A Gamified Mobile Health Framework for Pediatric Tuberculosis Treatment Adherence

Ivan Rachmawan[1], Badrul Munif[2], Muhamad Rois[3], Hasim As'ari[4], Atik Pramesti, Wilujeng[5]

[1,3,4]Lecture of the Computer Science Department, University of Dr. Soekardjo, Banyuwangi, Jawa Timur 68422, Indonesia

[3,5]Lecture of Nursing Department, University of Dr. Soekardjo, Banyuwangi, Jawa Timur 68422, Indonesia

ABSTRACT: Tuberculosis (TB) treatment in children requires long-term adherence to anti-tuberculosis drug therapy (OTD), which often leads to boredom and refusal to take medication. Non-adherence to treatment can increase the risk of treatment failure, relapse, and drug resistance. This study proposes a mobile health-based gamification framework designed to improve treatment adherence in pediatric TB patients by integrating game elements into the therapy monitoring process. The gamification framework was developed using a user-centered approach by identifying factors influencing adherence through interviews with pediatric patients, medication supervisors (PMOs), and healthcare professionals. Aspects of medication adherence were mapped using the Morisky Medication Adherence Scale (MMAS-8) and classified into dimensions of behavior, motivation, knowledge, and memory. User characteristics were analyzed using the HEXAD gamification user types questionnaire to determine the dominant user type. The analysis showed that the dominant user type in pediatric TB patients was the player type, followed by the socializer type and the free spirit type. Based on these findings, a gamification framework was designed that includes points, rewards, challenges, reminders, and progress visualization mechanisms. Expert evaluation using the After-Scenario Questionnaire (ASQ) demonstrated high levels of satisfaction and confidence that the proposed framework has the potential to improve treatment adherence. This study demonstrates that mobile health-based gamification design has strong potential as a behavior change strategy to support long-term pediatric TB treatment.

KEYWORDS: Gamification, Mobile Health, Pediatric Patients, Tuberculosis, Treatment Adherence

INTRODUCTION

Tuberculosis (TB) remains a global health problem with a significant incidence rate in children (WHO, 2024). Treatment of TB in children requires long-term therapy for six to eight months with the obligation to take OAT every day (Duarte et al., 2025). Treatment of TB in children requires long-term therapy for six to eight months with the obligation to take OAT every day. (Leddy et al., 2022). Non-compliance with TB therapy can result in treatment failure, increased risk of relapse, and the emergence of drug resistance (Ferreira et al., 2025). Studies show that non-adherence to tuberculosis therapy remains high in many settings. For example, research in Indonesia reported that approximately 27.2% of TB patients were non-adherent to their treatment. (Lolong et al., 2023). In some populations, especially high-risk groups (e.g., during a pandemic or in regional studies), non-adherence can reach much higher rates. For example, one study found 34.5% non-adherence during a specific period. (Omar et al., 2024).

Therefore, innovative approaches are needed to support medication adherence in pediatric patients. Advances in mobile device technology have opened up opportunities for the application of mobile health (mHealth) as a means of monitoring and assisting with therapy (Wu et al., 2023). However, conventional mHealth systems that rely solely on reminders are often ineffective in maintaining children's motivation. This suggests that reminders alone are often insufficient to maintain long-term motivation for behavior change or adherence to therapy (Eaton et al., 2024). A systematic review study found that gamification, as the application of game elements in non-game contexts, has the potential to increase engagement and positively influence behavior change (Alzghoul, 2024). This study aimed to design a mobile-based gamification framework to improve TB treatment adherence in pediatric patients.

Gamification is defined as the use of game elements in a non-game context to increase user motivation and engagement. In the health context, gamification has been used to encourage behavior change, such as increased physical activity, chronic disease management, and medication adherence (Alzghoul, 2024). Several studies have shown that game elements such as points, badges, challenges, and leaderboards can increase users' intrinsic and extrinsic motivation. (Khaldi et al., 2023). TB treatment using mobile technology is more focused on monitoring compliance, but is still limited in motivational aspects, especially in pediatric patients

who have cognitive, emotional and self-regulation limitations (Eaton et al., 2024) Therefore, the HEXAD gamification user types model is needed, which can provide a systematic approach to designing gamification based on user characteristics, so that the game elements used can be tailored to the user's dominant motivations.

The HEXAD gamification user types model offers a systematic approach to gamification design by grouping users into six motivational types: Philanthropist, Socializer, Free Spirit, Achiever, Player, and Disruptor. *(Tondello et al., 2016)*. This approach allows developers to tailor game elements to users' dominant characteristics and motivations, making gamification interventions more personalized, relevant, and potentially effective in improving behavior change, including in the context of assisting with TB therapy in children.

