Original Article

Effectiveness of Game Health Education Anemia (GHEA) Guided by the Health Belief Model on Improving Knowledge and Attitudes Toward Iron-Deficiency Anemia Prevention Among Adolescent Girls: A Quasi-Experimental Study

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ABSTRACT

Background: Iron-deficiency anemia (IDA) remains a significant health problem among adolescent girls, affecting growth, academic achievement, and reproductive health. Traditional education methods like lectures and booklets are often less engaging and ineffective in changing behavior. Few studies have tested gamified, theory-based health education for anemia prevention in Indonesian adolescents. This study evaluated the effectiveness of the Game Health Education Anemia (GHEA) compared with a Digital Pocket Book in improving knowledge and attitudes toward IDA prevention among adolescent girls.

Methods: A quasi-experimental study, guided by the Health Belief Model (HBM) and reported according to the TREND checklist, was conducted at SMP Islam Ma'arif 02 Malang, Indonesia, in June 2025. Sixty female adolescents were selected through purposive sampling based on power analysis (effect size = 1.12, $\alpha = 0.05$, power = 0.95). Inclusion criteria were female students aged 12–18 years, healthy, and owning a digital device; exclusion criteria were prior exposure to digital anemia education or incomplete participation. Participants were equally assigned to an intervention group (GHEA) and a control group (the Digital Pocket Book). Data were collected using a validated questionnaire and analyzed with Wilcoxon signed-rank, paired t-, and Mann–Whitney U tests at a 0.05 significance level.

Results: The mean age of participants was 14 years (range 13–15). The GHEA group showed significant improvements in knowledge ($Z = -4.847$, $p < 0.001$) and attitudes ($Z = -4.275$, $p < 0.001$), while the control group showed smaller yet significant gains. Between-group analysis revealed higher post-test scores in the intervention group for both knowledge ($Z = -5.284$, $p < 0.001$) and attitudes ($Z = -3.081$, $p = 0.002$).

Conclusion: The GHEA intervention was more effective than the Digital Pocket Book in improving adolescents' knowledge and attitudes toward IDA prevention, indicating that gamification-based education can serve as an engaging and effective tool for school-based health promotion

Keywords: Adolescent; Anemia, Iron-Deficiency; Health Knowledge, Attitudes, Practice; Health Education; Games.

Implications for Practice:

- Integrating gamification-based tools like GHEA into clinical and community practice can enhance adolescent engagement and improve preventive outcomes in anemia management.
- Incorporating gamified education into health policy frameworks may optimize program delivery, support

Implications for Practice:

intersectoral collaboration, and strengthen national anemia prevention strategies.

- Embedding gamification in midwifery and nursing education offers a cost-effective, scalable approach suitable for resource-limited settings in Low- and Middle-Income Countries (LMICs).

Introduction

Iron-deficiency anemia (IDA) remains the most prevalent form of anemia worldwide. It poses a significant public health challenge, particularly among adolescent girls due to increased iron demands during growth and menstruation. According to the World Health Organization, approximately 30% of women aged 15–49 years and 37% of pregnant women globally are affected, with the highest burden in low- and middle-income countries, including Southeast Asia (WHO, 2023). Iron deficiency accounts for over half of all anemia cases (Gardner et al., 2023; L. Wang et al., 2024). During adolescence, IDA not only causes fatigue, dizziness, and pallor but also leads to impaired cognition, poor academic performance, and reduced physical endurance (Samson et al., 2022). Long-term consequences extend to adulthood, contributing to adverse maternal outcomes such as low birth weight and stunting (Kolarš et al., 2025). Strengthening adolescents' knowledge and attitudes toward anemia prevention is therefore essential for breaking this intergenerational cycle.

In Indonesia, the prevalence of anemia among females aged 15–24 years increased from 18.4% in 2013 to 32% in 2018, affecting approximately 14.7 million individuals (Adhi & Asmin, 2024). Further studies revealed that nearly half (48.9%) of adolescent girls experienced anemia, primarily due to inadequate dietary intake and poor adherence to iron supplementation (Loury Priskila et al., 2025). Local health surveillance in Malang City, East Java, confirmed that 45.7% of students at SMP Ma'arif, under the Janti Public Health Center, had mild to moderate anemia, likely related to iron deficiency. This high prevalence underscores the urgent need for school-based health education strategies that can effectively enhance adolescents' understanding and attitudes toward anemia prevention.

