" option and review them at their convenience.

It is important to note that as all stages of game design were conducted by the research team, the initial scenario of the game underwent multiple changes throughout the design process. As the written scenario became more tangible, ideas emerged to enhance the game's engagement and overall appeal.

2.6. Game design

We utilized the structured model of the ADDIE educational system to design DiaPo, incorporating five key stages: analysis, design, development, implementation, and evaluation [45,46]. In the initial stage, we conducted a needs assessment by analyzing the information requirements of type 2 diabetes patients and the educational process. Subsequently, the design phase involved determining the method of information transfer, followed by the production of educational content and the design of the educational game. The implementation stage focused on executing the educational process through the designed game, while the evaluation stage involved data collection and analysis.

Additionally, we employed the MDA (Mechanics, Dynamics, Aesthetics) framework to guide the design and development of the game [47–49]. Mechanics encompassed the game's rules, structure, and functional components that enable the game designer to control and direct player behavior. Game dynamics referred to the interaction of players with the functional components of the game, while aesthetics pertained to the emotional reactions of players following their interaction with the game.

During the game design phase, we created prototypes for each game component, implementing cycles of repetition and new solutions. The game stages were designed to maximize appeal for type 2 diabetic patients, encouraging continued engagement. Our structured process included implementing the idea on paper, creating a prototype, documenting, selecting the general game mode, determining rules and challenges, deciding on game levels and player behavior, and adjusting values iteratively to optimize gameplay. We also maintained a comprehensive record of all values and their relationships.

To ensure that the game content was easily understandable and memorable, we applied principles from the evidence-based health communication guide [50–52]. This involved designing the appearance of game pages, strategically placing messages, and effectively utilizing graphic features. Each page was structured with specific titles and purposes, employing visual cues to emphasize key points. Consistency in content arrangement patterns, use of icons, colors, animations, and images across all game pages facilitated user navigation without requiring them to learn a new interface each time.

2.7. Programming

To develop the game DiaPo, Unity game engine was used, requiring a significant amount of programming. This involved connecting all game components through a set of language structures that control various aspects of the game [53–55]. The coding for DiaPo was done in Visual Studio 2019, and the game was ultimately developed as an application software program for the Android operating system, following the designed scenario [56].

The initial step in creating the game involved identifying the target population and defining the required system. This required the design team to conduct research on specialized websites to determine the most commonly used devices and their features [57]. Factors such as screen resolution, internet accessibility via mobile phones, tablets or desktops, accessibility, required network specifications, and data consumption were carefully analyzed. Additionally, specific features for gamification and gameplay were also taken into

consideration [58–61].

The development of a game is guided by several essential requirements to ensure its success. These requirements include the ability to play the game offline on the mobile platform, the ability to use the game without the need for registration, compatibility with simple processors and low memory devices, maintenance of the player's score history, the ability to share the game on social networks, display of the user's rank, provision of additional information for game questions, and provision of information about the project, institution, and team. By keeping these requirements in mind, the design team can create a game that is accessible, engaging, and tailored to the needs of the target population [62,63].

The educational content within DiaPo aims to improve the self-management skills of type 2 diabetes patients. To achieve this, the Sukr framework was utilized as a guideline for designing a game-like self-management system for diabetes (Fig. 1). Educational content was incorporated into gamification using the framework's eight components, which are crucial for successful gamification of diabetes self-management [22,64,65].

Gamification is a powerful tool that can be used to create an enjoyable and engaging learning experience. Our team has developed a game specifically designed to educate type 2 diabetes patients about essential aspects of self-management. The game incorporates four key elements: Fun, Self-Management, Growth, and Motivation [66,67].

In terms of Fun, the game integrates badges, points, challenges, and competition to enhance user engagement. Users can earn points through correct responses to questions, allowing them to track their ranking compared to others. Captivating animations related to the educational content have also been incorporated to further enhance the game's appeal and interactivity.

Regarding Self-Management, our game comprehensively covers the educational requirements of type 2 diabetes patients. It is structured into six axes, each featuring relevant and visually appealing animations and images. The content has been meticulously analyzed using segmentation, thematic analysis, and standardization. Messages have been evaluated for accuracy, transparency, relevance, and comprehensiveness. Users receive feedback symbolized by each educational axis, such as a blood drop animation with a confirmation sign for knowledge-based messages related to blood pressure.

Growth is an essential element of our game. Providing meaningful and relevant feedback is integral to the success of gamification. We ensure continuous feedback throughout the game, including rewards and incentives. Users can earn cups signifying progress upon completion of each axis. Feedback is also utilized to encourage users to revisit messages if they answer questions incorrectly. Phased feedback is provided every 5 to 6 messages, allowing users the option to continue or exit the game.

Motivation is another key component of our game. Our focus is on providing accurate, comprehensive, and transparent answers to the questions and informational needs of type 2 diabetes patients. Internal motivation is expected from users to engage with the game. Additionally, visual and auditory factors, along with an attractive design, serve to boost external motivation. Users can earn points and monitor their progress in the game, thereby increasing their awareness of diabetes self-management and motivating continued participation.

Recognizing the significance of social interaction in gamification, we have incorporated features that allow users to share the game with friends through active social networking platforms on their smartphones. Furthermore, users have the opportunity to engage with the game design team, ask questions, participate in surveys, and provide feedback on their experience with the game's content, appearance, and usability.

