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DEVELOPMENT OF GAME APPLICATION-BASED EDUCATION TOWARDS ADOLESCENTS' KNOWLEDGE LEVEL: MIXED METHODS

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ABSTRACT
Diabetes mellitus (DM) is a chronic disease whose prevalence continues to increase, including in adolescents. Knowledge about DM prevention in adolescents remains low, so innovative and engaging educational media are needed. This study aims to evaluate the effectiveness of educational games based on crossword puzzles and word searches in increasing the knowledge of adolescents at risk of DM. The study employed a Research and Development (R&D) design, comprising stages of application design, expert validation, and limited trials, conducted on 35 adolescents aged 12–18 years using purposive sampling. Community nurses and psychiatric nurses carried out validation. Knowledge was measured using the Diabetes Knowledge Questionnaire-24 (DKQ-24) through pre-test and post-test, and then analysed using the Wilcoxon Signed-Rank Test. The results showed a significant increase in knowledge scores from 11.0 ± 1.8 in the pre-test to 18.4 ± 1.7 in the post-test ($p < 0.05$). Expert validation confirmed that the application is suitable for use as an educational medium, with satisfaction scores > 4.0 in most aspects. Respondents found the game to be interactive, fun, and helpful in understanding important concepts related to diabetes, although some felt that the difficulty level needed adjustment. This educational game effectively increases the knowledge of adolescents at risk of diabetes and has the potential to be integrated into adolescent health promotion programs. Interactive technology-based media can serve as an engaging educational alternative, supporting community efforts to prevent diabetes.

Keywords: adolescent; diabetes mellitus; educational games; knowledge; teenagers

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INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic disease characterized by elevated blood glucose levels, which, if uncontrolled, can lead to serious health complications (Guo et al., 2023; Ramachandra Bhat et al., 2019). The two most common types of DM are type 1 diabetes (T1D) and type 2 diabetes (T2D). Type 1 Diabetes (T1D) is an autoimmune disease characterized by the destruction of insulin-producing beta cells in the pancreas, resulting in absolute insulin deficiency (Nassar et al., 2021). In contrast, type 2 diabetes (T2D) is characterized by insulin resistance and relative insulin deficiency. Distinguishing between these two types is crucial for optimal treatment, as patients with type 1 diabetes (T1D) require exogenous insulin supplementation. In contrast, patients with T2D may benefit from lifestyle interventions, oral hypoglycemic agents, or insulin, depending on the severity and progression of the disease (Cano-Cano et al., 2022; Eberle & Stichling, 2021; Guo et al., 2023). Genetic or viral factors can cause type 1 Diabetes (T1D). This type of disease mainly occurs in childhood or adolescence but can also develop during adulthood (Nevo-Shenker et al., 2020). Adolescence is the transitional phase of life between childhood and adulthood, spanning from approximately 10 to 19 years of age. It is a unique stage of human development and a crucial time for laying the foundation for good health. Adolescents experience rapid physical, cognitive, and psychosocial growth. This influences their feelings, thinking, decision-making, and interactions with the world around them. To grow and develop healthily, adolescents require comprehensive, age-appropriate information to inform the design and delivery of interventions that improve and maintain their health (WHO, 2023).

According to data from the International Diabetes Federation (IDF), approximately 463 million people aged 20-79 years worldwide had diabetes in 2019, and this number is expected to increase to 700 million by 2045 (IDF, 2020). The prevalence of diabetes mellitus (DM) in Indonesia increased by 8.5% of the total population in 2018 (KemenkesRI, 2020). According to data from the Gondang Community Health Center in Tulungagung Regency, the number of DM sufferers over the past three years was recorded at 432 patients in 2019, 457 patients in 2020, and 457 patients in 2022. According to data from the Central Statistics Agency (BPS) of Tulungagung Regency, the number of Generation Z (born between 1997 and 2012) reached 6,792 (Badan Pusat Statistik Kabupaten Tulungagung, 2021). According to research by Al-Shorman et al., overall self-efficacy scores increased significantly after health education was provided to adolescents and their parents, particularly those with children who have diabetes (Al-Shorman et al., 2023). Meanwhile, research in Indonesia by Ratnasari states that health information is urgently needed today, and awareness of healthy lifestyles can be achieved if health education is provided optimally. The public will be more likely to adhere to health measures if they are frequently exposed to information and receive as much information as possible through various media, such as reading, watching, and receiving health education from existing health services (Ratnasari, 2019).