Despite the implementation of national programs such as weekly Iron and Folic Acid Supplementation (IFAS) and Gerakan Aksi Bergizi, adolescents' knowledge and attitudes toward anemia prevention remain suboptimal (Helmyati et al., 2024; Hidayanty et al., 2025; UNICEF, 2023). Studies have shown that limited health literacy and negative perceptions of supplementation contribute to poor program participation (Jayanti & Anggraeni, 2025). Traditional health education methods, mainly lectures, posters, and pamphlets, tend to be unidirectional and less appealing to Generation Z adolescents (Allifah Vakhroh et al., 2022). In contrast, interactive and visually engaging media are more effective in capturing attention and improving learning outcomes (Aloi et al., 2025; Gkintoni et al., 2024; Mancone et al., 2024). "As digital literacy increases and adolescents spend more than three hours daily on screens (IDN Research Institute, 2025). Game-based learning emerges as a promising tool for enhancing health knowledge and shaping positive attitudes.

However, existing game-based health interventions often lack a strong theoretical foundation and sufficient interactivity, limiting their impact on learners' understanding and motivation (Alzghoul, 2024; Aschentrup et al., 2024; Glass & Galati, 2025). The Health Belief Model (HBM) provides a robust framework for

guiding such interventions, emphasizing perceived susceptibility, severity, benefits, barriers, cues to action, and self-efficacy (Huang et al., 2020; Muzayyana & Aini, 2024; Zewdie et al., 2022). When applied to anemia prevention, HBM can help enhance adolescents' knowledge and reshape their attitudes by increasing awareness of personal risk, emphasizing the seriousness of the condition, and highlighting the benefits of preventive actions (Andani et al., 2021). In this study, the constructs of the HBM were mapped to the targeted outcomes. Perceived susceptibility, severity, and benefits were expected to enhance adolescents' knowledge of iron-deficiency anemia, whereas perceived barriers, cues to action, and self-efficacy were anticipated to promote more positive attitudes toward its prevention. These relationships are illustrated in the conceptual framework (Figure 1).

However, few interventions have empirically tested gamification approaches grounded in behavioral theory, such as the Health Belief Model (HBM), for anemia prevention among Indonesian adolescents. Previous studies have mainly focused on conventional health education methods or non-theoretical digital games, which often fail to produce sustained improvements in health knowledge and attitudes. This highlights a critical need for theoretically grounded, interactive educational strategies that can effectively engage adolescents in learning about anemia prevention. To address this gap, the present study introduces the Game Health Education Anemia (GHEA), an interactive digital game designed on Kahoot! platform to enhance adolescents' engagement and understanding. GHEA integrates five core components educational animation videos, story-based learning, structured educational materials on anemia, quiz-based gamification, and teamwork to create an active, collaborative, and enjoyable learning experience (Adiati et al., 2023; Adipat et al., 2021; Aggrawal & Boowuo, 2023; Febrianti et al., 2023; Shofiyyah et al., 2024; A. I. Wang & Tahir, 2020). Guided by the Health Belief Model (HBM), GHEA aims to enhance adolescents' knowledge and attitudes toward iron-deficiency anemia prevention by increasing perceived susceptibility and perceived severity, emphasizing the benefits of preventive actions, reducing perceived barriers to behavioral change, providing cues to action through interactive feedback, and strengthening self-efficacy through teamwork and collaborative learning. This study aimed to evaluate the effectiveness of the GHEA intervention, guided by the Health Belief Model (HBM), compared to the Digital Pocket Book, in improving knowledge and attitudes toward iron-deficiency anemia prevention among Indonesian adolescent girls.