Drawing from Maslow's theory, our gamification elements aim to fulfill users' need for respect and recognition within the right context. Users can view their leaderboard ranking, progress bar, and receive trophies, thereby satisfying their need for acknowledgment and positively impacting their self-esteem. The game's progress bar displays the user's advancement in all stages of the game, while also allowing them to track completion of image puzzles related to the educational axes.

Personalized profiles are essential in showcasing users' goals and abilities within the gamified system, thus enhancing their ability to interact with the platform. At the onset of the game, users can introduce themselves by selecting a preferred name and answering questions related to their diabetes self-management lifestyle to receive tailored feedback.

To ensure lasting effects of gamification, we have integrated specific elements (stimulus, flow, storyline/theme, and flip) into the Sukr framework based on game design and behavioral theories. Flow and storyline are effective in sustaining long-term user attention in educational games, while trigger and flip are designed to influence user behavior in a desired direction. Additionally, we send

Fig. 1. Wheel of sukr.

reminders to encourage users to engage with the game and receive educational messages. These reminders undergo review and approval by three experts specializing in medical education, clinical psychology, and medical informatics.

2.8. Third phase: game evaluation

In the third phase of the project, an assessment was conducted on a serious game aimed at educating individuals on self-management of type 2 diabetes. This evaluation occurred at two distinct levels: process evaluation, effect evaluation. The process evaluation, entailed comprehensive testing of the initial version of the DiaPo game from various perspectives. This involved identifying any bugs and making necessary enhancements prior to its release. The game was downloaded and installed on multiple devices to uncover any potential issues. The initial test version, known as the "Alpha" version, was made available to testers during the game design phase, enabling the research team to modify and enhance the game before finalization [68,69]. The research team, comprising individuals with expertise in endocrine and medical informatics, as well as game design specialists, provided valuable feedback that was instrumental in refining the game and addressing any identified issues. Through this iterative process, general defects within the game were identified and rectified, ensuring an improved final product.

In order to effectively communicate and distribute our game to our target audience, we employed a comprehensive approach that involved a variety of coordinated actions. One key aspect of our strategy was the establishment of dedicated social network accounts on platforms such as Telegram, Bale [70], and Eitaa [71]. These platforms played a vital role in our outreach efforts, serving as important channels for engaging with our audience and disseminating information about DiaPo. Additionally, we strategically placed posters in diabetes clinics to encourage patients to participate in DiaPo through our digital channels. Furthermore, we expanded our outreach by directly contacting patients, obtaining their contact information, including phone numbers, and reaching out to them through personalized invitation messages. These messages were tailored specifically for individuals living with Type 2 Diabetes Mellitus, extending a warm invitation to join the DiaPo community. Our goal was to ensure that DiaPo was accessible to those with Type 2 Diabetes Mellitus by providing multiple avenues for engaging with our educational game.

The study conducted a thorough statistical analysis using a dataset obtained from a dedicated email for the game. This dataset encompassed a wide range of variables, including user demographics such as age, gender, and educational background, as well as performance metrics related to user engagement in the game. These metrics comprised the number of correct and incorrect answers, total duration of participation, and frequency of game utilization. Additionally, the dataset tracked user progress through the questions section, including the number of questions answered and remaining. It also included individual scores achieved by users, which served as indicators of their performance and mastery of the game's content. Moreover, qualitative insights from user feedback via polls and messages provided valuable information about user perceptions and experiences. The meticulous analysis of this comprehensive dataset aimed to extract meaningful insights and draw robust conclusions, thereby enhancing our understanding of user engagement and learning outcomes within the DiaPo diabetes empowerment game.

Analyzing the evaluation results using specific heuristics allowed us to identify the strengths and weaknesses of the DiaPo game's user interface. Furthermore, incorporating both experts and real users in the evaluation process enriched its significance, offering a diverse perspective on usability and user satisfaction. The insights obtained will guide us in refining and enhancing the game's user interface, ultimately contributing to an improved user experience and the successful achievement of our educational objectives.

2.9. Ethical aspects

The project places a strong emphasis on ethical considerations, particularly in relation to data protection and privacy. It adheres to stringent standards to ensure the safeguarding of user information. Notably, the project does not require user registration, and no user data is stored in databases. Instead, only indirect reports and temporary data related to user interactions are utilized for analysis, thus prioritizing the rigorous protection of user privacy. Importantly, the project fully complies with all data usage regulations in the Islamic Republic of Iran and transparently communicates to users about the indirect use of non-sensitive data, thereby promoting transparency and fostering trust. Furthermore, the project has undergone a comprehensive ethical review and obtained approval from the Ethics Committee of Mashhad University of Medical Sciences, as evidenced by the Ethics Committee Code: IR.MUMS. REC.1400.105. This underscores the project's unwavering commitment to upholding ethical and legal standards, particularly with regard to data usage and privacy. Prior to engaging in any research procedures, written informed consent was diligently obtained from all participants, ensuring that they were fully informed and had the opportunity to explicitly grant consent for their participation. This meticulous process reflects the project's dedication to upholding ethical principles and safeguarding the rights of participants. The project's unwavering commitment to obtaining informed consent further underscores its adherence to ethical and legal standards across all aspects of implementation, particularly in relation to data usage and privacy.

3. Results and discussion

The research findings will be presented as the outcomes of three phases of needs assessment, game design and game evaluation.

3.1. First phase: need assessment

A structured review was conducted to identify the information needs of type 2 diabetes patients. A search in the PubMed databases yielded 142 articles, and upon review, it was discovered that a similar study had gathered information needs from 26 articles.