One effective way to increase public knowledge and awareness among individuals with diabetes is through ongoing health education and counseling, which can refresh and remind them of management principles (Ratnasari, 2019). Health education is provided to enhance individual knowledge, attitudes, and behaviors, to improve diabetes prevention (Karingga et al., 2023a, 2023b; Simbolon et al., 2021). Thus, patient education can contribute to disease prevention by motivating sufferers to become more independent and adopt healthier methods (Sassen, 2017). Education also plays a crucial role in encouraging patients to engage in risk reduction for optimal health proactively (Kent et al., 2013). Therefore, more adaptive and engaging intervention strategies are needed. Educational games, also known as serious games, offer a promising alternative approach. Through interactive and contextual presentation of material, games can enhance adolescents' understanding and engagement in health issues (Radhakrishnan et al., 2021). Furthermore, game elements such as challenges, instant feedback, and decision-making simulations enable more effective and enjoyable learning (Abdillah et al., 2024). However, there are still limited games developed explicitly for DM education in adolescents, especially those that are evidence-based and designed to promote long-term behavior change. This study aims to develop and evaluate an educational game aimed at adolescents at risk of DM, using a scientifically integrated approach to improve health literacy and foster sustainable healthy lifestyle behaviors.

METHOD

This study employed a Research and Development (R&D) approach with a mixed-methods design, combining qualitative and quantitative methods to develop and evaluate an educational game application designed to improve diabetes mellitus (DM) knowledge among at-risk adolescents. The model used refers to the basic stages of R&D, including problem identification, data collection, product design, design validation, feasibility testing, and limited trials. The first stage began with identifying potential issues and problems that formed the basis for product development. Researchers conducted initial observations and interviews with adolescents at risk of DM, their parents, and healthcare professionals to explore their understanding of DM and their preferred educational media. Data obtained from these interviews and observations were then analyzed qualitatively to gain an in-depth knowledge of adolescents' emotional needs and preferences for digital interventions. Next, quantitative data were obtained through a questionnaire that measured adolescents' knowledge levels regarding DM. This data collection was used to develop the concept of educational materials to be integrated into the game.

During the product design stage, the collected information was used to develop the initial concept for an educational game based on crossword puzzles or word searches. Each game level is designed to convey important information related to DM, with educational materials or summaries of the

topics discussed at each stage of the game as a bonus. This process is outlined in a Game Design Document (GDD), which covers the storyline, game mechanics, user interface (UI) design, and user experience (UX). The design emphasizes creating a game that is both educational and enjoyable, while addressing the emotional factors of teenagers to keep them engaged and motivated.

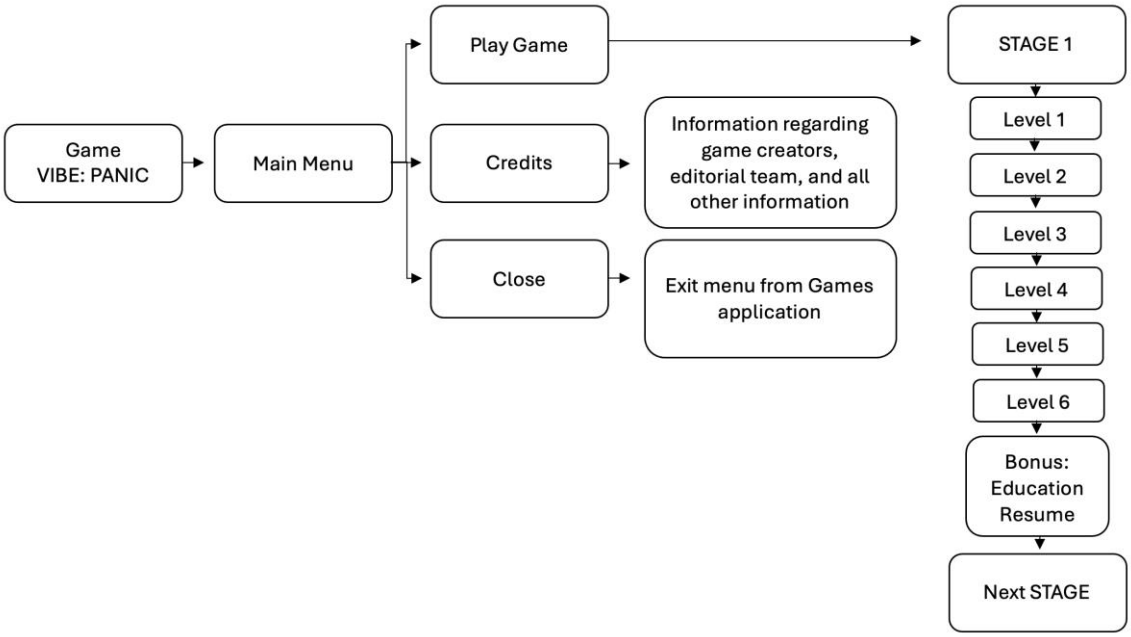


Figure 1. Game Application Flowchart

In the design validation stage, the game was validated by experts, including community nurses and psychiatric nurse specialists. The purpose of this validation was to ensure that the game design aligns with the emotional and psychological needs of adolescents and that the educational material presented is accurate and grounded in scientific evidence. Based on feedback from the experts, improvements and revisions were made to the design to enhance the game's quality and acceptability.