Methods

Study Design

This study employed a quasi-experimental pretest–posttest control group design, guided by the Health Belief Model (HBM) and reported according to the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) checklist. The intervention was conducted in June 2025 over a four-week period at SMP Islam Ma'arif 02 Malang, East Java, Indonesia.

Participants

A purposive sampling technique was employed in accordance with the TREND guideline to recruit participants who met the eligibility criteria. The study involved female adolescents enrolled at SMP Islam Ma'arif 02 Malang, East Java, Indonesia, representing a high-risk group for iron-deficiency anemia due to increased physiological demands during growth and menstruation. Recruitment was conducted in June 2025, in coordination with the school's administration, to ensure both administrative feasibility and adherence to inclusion criteria.

The inclusion criteria were female adolescents aged 12–18 years, in good general health, owning a digital device

(smartphone or tablet), and willing to participate from pretest to posttest. The exclusion criteria included refusal to provide informed consent, prior exposure to digital game-based anemia education, and incomplete participation in any study phase.

A total of 60 eligible students were identified and allocated into two groups (intervention and control) based on classroom clusters to minimize contamination between participants. Written informed consent was obtained from all participants and their legal guardians prior to data collection. No participants were lost to follow-up or excluded from analysis.

A total of 86 students were assessed for eligibility. Twenty-six students were excluded due to unavailability during data collection (Class VIII E, n = 4; Class VII B, n = 12; Class VII A, n = 10). Sixty eligible participants were allocated by class-cluster composition to the intervention group (GHEA; n = 30) or the control group (Digital Pocket Book; n = 30). All participants completed the intervention and post-test, and all were included in the final analysis (n = 60). No dropout or adverse events were reported.

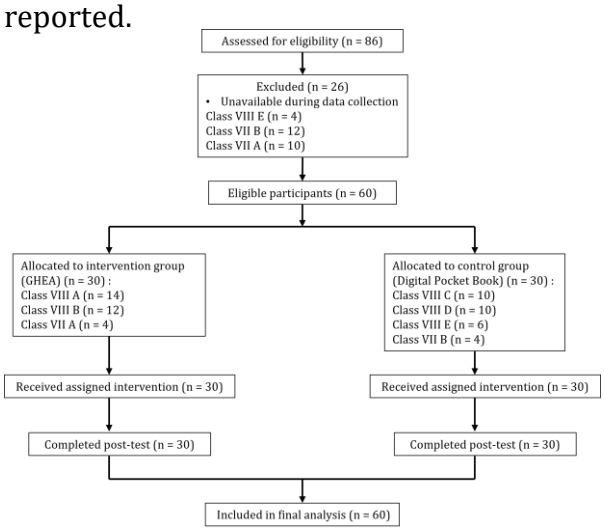

Figure 2. TREND Flow Diagram of Participant Recruitment, Allocation (by Class-Cluster Composition), and Analysis.

The sample size was determined a priori using G*Power 3.1 with an effect size of 1.12 (Abu-Baker et al., 2021), a significance level of α = 0.05, and a statistical power of (1–β) = 0.95, yielding a minimum of 53 participants. To account for a potential 10% attrition rate (f = 0.10), the adjusted sample size was calculated using the formula:

$$n' = \frac{n}{1-f} = \frac{53}{0.9} \approx 59$$

Thus, the final sample consisted of 60 participants, divided equally into the intervention and control groups (30 each). All participants completed the study, with no dropouts recorded.

Instruments

The questionnaire used in this study was adopted and adapted from a validated instrument developed by Indriasari et al. (2022) to measure adolescents' knowledge and attitudes toward iron-deficiency anemia prevention (Indriasari et al., 2022). The original questionnaire demonstrated satisfactory psychometric properties, with Cronbach's alpha values of 0.713 for the knowledge section and 0.726 for the attitude section, indicating acceptable internal consistency.

The adaptation process involved forward–backward translation between English and Indonesian by two bilingual experts in nursing and public health to ensure semantic and conceptual equivalence. The Indonesian version was subsequently pilot-tested among 36 adolescent girls with similar characteristics to the study population to assess clarity, cultural appropriateness, and comprehension. Minor linguistic adjustments were made based on feedback before the instrument was finalized for use in this study.