According to the guidelines published by the Agency for Healthcare Research and Quality (AHRQ), if the research question of an existing study aligns with the PICO elements of the ongoing study, the existing study can be considered for use in the new study. As a result, 14 articles were accepted for inclusion in the current study. To supplement the findings, a search was conducted between July 2015 and October 2021, resulting in the retrieval of 42 articles, of which 3 were eligible for inclusion. In addition, 58 clinical guidelines were retrieved from the International Bank of Clinical Guidelines, and 4 were accepted for full text review. The Diabetes Educator Training Guide in the Systematic Comprehensive Model of Health Education and Promotion (SHEP) was also reviewed as an internal source.

To identify and screen the most important informational needs of type 2 diabetes patients, three nurses with expertise in diabetes self-management were enlisted to validate the messages. The evaluation process involved assessing the messages for accuracy, transparency, relevance, and comprehensiveness. Messages scoring above 75 % in each index were accepted, while those scoring below 75 % underwent correction and re-evaluation. Approximately half of the messages were accepted in the initial stage, with the remaining undergoing a second stage of evaluation. Based on the results of the first validation stage, appropriate corrective actions were taken, including deletion, rewriting, or literary editing, depending on the specific shortcomings identified. In cases where the completeness of messages was not approved, new messages were added. Ultimately, 192 messages across 10 chapters were approved, with an average evaluator score of 97.75 % for accuracy, 87.86 % for transparency, 83.5 % for relevance, and 82.47 % for comprehensiveness, all of which were considered acceptable.

To develop a questionnaire aimed at evaluating the information requirements of individuals with type 2 diabetes, we proceeded by creating 192 educational messages categorized into 10 distinct headings. These messages were subjected to evaluation by three assessors to ensure their appropriateness. Subsequently, we administered the questionnaire to 10 type 2 diabetes patients to gauge the perceived significance and urgency of self-care education needs related to diabetes. Following the collection of responses, we calculated an importance and priority index for each heading, considering those that scored above 75 % as meeting the necessary criteria. These selected messages and headings were then deemed as the final educational content suitable for inclusion in the DiaPo educational game.

The process of identifying and prioritizing the information needs of type 2 diabetes patients has resulted in the identification of six main axes, each with specific topics that are essential for patient education and support. These axes, labeled as diabetes, nutrition, drug use, physical activity, blood pressure control, and foot health, encompass a wide range of knowledge-based messages that are crucial for the management and understanding of type 2 diabetes.

The diabetes axis comprises 28 messages that cover factors affecting high blood sugar, signs of high blood sugar in the body, and the consequences of high blood sugar. These messages are fundamental in helping patients understand the impact of their condition and how to manage it effectively.

In the nutrition axis, 37 knowledge-based messages focus on the dangers of improper nutrition, the effects of high sugar intake, and the importance of following proper nutrition for controlled sugar levels. These messages aim to guide patients in making informed dietary choices to better manage their diabetes.

The library of drug use messages includes 8 knowledge-based messages that provide information on the application, mechanism of action, conditions of use, and side effects of drugs used in diabetes management. Additionally, these messages address motivational aspects and overcoming obstacles to regular drug use, offering patients comprehensive support in medication management.

The physical activity axis covers 25 messages that emphasize the importance and benefits of physical activity, highlight the risks of inactivity, and provide sports recommendations tailored to different weather conditions throughout the year. These messages aim to encourage patients to engage in regular physical activity as part of their diabetes management plan.

The blood pressure control axis contains 53 knowledge-based messages that address the causes of high blood pressure, signs and symptoms of hypertension, as well as its complications and consequences. These messages are crucial in educating patients about the importance of blood pressure management in relation to their diabetes.

Finally, the foot health axis encompasses 6 messages that offer guidance on choosing the right shoes and foot care practices. These messages are essential in preventing and managing diabetic foot complications, which are common among type 2 diabetes patients.

In summary, the identification of these knowledge-based messages across the six main axes provides valuable insights into the information needs of type 2 diabetes patients. These messages are integral in shaping the educational content and support systems aimed at empowering patients to effectively manage their condition and improve their overall well-being.

The serious game's educational objectives are specifically tailored to address the information needs of individuals dealing with type

((((Need*[Title] OR Wish*[Title] OR Desire*[Title] OR Preference*[Title] OR Request*[Title] OR require*[Title] OR Seek*[Title] OR provision*[Title] OR perception*[Title] OR expectation*[Title] OR interest*[Title] OR question*[Title] OR ask*[Title] OR search*[Title] OR demand*[Title] OR call*[Title] OR Talk*[Title])) AND (Information[Title] OR Knowledge[Title] OR Awareness[Title] OR Self-care[Title] OR self-management[Title] OR education[Title] OR support[Title])) AND (Diabetes[Title] OR Type 2 diabetes[Title] OR Diabetes mellitus type 2[Title] OR Diabetic[Title] OR T2DM[Title])) AND (Patient*[Title] OR People[Title])

2 diabetes. The game encompasses six distinct subject areas, each meticulously designed to deliver targeted information and support. The first area, The Diabetes Alphabet, provides a comprehensive understanding of the factors influencing blood glucose levels, elucidating symptoms and consequences while delving into detailed exploration. The nutritional advice section offers crucial insights into the risks of poor nutrition and non-compliance with dietary guidelines, emphasizing controlled carbohydrate intake and healthy eating habits. The drug use segment delves into the complexities of medication management, offering valuable information on usage, mechanisms of action, and potential side effects, along with addressing motivational aspects and strategies for overcoming barriers to medication adherence.