Following the revisions, in the feasibility test stage, the game prototype was tested by a small group of adolescents at risk of DM. At this stage, the game's functionality, understandability, and appeal were tested. Feedback from users and experts was used to evaluate the game's feasibility for larger-scale trials. The final stage was a limited trial with 35 adolescents at risk of DM according to the inclusion criteria (family with a history of diabetes, obese adolescents, lack of physical activity) and exclusion (adolescents with physical limitations, adolescents with a background of parents and health vocational education, and DM sufferers) using a purposive sampling technique. They completed pre- and post-tests to measure changes in their knowledge and attitudes toward DM before and after using the game. Quantitative data obtained from the questionnaires were analyzed using the Wilcoxon rank sum test to identify significant changes. Additionally, qualitative data from interviews and observations during the trial were analyzed thematically to evaluate user experience, the effectiveness of the educational materials, and any challenges encountered during the game's use. The results of this trial will serve as the basis for further revisions and the development of more optimal products.

RESULT

This study involved 35 adolescents aged 12 to 18 years who were at risk of diabetes mellitus (DM). Inclusion criteria included adolescents with risk factors such as obesity, a family history of DM, or an unhealthy lifestyle. Up to fifty-five percent of the participants were female, with the majority coming from lower-middle-income families. Before the application's implementation among respondents, the feasibility and design validation results indicated that the game was suitable for use as an educational medium for adolescents. Experts, including psychiatric nurses and community nurses, assessed that the game design was ideal for adolescents' emotional and psychological needs, and that the material presented was grounded in scientific evidence. This validation ensured that the

game was not only visually appealing and interactive but also educational in a way that was fun and easily understood by adolescents.

Table 1.
Results of the Feasibility Assessment of Educational Game Applications

No	SUS Statement	Average Score (1-5)	Description
1	"I found this app easy to use."	4.4	Users found the game interface intuitive and easy to use.
2	"I found this app too complicated."	2.2	A small percentage of users found the app to be moderately complex.
3	"I found this app to work well."	4.7	Users found the app to function smoothly and without technical issues.
4	"I found this app very consistent."	4.5	The app interface was consistent throughout and the user experience was smooth.
5	"I felt I needed to learn a lot to be able to use this app."	2.5	Users found the app relatively easy to understand without extensive training.
6	"I felt this app made me feel confident using technology."	4.3	Users felt comfortable and confident using the app.
7	"I didn't find this app easy to use."	2.1	Users encountered some minor difficulties, but they did not detract from the overall experience.
8	"I felt this app had too many useful features."	4.6	Users felt the app provided helpful features.
9	"I felt I needed to rely on technical support to use this app."	2.3	Users found the app simple enough to use without technical assistance.
10	"Overall, I really enjoyed my experience using this app."	4.8	Users were satisfied and happy with their experience using the game app.

Before the intervention through the Educational Game Application (VIBE), a pre-test was conducted to determine the participants' level of knowledge regarding diabetes mellitus (DM). This knowledge measurement is crucial in providing a basis for comparison with post-intervention results, enabling an objective evaluation of the application's effectiveness. The instrument used was the Diabetes Knowledge Questionnaire-24 (DKQ-24), a standard questionnaire widely used to assess individuals' understanding of diabetes. Furthermore, the same questionnaire was administered again after the intervention, as a post-test, to determine the extent of changes or improvements in knowledge among adolescents at risk of diabetes.

Table 2.
Average Knowledge Score of Respondents

Measurement	Mean ± SD	Minimum	Maximum
Pre-Test	11,0 ± 1,8	8	14
Post-Test	18,4 ± 1,7	15	21

Based on the table above, the average knowledge score of respondents before the intervention (pre-test) was 11.0 ± 1.8, with the lowest score being eight and the highest being 14. This indicates that adolescents' knowledge level was still in the low to moderate category (approximately 45.8% of the maximum score of 24). After the intervention using the Educational Game Application, the average score increased to 18.4 ± 1.7, with a minimum score of 15 and a maximum score of 21, or approximately 76.7% of the maximum score. The average difference of 7.4 points indicates a consistent increase in knowledge across all respondents. The Wilcoxon Signed Rank Test showed a p-value <0.05, concluding that there was a significant difference between knowledge scores before and after the intervention.