This study used only the knowledge and attitude sections of the instrument.

The knowledge section consisted of 10 multiple-choice questions, scored 1 for correct and 0 for incorrect answers, yielding a total score range of 0–10.

The attitude section comprised 10 items rated on a 4-point Likert scale from 1 (strongly disagree) to 4 (strongly agree), producing a total score range of 10–40.

Higher total scores indicated better knowledge and more positive attitudes toward anemia prevention. Formal permission to adopt and use the instrument was obtained from the corresponding author, Dr. Rahayu Indriasari, via official email correspondence.

Intervention

The intervention was implemented in June 2025 at SMP Islam Ma'arif 02 Malang, involving 60 female students who met the inclusion criteria. Participants were divided into two groups: intervention and control, each consisting of 30 students. Grouping was coordinated with the school administration to prevent cross-contamination between classes. All procedures were conducted face-to-face in classroom settings.

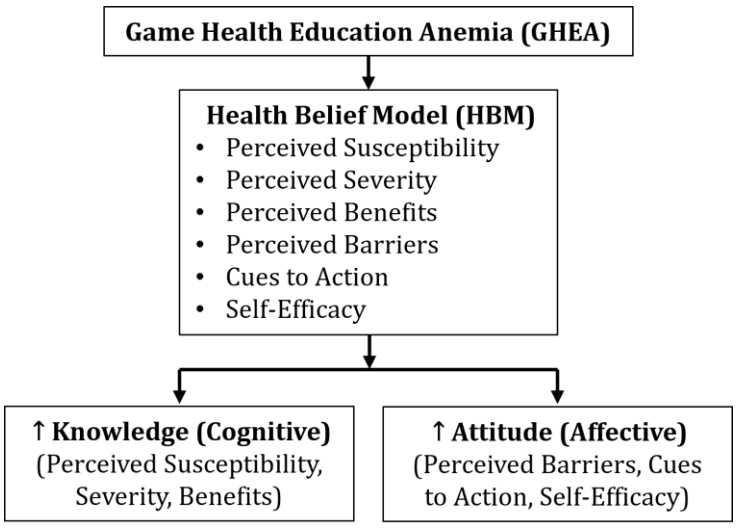

Figure 2. Conceptual Framework Based on the Health Belief Model (HBM)

The intervention was designed based on the Health Belief Model (HBM), which emphasizes six core constructs: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy. The GHEA was developed to operationalize these constructs as follows:

- Perceived susceptibility & severity: presented through animated stories illustrating the risks and impacts of anemia in adolescent girls.
- Perceived benefits: emphasized through discussions on healthy dietary habits and iron supplementation.
- Perceived barriers: addressed through problem-solving activities embedded in the quizzes.
- Cues to action: provided via in-game prompts, reminders, and visual feedback.

Self-efficacy: strengthened through team-based competition and immediate reinforcement of correct answers.

The intervention consisted of three stages:

Pre-test

At baseline, all participants completed the Knowledge and Attitude Questionnaire on anemia prevention via Google Forms, which took approximately 40 minutes. Before administration, the researcher explained the study objectives and confidentiality procedures. Participants were identified only by initials to maintain anonymity.

Health education sessions

The educational program was delivered over four sessions within one month, each lasting about 60 minutes.

- Intervention group: received health education through GHEA, an interactive game-based learning

media integrating animated educational videos and quizzes on the Kahoot! Platform. Each session included six segments combining storytelling, discussion, and quiz-based evaluation. The 30 participants were divided into six subgroups of five to enhance collaboration and engagement. Immediate feedback was provided after each quiz item to reinforce learning.

- Control group: received standard health education using the Digital Pocket Book for Anemia Prevention in Adolescents published by the Indonesian Ministry of Health (Kemenkes RI, 2023). Each session comprised 30 minutes of self-reading, followed by a 15-minute slide presentation by the facilitator and a 15-minute discussion.