Recognizing the significance of physical activity, the game includes three key areas highlighting its importance and benefits, outlining the risks of physical inactivity and providing comprehensive exercise recommendations. The blood pressure category is divided into five sections, clarifying the factors contributing to high blood pressure and delivering messages about symptoms, complications, and potential consequences, offering a comprehensive understanding of the field. Lastly, the foot health section offers valuable guidance on selecting appropriate footwear and optimal foot care practices, raising awareness about the importance of effective foot health management.

Through these intricately designed subject areas, the serious game effectively achieves its educational objectives, equipping users with the knowledge and skills necessary for informed and empowered self-management of type 2 diabetes. These outcomes underscore the game's commitment to providing comprehensive learning experiences for its users.

In the process of conducting a review for the purpose of digital game design, a comprehensive search strategy yielded a total of 1572 studies. These articles underwent thorough scrutiny to identify and eliminate any duplications, resulting in 1397 unique articles. Subsequently, two researchers independently assessed the titles and abstracts of the remaining articles, leading to the exclusion of 1252 articles that did not align with the predetermined inclusion criteria. The full text of the remaining 145 articles was then obtained and meticulously examined, with particular attention given to screening their references in order to identify any additional relevant articles not captured in the original search. Following this rigorous screening process, 84 articles were excluded based on the established exclusion criteria, leaving 61 articles for further analysis. Additionally, two articles were excluded due to unavailability of their full text, ultimately resulting in a total of 59 articles being included in the study. This systematic and meticulous approach ensured that the final selection of articles was comprehensive and aligned with the objectives of the review in the context of digital game design.

The digital health interventions studied were classified into six groups based on the type of intervention, taking into consideration factors such as simplicity, comprehensibility, and technological complexity. The categories include telehealth, which encompasses telemedicine, telecare, teleconferencing, teleconsultation, tele education, telemonitoring, videoconferencing, and real-time video or audio interventions. Another category is mHealth, which utilizes mobile applications, messaging systems, telephone systems, and call centers. Web-based services make use of Internet-based tools, online services, and patient portals. Game-based support involves games, serious games, gamification, virtual reality, and digital games. Social platforms utilize social media platforms such as Facebook, YouTube, Instagram, Twitter, Pinterest, Reddit, LinkedIn, Tik Tok, Snapchat, QQ, WhatsApp, and Telegram. Lastly, the sensor/device/computer category involves wearable devices, personal digital assistants, personal smart assistants, pocket computers, pagers, touch screens, computer-aided assessment, self-monitoring devices, interactive CD-ROM programs, and portable monitoring devices.

There may be overlap between these categories; for example, mobile devices can be used for digital gaming or remote monitoring. The most common types of interventions evaluated in the reviews were mobile health, web-based interventions, telehealth, sensor/device/computer interventions, social platforms, and game-based interventions. Approximately 25 % of the reviews examined only one type of intervention. A significant majority of the studies reported positive effects of digital health interventions on diabetes self-management.

3.2. Second phase: design and implementation of digital game

The outcomes of the second phase involved the creation and execution of the digital game, including the compilation of the game scenario. Initially, the game design team developed the game graphics, encompassing the logo and graphic design for each scene in accordance with the game scenario (Fig. 2). The usage of these graphics is permitted for non-commercial purposes upon obtaining consent from the game designer. The serious game's main interface features buttons to access educational messages on predefined
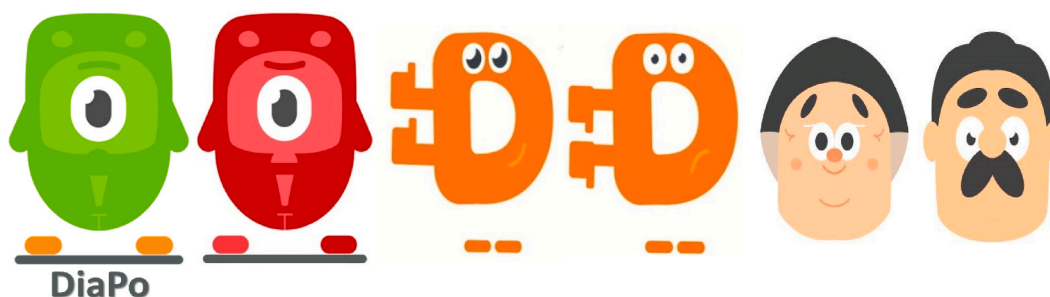

Fig. 2. sample of game prototype.

topics, accompanied by a progress bar indicating the player's progression and the accuracy of their answers. A quick access icon allows players to exit the game, while the option to save important and favorite messages is available in the middle and bottom of the page. The main menu enables users to select their topic of interest, explore training messages, view earned points, participate in surveys, access saved messages, communicate with game support, and obtain additional information about the project and development team, all while ensuring privacy protection and allowing username changes. Upon exiting the game, players have the option to share it via social networks.

Upon selecting a topic from the main menu, users are presented with a series of questions. Following their responses, users receive feedback on the accuracy of their answers, accompanied by audio-visual effects for enhanced engagement. Successful completion of all questions results in a congratulatory message and a trophy next to the relevant topic. Conversely, incorrect answers prompt a message encouraging users to retry the questions. The score page displays the number of correct and incorrect answers for each user, providing a comprehensive overview of their performance within the game.