The HEXAD gamification user types model provides a relevant theoretical framework to address this need, as it allows for the personalization of gamification elements based on the user's motivational type. Integrating mHealth principles and HEXAD-based gamification in assisting with TB therapy in children is expected to create interventions that not only serve as adherence monitoring tools but also as a means of sustainably increasing intrinsic and extrinsic motivation (Subirats et al., 2023). Therefore, this study develops a conceptual framework that links the implementation of HEXAD-based gamification in mHealth systems with increased user engagement and adherence to TB therapy in children, which then becomes the basis for formulating research hypotheses.

MATERIALS AND METHODS

Research Design
This research uses a design-oriented research approach consisting of four stages, namely identification of compliance factors, data collection, data analysis, and evaluation of gamification design.

Setting
This research was conducted at the Klatak Community Health Center (Puskesmas) in Banyuwangi Regency, East Java. The location was selected based on the high number of childhood TB cases and the community's familiarity with mobile technology. The study used a design and development (design research) approach with the following stages: survey scale construction, data collection, data analysis, and post-scenario evaluation. Data collection was conducted through interviews, questionnaires, and medical record studies of pediatric TB patients.

Sample
The sample used in this study were children diagnosed with pulmonary TB and registered as active patients at the Klatak Community Health Center (Puskesmas). These included children aged 6–18 years, undergoing intensive or advanced TB treatment, accompanied by a parent/family member (PMO), and willing to participate in the research process, interviews, and questionnaires. Based on these criteria, the total sample size was 9 pediatric patients with pulmonary TB out of a total of 12 pediatric TB patients registered at the Klatak Community Health Center in 2018. In addition to the pediatric patients, the study also involved: the Drug Swallowing Supervisor (PMO) for each patient and four experts (2 physicians and 2 psychologists) during the scale construction and gamification design evaluation stages.

Data Collection
Data was collected through interviews with pediatric TB patients, PMOs, and healthcare workers. The MMAS-8 instrument was used to identify factors influencing treatment adherence. User type characteristics were determined using the HEXAD gamification user types questionnaire to determine user motivational tendencies.

Data Analysis
The MMAS-8 items were grouped into behavioral, motivational, knowledge, and memory aspects based on expert interpretation. The HEXAD questionnaire data was analyzed to determine the dominant user types that informed the selection of gamification elements.

Gamification Framework Design.
The gamification framework was designed by mapping adherence aspects and user types into relevant game elements, such as a points system, daily challenges, virtual rewards, medication reminders, and therapy progress visualizations.

Evaluation

The evaluation was conducted by experts using the After-Scenario Questionnaire (ASQ) to assess satisfaction and confidence in the effectiveness of the proposed gamification design

RESULTS

Results of the Medication Adherence Measurement Scale Construction

The results of interviews with experts (doctors and psychologists) regarding the Morisky Medication Adherence Scale (MMAS-8) resulted in a grouping of factors influencing medication adherence in pediatric TB patients into four main aspects: behavior, motivation, knowledge, and memory.

Table 1. Interpretation of MMAS-8 Items by Experts

Item Code	MMAS-8 Question (Summary)	Compliance Aspect
Q1	Forgot to take medication	Behavior
Q2	Failed to take medication	Motivation
Q3	Stopped taking medication due to side effects	Knowledge
Q4	Forgot to take medication when traveling	Behavior
Q5	Took medication yesterday	Memory
Q6	Stopped medication when feeling well	Knowledge
Q7	Feels like taking medication every day is a hassle	Motivation
Q8	Difficulty remembering to take medication	Behavior

Based on table 1, it shows that non-compliance with TB treatment in children is not only caused by forgetfulness, but is also influenced by understanding the disease, psychological fatigue, and intrinsic and extrinsic motivation.

Results of Identification of PMO and Pediatric Patient Problems

The results of interviews with Drug Swallowing Supervisors (PMO) and pediatric TB patients identified various obstacles during the treatment therapy process.

Table 2. Results of Identification of PMO and Pediatric Patient Problems

Source	Main Problems	Compliance Aspect
PMO	Forgetting medication and check-up schedules	Memory
PMO	Concerns about medication side effects	Knowledge
PMO	Lack of understanding the risks of withdrawal	Knowledge
Children	Boredom in taking long-term medication	Motivation
Children	Refusing to take medication due to side effects	Behavior
Children	Not being reminded when it's time to take medication	Memory

Based on table 2. These results emphasize the importance of an approach that is able to overcome boredom, increase understanding, and strengthen the role of PMO in the therapy process.