Post-test:

Four weeks after the final session, all participants completed the same Knowledge and Attitude Questionnaire via Google Forms, requiring approximately 30 minutes to complete. The researcher then conducted a brief evaluation, provided appreciation certificates, and officially closed the program.

Fidelity and Safety Monitoring

To ensure consistent implementation of the intervention, all educational activities in the intervention group were directly conducted by the principal researcher, following a standardized intervention manual that had been previously developed. In contrast, the control group sessions were supported by a trained facilitator a registered nurse and lecturer with expertise in community health education who also adhered to the same intervention guidelines. Session checklists were used to monitor compliance with the intervention protocol. A research assistant observed each session to verify timing accuracy, content delivery consistency, and participant engagement. No adverse events or safety issues were reported throughout the study.

Data Collection

Data collection was conducted in June 2025 at SMP Islam Ma'arif 02 Malang, Malang Regency, East Java. The process comprised three main stages: pre-test, four educational intervention sessions, and post-test assessments. The principal researcher supported all health education sessions in the intervention group, administered the questionnaires, and ensured procedural fidelity throughout the study. Two trained research assistants supported the data collection process by distributing and monitoring the completion of Google Form questionnaires, organizing classroom logistics, and providing technical support during the GHEA sessions. Data quality assurance was ensured through enumerator training, double-entry verification, and automatic validation settings embedded in Google Forms to prevent incomplete responses. The research team performed consistency checks after each data collection phase. All questionnaires were fully completed, and no missing data required imputation.

Intervention fidelity was maintained by using standardized session plans, structured scripts, and researcher checklists for each session. The principal researcher facilitated all GHEA sessions directly to ensure uniform delivery and adherence to content.

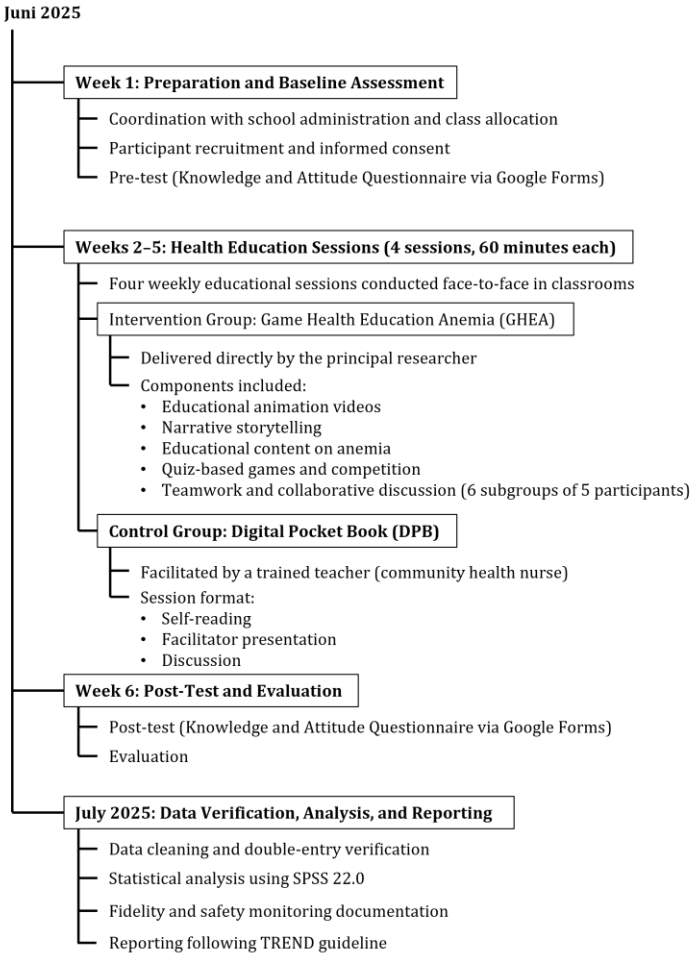

Figure 3. Workflow of Data Collection and Intervention Implementation

Figure 3. Workflow of Data Collection and Intervention Implementation showing the sequential process of recruitment, pre-test, intervention sessions, post-test, and data analysis conducted at SMP Islam Ma'arif 02 Malang in June–July 2025.