The necessary system for serious game development encompasses a comprehensive array of essential requirements aimed at optimizing accessibility, usability, and user engagement. The game is specifically engineered to offer a seamless and consistent experience across various mobile platforms, ensuring that users can easily access it without the need for a cumbersome registration process. Furthermore, the game is designed to be compatible with devices possessing limited processing power and memory capacity, thereby extending its reach to a wider audience. In addition, users have the capability to enjoy uninterrupted gameplay in offline mode, eliminating the dependence on an internet connection. This feature enhances the game's accessibility and usability, particularly in areas with limited connectivity.

Moreover, users are empowered to track their progress and achievements over time, maintaining a comprehensive history of their game scores. This functionality not only fosters a sense of accomplishment but also encourages continued engagement with the game. Furthermore, users have the ability to share their game experiences and achievements on social networks, thereby promoting interaction within the community. This social element adds a layer of engagement and connectivity, enriching the overall user experience.

Additionally, users can view their ranks and compare their performance with that of other users, fostering a sense of healthy competition and motivation for improvement. This competitive aspect can serve as a powerful incentive for continued engagement and skill development. Furthermore, users have access to additional information and can pose game-related questions to an expert team. This feature enhances the educational value of the game by providing users with a direct channel for seeking clarification and additional insights.

It is worth noting that the transparency of the academic members who approved the project and the expert team who developed the game contributes to building user trust. This transparency underscores the commitment to quality and expertise, instilling confidence in the game and its educational value.

In summary, these meticulously crafted system requirements are geared towards ensuring that the serious game not only effectively delivers educational content but also offers a user-friendly and engaging experience that caters to the diverse needs and preferences of its audience. By prioritizing accessibility, usability, and user engagement, the game is poised to make a meaningful impact in the realm of serious game development.

In the development of a diabetes-centered educational game, the ADDIE educational system design model was utilized as a foundational framework, guiding the process through five distinct phases. The initial phase, known as the needs assessment phase, involved a comprehensive analysis of the information requirements of individuals with type 2 diabetes, with the objective of identifying essential components for the educational process. Subsequently, the design study phase focused on determining the most effective approach for delivering necessary information, taking into consideration both educational content and game design. The subsequent development phase encompassed the creation of educational content and the actual design and construction of the serious game within the Unity environment. Following this, the implementation study phase was dedicated to executing the educational process and making the designed game accessible to the target audience. Finally, the evaluation study phase involved an extensive collection of data and analyses to assess the game's effectiveness in achieving its educational objectives.

Throughout the design and development stages, the MDA (Mechanics, Dynamics, Aesthetics) framework was extensively incorporated into the game. This framework played a pivotal role in shaping the mechanics, dynamics, and aesthetics of the game, ultimately resulting in a comprehensive and captivating user experience. The focus on mechanics centered on establishing the rules and structural components of the game, providing the game designer with the ability to influence player behavior and shape their interaction with game elements. In addressing dynamics, emphasis was placed on the interaction between players and the functional aspects integrated within the game, ensuring that player reactions to game mechanics were carefully evaluated to maintain an engaging and responsive user experience. Aesthetic considerations were directed towards the emotional impact of player interactions within the game environment, aiming to evoke specific emotional responses and interactions from players to create an immersive and emotionally resonant overall game experience.

The gamification of educational content has become increasingly popular in the field of education, with the Sukr framework, also known as the Sukr Cycle, emerging as a valuable tool for this purpose. This framework comprises eight key components that contribute to an engaging and multifaceted user experience, making it a valuable asset in the gamification of educational content. By integrating the Sukr framework into serious games, educational content can be contextualized in a way that promotes user engagement and enhances learning outcomes.

The game begins by allowing users to personalize their experience through the selection of a username and description of their unique style of self-management. This initial step encourages users to reflect on their self-management choices and receive feedback, thereby increasing their understanding and active participation (Fig. 3). The game encompasses various aspects related to diabetes self-management, including user information, blood sugar control, dietary choices, physical activity, blood pressure, foot care, stress

levels, sleep patterns, and lifestyle habits. The incorporation of engaging animations throughout the game ensures that an element of fun is maintained while delivering educational content.

Knowledge-based messages about blood pressure are presented in the form of questions, with correct answers triggering positive animations and confirmation icons. This integration of text, sound, and images engages users' senses and enhances their understanding and retention of the content. The game is designed across six dimensions, each enriched with attractive animations and images. Careful content analysis ensures that educational messages are accurate, clear, relevant, and comprehensive. A progress bar visually tracks the user's advancement through the game, reinforcing a sense of accomplishment and value. Continuous feedback is provided as users respond to knowledge-based messages, with instant audio and video feedback enabling them to gauge the accuracy of their choices. Users also receive badges as they progress through each dimension, serving as a motivational tool.

The phased delivery of content ensures that users receive feedback and opportunities to review. Users witness the gradual completion of puzzles related to educational dimensions as they choose the correct options, with scores and progress tracking encouraging continued engagement and increasing awareness of diabetes self-management. Notification reminders prompt users to re-engage with the game and receive additional messages, ensuring that their information needs are consistently met. The game's foundation in meeting the information needs of type 2 diabetes patients is evident in its provision of accurate, comprehensive, and transparent answers that serve as internal motivation and align with users' information needs.

Extrinsic motivation is fostered through attractive design, visual and auditory elements, and gamification features. The comprehensive educational content covers all aspects of diabetes self-management in every dimension, with feedback delivered through carefully designed personas associated with each training aspect to sensitively educate users on best practices and potential pitfalls. Additionally, the game allows users to share it with their friends on active social media platforms and interact with the game design team through polls, ensuring a collaborative and community-oriented approach.