Characteristics of Child TB Patient Gamification User Types

The results of measuring user types using the Hexad Gamification User Type Questionnaire show that children with TB have a strong tendency towards certain user types.

Table 3. Percentage of Gamification User Types for Pediatric TB Patients

Percentage of Gamification User Types for Pediatric TB Patients	Presentage (%)
Player	84,05
Socializer	82,38
Free Spirit	79,29
Achiever	78,33
Philanthropist	69,76
Disruptor	46,19

Based on table 3. The type of use is dominated by the Player type, followed by Socializer and Free Spirit, which indicates that children are more motivated by rewards, competition, social interaction, and freedom to explore.

Mapping Compliance Aspects with Gamification Elements

Based on the analysis results, compliance aspects are then mapped with appropriate game elements to form a gamification framework.

Table 4. Mapping Compliance Aspects and Gamification Elements

Compliance Aspect	Gamification Elements
Behavior	Daily challenges, checklist, progress bar
Motivation	Poin, badge, reward virtual, leaderboard
Knowledge	TB educational games, interactive quizzes, storytelling
Memory	Level-based reminders, adaptive notifications

Based on table 4. This framework is designed so that each element of the game directly targets the main causes of medication non-compliance.

DISCUSSION

The results of this study indicate that adherence to childhood TB treatment is a multidimensional phenomenon that cannot be effectively addressed through a reminder approach alone. Traditional reminder approaches generally only target memory aspects, while this study found that adherence is influenced by behavior, motivation, knowledge, and memory, which interact and influence each other. In theory, the self-care approach used in chronic disease management emphasizes that health care behaviors involve complex cognitive and motivational processes, including self-monitoring and long-term symptom management (Mosleh et al., 2024).

The Health Belief Model is also highly relevant in the context of medication adherence because it asserts that an individual's perception of benefits, barriers, and cues to action significantly influence the decision to adhere, making approaches that rely solely on reminders insufficient to address psychosocial and motivational barriers. (Alyafei & Easton-Carr, 2024). This finding is also consistent with recent studies showing that interventions that combine behavior modification with theory-based education are more effective in improving adherence to treatment (Tian et al., 2024). Therefore, TB treatment adherence interventions for children need to be designed in a comprehensive and integrated manner, combining cognitive, motivational, and behavioral aspects to produce sustainable behavioral changes.

The dominance of Player and Socializer user types suggests that children are more responsive to reward-based approaches, challenges, and social interactions than to passive education. This finding aligns with Self-Determination Theory, which states that intrinsic motivation develops when the need for competence and relatedness is met through achievement and social interaction (Ryan & Deci, 2020). Recent systematic studies have shown that gamification with points, levels, and social features significantly increases engagement and adherence to health behaviors in children compared to conventional educational approaches (Sardi et al.,

2017). Within the framework of behavior change gamification, game elements act as reinforcement, encouraging the gradual formation of healthy habits through repetition and positive feedback. The authors argue that in the context of pediatric TB treatment, this approach is more appropriate to the child's psychosocial developmental stage and has the potential to lead to more sustained engagement.

The involvement of PMOs with Philanthropist characteristics strengthens the framework's effectiveness because the system not only motivates children as patients but also facilitates caregivers as active partners in the therapy process. This finding aligns with Family-Centered Care Theory, which emphasizes that family involvement is a key component in the successful treatment of chronic illnesses in children. Empirical evidence shows that consistent family support significantly contributes to improved treatment adherence and long-term therapy sustainability in pediatric populations (Subirats et al., 2023). The perspective of Self-Care Theory in Chronic Illness, caregivers act as self-care agents who bridge the limitations of children's abilities in carrying out independent care (Riegel et al., 2019). Integrating the child and the PMO into a single mobile health ecosystem allows for continuous monitoring, two-way feedback, and more effective collaboration. The authors argue that this collaborative approach improves treatment adherence while strengthening the emotional bond between the child and caregiver.

CONCLUSION

Overall, the resulting gamification framework has the potential to be an innovative solution for improving adherence to pediatric TB treatment, particularly in long-term therapy, which is prone to burnout and discontinuation. Although this research is still limited to the design and expert evaluation stages, the results provide a strong foundation for future implementation and clinical effectiveness trials. This study proposes a mobile health-based gamification framework to improve adherence to TB treatment in pediatric patients. By integrating a user-centered approach and the HEXAD gamification model, the designed framework is able to accommodate behavioral and motivational factors that influence adherence.

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