Data Analysis

Data analysis was conducted using both univariate and bivariate approaches. Univariate analysis described the demographic characteristics of participants and summarized baseline knowledge and attitude scores related to anemia prevention. Bivariate analysis assessed the effectiveness of the intervention by comparing pre- and post-test scores within and between groups.

The normality of data distribution was assessed using the Shapiro–Wilk test because each group consisted of fewer than 50 participants. Variables with normally distributed data ($p > 0.05$) were analyzed using parametric tests, while non-normally distributed data ($p < 0.05$) were analyzed using non-parametric tests. Specifically:

- Within-group comparisons (pre-test vs. post-test) used the paired t-test for normally distributed data and the Wilcoxon signed-rank test for non-normally distributed data.
- Between-group comparisons (intervention vs. control) used the independent samples t-test for normally distributed data and the Mann–Whitney U test for non-normally distributed data.

The effect size was calculated to determine the magnitude of intervention impact. For parametric tests, Cohen's d was computed; for non-parametric tests, effect size (r) was obtained using the formula $r = Z / \sqrt{N}$, where Z is the test statistic and N is the total number of observations. Effect size values were interpreted as small (0.1–0.3), medium (0.3–0.5), or large (>0.5). Ninety-five percent (95% confidence intervals) were reported for main estimates to enhance the interpretability of the findings.

All statistical analyses were conducted using IBM SPSS Statistics version 26.0 (Armonk, NY, USA), and effect sizes were verified using the online calculator at https://www.socscistatistics.com/effectsize/. A two-tailed p-value <0.05 was considered statistically significant.

Ethical Considerations

Ethical approval for this study was obtained from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Brawijaya

(No.156/UN10.F17.10.4/TU/2025). All participants and their guardians provided written informed consent prior to participation. The study adhered to the principles of the Declaration of Helsinki on ethical research involving human participants.

No adverse events or safety issues were reported during the intervention and data collection period.

Results

A total of 60 female students participated in this study. Participants' ages ranged from 13 to 15 years, with the majority aged 14 years (58.3%). Most fathers were private employees (56.6%), while most mothers were unemployed (60.0%). In terms of education, more than half of fathers (53.3%) and nearly half of mothers (46.6%) had completed senior high school. The majority of families had a monthly income between Rp 1,500,000 and Rp 3,500,000 (58.3%). Table 1 illustrates the demographic characteristics of the participants, indicating that most came from lower- to middle-income families with similar parental educational backgrounds.

Table 1. Demographic Characteristics of Participants

Characteristics	n (%)
Age (years)	
13	8 (13.3)
14	35 (58.3)
15	17 (28.3)
Father's Occupation	
Private employee	34 (56.6)
Entrepreneur / Self-employed	13 (21.6)
Laborer / Farmer / Trader Unemployed	11 (18.3)
	2 (3.3)
Mother's Occupation	
Private employee	14 (23.3)
Entrepreneur / Self-employed	7 (11.6)
Laborer / Farmer / Trader Unemployed	3 (5)
	36 (60)
Father's Education	
Elementary school	15 (25)
Junior high school	11 (18.3)
Senior high school	32 (53.3)
Bachelor's degree	2 (3.3)
Mother's Education	
Elementary school	8 (13.3)
Junior high school	22 (36.6)
Senior high school	28 (46.6)
Bachelor's degree	2 (3.3)
Parents' Monthly Income	
< Rp. 1.500.000	21 (35)
Rp. 1.500.000 – Rp. 3.500.000	35 (58.3)
> Rp. 3.500.000	4 (6.6)

Notes: ***Data are presented as frequency (percentage). Total participants = 60***

Table 2 presents the descriptive statistics of knowledge and attitude scores before and after the intervention. In the GHEA group, the mean knowledge score increased from 7.23 ± 1.79 to 9.43 ± 0.97, and attitude scores rose from 29.73 ± 4.65 to 35.03 ± 3.58. In the Digital Pocket Book group, knowledge improved from 6.77 ± 1.91 to 7.30 ± 1.78, and attitude scores increased from 15.00 ± 1.98 to 16.80 ± 2.11. These results indicate that both interventions improved participants' knowledge and attitudes, with greater gains observed in the GHEA group.