Overall, the Sukr framework is intricately woven into the fabric of the game, creating an engaging learning experience that addresses intrinsic and extrinsic motivation, promotes learning, and fosters a sense of growth and achievement among users.

The development process for the DiaPo self-management training game involved several key steps, all of which were crucial in creating an engaging and educational gaming experience. Using Visual Studio 2019 and the Unity environment, the game was meticulously programmed to ensure a seamless and immersive experience for the players. The hierarchical approach to the design process can be outlined as follows:

Firstly, educational content and knowledge-oriented messages were compiled to form the foundation of the game's learning objectives. This was followed by the design of the game play style, which was carefully crafted to align with the educational content and provide an interactive learning experience for the players. The compilation of the game scenario and the design of required items were then carried out to further enhance the overall gaming environment.

In the Unity 2020.3.33f1 environment, items were strategically placed to optimize the visual and functional aspects of the game. The presentation of educational messages was designed using the Sukr framework, ensuring that the delivery of educational content was both effective and engaging. These educational messages were then integrated into the Unity environment to seamlessly blend with the overall gaming experience.

The design and placement of game characters, along with the creation and integration of required animations, played a pivotal role in bringing the game to life. This was followed by meticulous game programming and coding in the Visual Studio 2019 environment, ensuring that all elements of the game functioned seamlessly and in accordance with the intended design.

Attention to detail was also given to the Unity environment lighting, as well as the incorporation of voicing and sound effects to further enhance the immersive nature of the game. The design of the game list, along with alpha output for game modification and beta output for bug fixes, were essential in refining and optimizing the game for release.

In summary, the development process for the DiaPo self-management training game involved a systematic and comprehensive approach to game design, programming, and integration of educational content. Each step was carefully executed to ensure that the final product delivered an enriching and enjoyable experience for players while effectively conveying key self-management principles.

3.3. Third phase: game evaluation

In the third Phase, results of the digital game evaluation involved two key stages: process evaluation and effect evaluation. During the process evaluation, which took place during the development of the Alpha version of the game, the research team had the opportunity to identify and address general defects in the game design. This stage allowed for modifications and improvements to be made before the finalization of the game. Moving on to the effect evaluation, which took place during the "Beta" version, the focus shifted to examining the effectiveness of the game and gathering feedback from the target audience [72,73]. Specifically, a pilot group
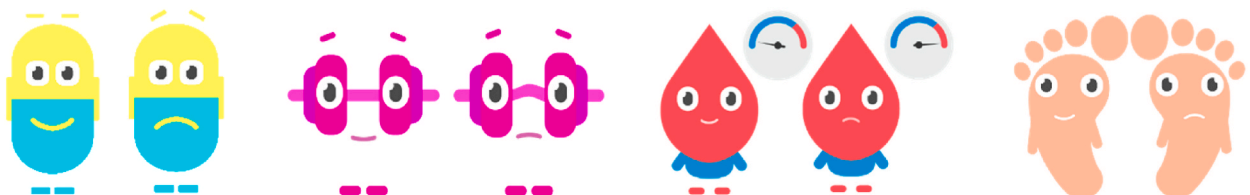

Fig. 3. feedback characters for Medication Use, Physical Activity, Blood Pressure, and Foot Health.

of type 2 diabetes patients provided valuable insights that were incorporated into the game to enhance its relevance and impact. Additionally, a broader group of testers, including experts in game design, application design, website design, as well as endocrinologists and diabetologists, further evaluated the beta version from various perspectives. This comprehensive testing process enabled the identification and resolution of minor issues, ensuring that the creators were satisfied with the modified version of the game prior to its release.

Over the span of three months, DiaPo was successfully distributed to patients, resulting in a total of 142 installations being completed. Among these installations, 109 individuals actively engaged with the educational messages by reading and interacting with them. DiaPo is designed with 17 demographic questions and 157 educational questions, thus offering a comprehensive assessment framework that integrates several key parameters. Users are provided with the flexibility to access and review the educational messages as many times as they desire, enabling them to revisit and reinforce their understanding of the content at their convenience. A report detailing the functional parameters of the educational game DiaPo, based on a sample size of 53 users, provides valuable insights into its effectiveness and user engagement (Table 1).

Users' feedback on the program was assessed through a survey, with 25 participants providing responses on various aspects of the program. The survey questions aimed to gain insights into user satisfaction, experience, and perceived usefulness of the app, enabling an evaluation of its effectiveness and identification of areas for improvement based on user feedback. The quality of the game was evaluated using the MEEGA + scale, with 21 users actively participating in the process (Table 2). This scale allowed for the classification of the game into different quality levels based on user perception, ranging from low quality to excellent quality. The quality level was determined by collecting data using the MEEGA + measurement tool. Additionally, a comprehensive quality assessment was conducted to gather users' views on the dimensions of usability, player experience, and perceived learning in the DiaPo educational game. Each criterion was rated on a scale of 1–5, with the maximum cumulative score across all dimensions being 105, providing average scores and clarifying the performance of the game across various dimensions.