Qualitative data obtained from interviews and observations indicated that adolescents felt actively engaged in the game, with many reporting that the game was enjoyable and motivated them to change their diet and increase physical activity. One participant stated, "I learned about the glycemic index and how to choose foods after playing this game. It really helped me be more mindful of what I eat." While feedback was mostly positive, some participants indicated that the difficulty level on some levels was too challenging and needed adjustments to increase their comfort and engagement.

A limited trial also showed that most participants began to apply the knowledge gained in their daily lives, such as reducing their consumption of sweets and choosing healthier foods, as well as increasing the frequency of physical activity, such as walking. This suggests that this educational game can be an effective tool in changing the behaviours of adolescents at risk for diabetes toward healthier ones. Overall, the results of this study suggest that educational games based on crossword puzzles and word searches have significant potential to enhance knowledge, attitudes, and behaviours related to diabetes among adolescents. By combining academic and entertainment elements, this game could be an effective alternative intervention to support diabetes prevention in at-risk adolescent populations.

DISCUSSION

This study demonstrates that the use of educational games based on crossword puzzles and word searches significantly improves adolescents' knowledge of diabetes mellitus (DM). Before the intervention, adolescents' knowledge regarding DM was low, with an average score of 11, which then increased to 18.4 after interacting with the educational game. This finding aligns with research by Marsiami (2021), which demonstrated the ability of games to improve health knowledge in adolescents (Azizati Salmas Marsiami, 2021). This improvement was primarily due to the interactive and fun approach to delivering the material, which made adolescents more interested in actively participating and learning essential concepts regarding DM, such as blood sugar management, healthy eating patterns, and the importance of physical activity.

In addition to increased knowledge, this study also demonstrated significant changes in the attitudes and behavioural intentions of adolescents regarding health. In the pre-test, their attitude and behavioural intentions scores were still low; however, after using the educational game, their post-test scores showed a significant increase. This improvement aligns with the findings of research by Fauziyah et al. (2025), who discovered that gamification elements, such as challenges and rewards, can encourage healthy behaviours among adolescents (Nina Rohmatul Fauziyah et al., 2025). In this game, participants were challenged to choose healthy foods and commit to higher physical activity goals. The use of elements such as level achievements and educational bonuses at the end of each stage proved effective in increasing adolescent motivation and engagement. However, although this educational game successfully increased knowledge and behavioural intentions, some participants expressed that the difficulty level of some game levels was too high. This highlights the importance of adjusting gamification elements to ensure that the user experience remains enjoyable and not overwhelming. This adjustment in difficulty level is also discussed by Sun et al. (2023), who emphasise that the development of educational media for adolescents must consider the level of accessibility so that all audiences can feel comfortable and avoid frustration in participating in the game (Sun et al., 2023).

The practical implications of this research indicate that technology-based educational games can be an effective tool in supporting public health programs, particularly in the prevention of diabetes mellitus in adolescents. A program like this could easily be integrated into school activities or adolescent health clinics, as adolescents are more drawn to interactive and entertaining forms of media. This research also presents opportunities for further development by incorporating additional personalised features, such as real-time health monitoring and integration with wearable devices, to provide a more immersive and contextual experience. This study has several limitations, including the limited number of participants and the reliance on self-report measures to assess behaviour change. Therefore, further research is needed to involve larger and more diverse samples and use more objective measurement techniques, such as digitally monitored physical activity and food consumption.

CONCLUSION

This study demonstrates that an educational game based on crossword puzzles and word searches is efficacious in improving adolescents' knowledge, attitudes, and behavioural intentions regarding

diabetes mellitus (DM) prevention. The trial results showed a significant increase in knowledge scores from 11.0 to 18.4 after the intervention, accompanied by positive changes in adolescents' attitudes and motivation to adopt healthy lifestyles, such as choosing nutritious foods and increasing physical activity. Expert validation also confirmed that the game design aligns with the emotional and psychological needs of adolescents and is suitable for use as an evidence-based educational medium. The implications of this study suggest that educational games can be an effective alternative strategy in health promotion programs, especially among adolescents who are more attracted to interactive media. Integrating this game into school activities and adolescent health services has the potential to support early diabetes prevention efforts. However, limitations such as the limited number of participants and the use of self-report instruments suggest the need for further research with larger sample sizes, more objective measurement methods, and the development of adaptive features to make the game more relevant and sustainable in shaping adolescents' healthy lifestyle behaviours.

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