Table 2. Descriptive Statistics of Knowledge and Attitude Scores (Pre-Test and Post-Test)

Group	Variable	Pre-Test Mean ± SD (Min–Max)	Post-Test Mean ± SD (Min–Max)
Intervention	Knowledge	7.23 ± 1.79 (4–9)	9.43 ± 0.97 (6–10)
	Attitude	29.73 ± 4.65 (19–40)	35.03 ± 3.58 (29-40)
Control	Knowledge	6.77 ± 1.91 (2-10)	7.30 ± 1.78 (3-10)
	Attitude	15.00 ± 1.98 (12-20)	16.80 ± 2.11 (13-21)

Notes: Data presented as Mean ± Standard Deviation (SD). Minimum and maximum values indicate the score range for each variable.

Independent-sample tests indicated no significant differences in baseline knowledge and attitude scores between the GHEA and Digital Pocket Book groups ($p > 0.05$), confirming initial group equivalence.

To examine the effects of the interventions within each group, pre-test and post-test scores were compared. Statistical tests were determined based on the Shapiro–Wilk normality results, applying parametric tests for normally distributed data and non-parametric tests for non-normally distributed data.

In the intervention group (GHEA), the Wilcoxon signed-rank test revealed significant improvements in both knowledge ($Z = -4.847$, $p < 0.001$) and attitude ($Z = -4.275$, $p < 0.001$). Similarly, the control group (The Digital Pocket Book, DPB) demonstrated significant increases in knowledge ($Z = -3.771$, $p < 0.001$) and attitude ($t = -8.752$, $df = 29$, $p < 0.001$). **Table 3** shows that while both interventions enhanced participants' knowledge and attitudes toward anemia prevention, the magnitude of improvement was greater in the GHEA group.

Table 3. Within-Group Comparison of Knowledge and Attitude Scores

Group	Variable	Test Value (Z / t, df)	p-value
Intervention	Knowledge	Z = -4.847	<0.001
	Attitude	Z = -4.275	<0.001
Control	Knowledge	Z = -3.771	<0.001
	Attitude	t = -8.752 df = 29	<0.001

Notes: Wilcoxon signed-rank test used for non-parametric data (knowledge and attitude in the intervention group; knowledge in the control group). Paired t-test used for parametric data (attitude in the control group). $p < 0.05$ is considered statistically significant

Further comparisons of post-test scores between the intervention group (GHEA) and the control group (The Digital Pocket Book) revealed statistically significant differences favoring the intervention group. The Mann–Whitney U test indicated higher post-test knowledge scores ($Z = -5.284$, $p < 0.001$) and attitude scores ($Z = -3.081$, $p = 0.002$) among participants who received the GHEA intervention. **Table 4** shows that the game-based health education approach (GHEA) was significantly more effective than the Digital Pocket Book in enhancing adolescents' knowledge and promoting positive attitudes toward anemia prevention.

Table 4. Between-Group Comparison of Post-Test Knowledge and Attitude Scores

Variable	Test Value (Z / t, df)	p-value
Knowledge	Z =-5.284	<0.001
Attitude	Z =-3.081	0.002

Notes: Mann–Whitney U test used for between-group comparisons (non-parametric data). $p < 0.05$ is considered statistically significant.

Discussion

The findings of this study indicate that the GHEA intervention was significantly more effective in improving adolescent girls' knowledge and attitudes toward anemia prevention than the Digital Pocket Book (DPB). These results can be interpreted through the framework of the Health Belief Model (HBM), which posits that health behavior is influenced by six core constructs: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy (Rosenstock, 1974).

In this study, the improvement in knowledge reflects strengthened perceptions of susceptibility, severity, and benefits, as participants became more aware of their personal risk, the serious consequences of anemia, and the advantages of preventive behaviors. Exposure to educational animation videos and informational content about anemia helped participants comprehend the importance of anemia prevention through concrete illustrations of its causes, consequences, and preventive strategies.