The users' assessment of the program was conducted through a survey, which aimed to gauge satisfaction and opinions regarding different aspects of the program. The survey questions provided valuable insights into user experience, satisfaction, and the perceived usefulness of the app. This evaluation enabled the identification of potential areas for improvement based on user feedback. The quality of the game was evaluated using the MEEGA + scale, with 21 users actively participating in the process. The MEEGA + scale allowed for the classification of the game into different quality levels based on user perception (Table 3). These levels ranged from low quality to excellent quality, with the determination made by collecting data using the MEEGA + measurement tool. Furthermore, a comprehensive quality assessment of DiaPo was conducted to provide average scores across various dimensions and clarify its performance. This assessment gathered users' views on the characteristics of three important dimensions of the DiaPo educational game: usability, player experience, and perceived learning. Each criterion was rated on a scale of 1–5, with 5 being the highest score, and the maximum cumulative score in all dimensions was 105. The evaluation revealed that DiaPo achieved high average scores in usability, player experience, and perceived learning outcomes, indicating a positive user response to the program.

Experts were enlisted to evaluate the quality of the educational game, DiaPo, through a questionnaire designed and reviewed by Mehraeen et al. [74] A total of 13 experts provided their opinions on four key aspects of DiaPo: user-friendliness, ease of use, security and reliability, as well as motivational and educational effects. Each aspect was rated on a scale of 1–5, with 5 being the highest score, resulting in a maximum cumulative score of 65 across all dimensions (Table 4). The expert group comprised 8 women and 5 men, with 4 holding doctorates and 9 possessing master's degrees. Additionally, 8 of the experts were employed professionals, while 5 were students, with 11 falling between the ages of 18 and 40, and 2 being over 40 years old. Upon consolidating the experts' scores, DiaPo was categorized into four distinct levels based on the total score: poor (25 % of the total score), moderate (25–50 % of the total score), good (50–75 % of the total score), and very good (more than 75 % of the total score). The average scores for user-friendliness, ease of use, security and reliability, and motivational and educational effects were 54.2, 50.5, 53.7, and 54.7, respectively.

4. Conclusion

In conclusion, the development of DiaPo, a mobile serious game designed to assist individuals in effectively managing type 2 diabetes, represents a significant advancement in addressing the escalating global diabetes epidemic. The research project underwent three distinct phases, each contributing significantly to addressing the educational needs of individuals with Type 2 Diabetes Mellitus (T2DM). The initial phase involved a comprehensive analysis to identify the specific educational requirements of T2DM patients, providing valuable insights regarding the informational gaps and challenges faced by patients in effectively managing their condition. The second phase focused on the development of an educational serious game tailored to the unique needs of individuals with T2DM, with the game scenario meticulously designed to deliver essential information and guidance. The final stage involved evaluating the

Table 1

Report of functional parameters of educational game (DiaPo) (n = 53).

Functional Parameters	Description (n = 157)	Mean ± SD
Checked questions	Number of questions that users have read	43 ± 111
Correct answers	Number of correct options selected in response to questions	145 ± 171
Wrong answers	Number of wrong options chosen in response to questions	140 ± 82
Game duration (minutes)	Amount of time users spends playing the game	27 ± 46
Times entering the game	Number of times users enter the game	6 ± 10

Table 2

Game survey questions to evaluate user satisfaction (n = 25).

Evaluation questions	Yes – n (%)	No – n (%)
Were the app messages helpful to you?	23 (92)	(8) 2
Was the app visually appealing to you?	(68) 17	(32) 8
Was the program easy to use?	(96) 24	(4) 1
Did you like the program overall?	(92) 23	(8) 2

Table 3

Evaluation of the quality of DiaPo game by users (n = 21).

Features of the game	options	Strongly agree	Agree	Neither agree nor disagree	disagree	Strongly disagree	Average (of 105)	Percent
applicability	The game design is attractive	8	5	4	3	1	80.33	76
	The font and color of the text have a good combination and consistency	6	9	2	4	0		
	Learning this game was easy for me	4	8	7	2	0		
	The rules of the game are clear and easy to understand	7	8	4	2	0		
	The fonts used in this game are easy to read	7	8	4	2	1		
	The colors used in the game are meaningful	8	7	4	1	1		
Player experience	This game is suitably challenging for me	6	9	4	2	0	80.8	76
	I feel satisfied with the things I have learned from the game	6	7	6	2	0		
	I recommend this game to my colleagues	4	10	5	2	0		
	I enjoyed the game	6	7	5	3	0		
	This game is a suitable training method for this disease	9	6	3	3	0		
Perceived learning	The game helped me remember the concepts of the diabetes alphabet	7	9	3	2	0	84.33	80
	The game helped me remember the concepts of diabetic nutrition	8	9	2	2	0		
	The game helped me remember the concepts of taking medicine	7	9	4	1	0		
	The game helped me remember the concepts of physical activity	6	10	2	3	0		
	The game helped me remember the concepts of blood pressure control	8	8	5	0	0		
	The game helped me remember the diabetic foot concepts	8	8	1	3	1		

game, incorporating feedback from users and experts to assess its effectiveness and usability, ensuring that the educational serious game truly met the needs of individuals living with T2DM and contributed to their overall well-being.

Leveraging the MEEGA + model, a comprehensive framework for evaluating educational games, our research focused on usability and player experience, both of which have a substantial impact on user satisfaction and learning outcomes. The evaluations from users and experts alike have indicated that DiaPo is a game of exceptional quality, with its user-friendly interface and valuable messaging appealing to a broader demographic. The game's narrative follows a type 2 diabetes patient earning positive points for making correct choices related to medication consumption, diet, physical activity, and more while receiving negative points for incorrect choices. User feedback has emphasized the value of DiaPo's messages and its user-friendly interface, demonstrating the game's potential to effectively cater to the educational needs of individuals managing type 2 diabetes. Furthermore, the game's appeal to users who were not regular digital gamers underscores its ability to engage a broader demographic.

The integration of gamification into the design of DiaPo represents a promising avenue for enhancing patient engagement and promoting positive behavior change. By leveraging technology and game-design principles, this innovative approach has the potential to revolutionize the delivery of self-management education for T2DM patients, ultimately improving their quality of life and reducing the burden of this chronic condition on healthcare systems. In the face of the growing global diabetes epidemic, innovative digital tools such as DiaPo offer a timely and effective approach to combatting this pressing global health challenge. The success of DiaPo serves as evidence of the capability of well-designed serious games not only to educate but also to motivate and engage individuals in their self-management journey, highlighting its potential for broad-reaching impact.

In summary, DiaPo exemplifies the potential of serious games to enhance diabetes self-management and empower patients through engaging and informative experiences. The development of DiaPo represents a significant advancement in addressing the educational needs of individuals managing type 2 diabetes. The success of DiaPo serves as evidence of the capability of well-designed serious games

Table 4

Evaluation of the quality of DiaPo educational game from the point of view of experts (n = 13).

Features of the game	Options	Strongly agree	agree	Neither agree nor disagree	disagree	Strongly disagree	Average (of 65)	Percent
User friendly	Readability of the text	6	7	0	0	0	54.17	79
	Appropriateness of the font used	6	5	1	1	0		
	Use the appropriate form and sign	4	5	4	0	0		
	The appropriateness of the music used	4	4	4	1	0		
	Variety of colors used	3	6	2	2	0		
	Desirability of the user environment	3	5	3	1	1		
ease of use	Ease of searching for information	3	4	4	2	0	50.5	77
	Easy to change pages	4	4	4	1	0		
	Ease of applying user settings	4	3	3	2	1		
	Easy registration of information	8	3	2	0	0		
	Ease of returning to the home page	4	5	3	1	0		
	Ease of returning to previous pages	5	4	2	2	0		
Security and reliability	Suitable reminder for training	5	6	1	0	1	53.67	82
	The level of security and confidentiality	5	6	2	0	0		
	The validity of the information	9	4	0	0	0		
	The accuracy of the information	8	5	0	0	0		
	Change username	4	4	1	3	1		
	Use username	4	4	2	2	1		
Motivational and educational effects	Providing appropriate educational information	8	5	0	0	0	54.71	84
	Use motivational messages	7	4	2	0	0		
	Motivate to follow the diet	6	6	1	0	0		
	Incentivize the visit	3	7	3	0	0		
	Motivation to continue treatment	5	4	4	0	0		
	Recommend the software to others	5	3	5	0	0		
	Willingness to use the software	5	3	5	0	0		

not only to educate but also to motivate and engage individuals in their self-management journey, highlighting its potential for broad-reaching impact. Further research and evaluation will be conducted to assess the effectiveness of DiaPo in promoting behavior change and improving health outcomes for T2DM patients, solidifying its role as a valuable tool in patient education and empowerment.

4.1. Key features

DiaPo incorporates several key features to enhance the learning experience for patients with T2DM. These features include.

- Gamified Learning: By integrating game mechanics such as points, rewards, and feedback, DiaPo aims to make self-management education engaging and motivating for patients.
- Interactive Animations: The use of interactive animations allows for immediate feedback on patient choices, reinforcing learning outcomes in a visually engaging manner.
- Flexibility and Adaptability: DiaPo is designed to be flexible and adaptable, catering to diverse learning styles and preferences among patients with T2DM.
- Multidisciplinary Approach: The development team's expertise in medical informatics, game design, and diabetes care ensures a comprehensive and holistic approach to patient education.

4.2. Clinical application

DiaPo has the potential to be integrated into clinical practice as a supplementary tool for T2DM education. Healthcare providers can recommend DiaPo to their patients as a means of reinforcing self-management strategies and providing ongoing support outside of clinical settings. The game's user-friendly interface and engaging content make it an attractive option for patients seeking additional resources for disease management.

4.3. Future directions

As mobile serious games continue to gain traction in healthcare, future directions for DiaPo include ongoing updates and enhancements based on user feedback and emerging technologies. Additionally, research studies can be conducted to evaluate the impact of DiaPo on patient knowledge, self-management behaviors, and clinical outcomes. Collaborations with healthcare organizations and patient advocacy groups can further promote the adoption of DiaPo as a valuable resource for T2DM education.

4.4. Limitation

The limitations of this article are.

1. Generalizability: Although the research focuses on developing a serious game for patients with type 2 diabetes, the findings might not apply universally to other populations without additional testing.
2. Cultural specificity: The study is centered around the Iranian context, specifically at Mashhad University of Medical Sciences, which could limit the applicability of the findings outside of that region unless cultural adaptation is performed.
3. Longitudinal evaluation: The article mentions future research and evaluation to assess the effectiveness of the serious game in promoting behavior change and improving health outcomes for type 2 diabetes patients. Without long-term follow-up data, it remains uncertain how sustainable the benefits of the intervention would be.

These limitations do not necessarily invalidate the work but rather highlight areas where further investigation or refinement might be needed to strengthen the conclusions drawn from the research.

Data availability statement

You can access my game by clicking on the following link:
https://s32.picofile.com/file/8478865642/DiaPo_V_2_0.apk.html.

CRediT authorship contribution statement

Sara Ghodousi Moghadam: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Zahra Mazloum Khorasani:** Writing – review & editing, Visualization, Supervision, Conceptualization. **Nahid Sharifzadeh:** Writing – review & editing, Visualization, Software. **Hamed Tabesh:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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