Meanwhile, the increase in positive attitudes represents a reduction in perceived barriers and an enhancement of cues to action and self-efficacy. This occurred because GHEA's game- and story-based approach created a more engaging, competitive, and collaborative learning experience. The quiz-based competition and real-time feedback served as cues to action that encouraged active participation, while teamwork strengthened self-efficacy through social support and collective confidence in adopting preventive behaviors against anemia.

From a mechanistic reasoning perspective, these improvements in knowledge and attitude are explained by the active learning principles embedded in GHEA (Nurbavliyev et al., 2022). Each component of GHEA educational animation videos, narrative storytelling, educational materials, quiz-based games and competition, and teamwork enhances both cognitive and affective engagement. The videos and narratives increase awareness of risk (perceived susceptibility) and understanding of disease impact (perceived severity). The educational content expands comprehension of the benefits of healthy behaviors (perceived benefits) while reducing learning barriers such as boredom or confusion (perceived barriers). The quiz games and competition provide cues to action through immediate feedback and motivational challenges. Teamwork reinforces self-efficacy through collaboration and peer support, promoting participants' confidence in practicing anemia-preventive behaviors.

Supporting these findings, Ghadam et al. (2023) demonstrated that digital game-based nutrition education significantly improved students' knowledge and attitudes compared with conventional methods such as lectures or leaflets (Ghadam et al., 2023). Similarly, Sari et al. (2022) reported that the WANTER health application effectively increased adolescents' knowledge and attitudes, although its impact on behavior remained inconsistent (Sari et al., 2022). Both studies emphasized that active engagement and immediate feedback are key determinants of effective digital learning.

In the Indonesian context, Nuryana et al. (2025) found that the Digital Pocket Book also improved adolescent girls' knowledge and attitudes toward anemia prevention, but the improvement was less substantial than in game-based interventions (Nuryana et al., 2025). This suggests that while traditional digital media remain beneficial, they may not sufficiently stimulate emotional engagement and motivation compared to GHEA, which integrates competition, narrative, and collaboration.

These elements not only serve as cues to action and enhance self-efficacy but also help reduce perceived barriers by making the learning process more enjoyable and easier to comprehend (Triantafyllou et al., 2025). Therefore, GHEA's structure theoretically supports the formation of positive attitudes by strengthening motivation, emotional experience, and adolescents' confidence in preventing anemia.

Conversely, some studies have reported differing outcomes, indicating that game-based interventions are not always effective when participant engagement is low or when the intervention duration is too short (Alzghoul, 2024). This indicates that gamification alone is insufficient without contextual relevance, sustained engagement, and a strong behavioral theory underpinning it (van Gaalen et al., 2021). Thus, integrating behavioral frameworks such as the HBM is crucial to ensure meaningful cognitive and affective transformation (Sailer & Homner, 2020).

Overall, this study confirms that the GHEA intervention, guided by the Health Belief Model (HBM), effectively improved adolescent girls' knowledge and attitudes toward anemia prevention. By operationalizing all six HBM constructs within a game-based learning environment, GHEA not only enhanced comprehension but also promoted motivation and confidence to engage in healthy behaviors. These findings underscore the importance of using theory-driven interactive media in adolescent health promotion. The integration of storytelling, competition, and teamwork successfully sustained engagement and strengthened learning outcomes. Altogether, GHEA demonstrates strong potential as an innovative and scalable strategy for school-based health education in Indonesia.

Implications and limitations

The findings of this study have both theoretical and practical implications. Theoretically, this study contributes to the integration of the Health Belief Model (HBM) within a gamification framework, demonstrating how all six HBM constructs perceived susceptibility, severity, benefits, barriers, cues to action, and self-efficacy can be operationalized through interactive learning components. This integration expands the application of HBM beyond traditional health education, offering a structured behavioral foundation for the design of digital learning interventions. Practically, the results indicate that GHEA can be used as an innovative, engaging, and theory-driven health education tool in school-based programs to enhance adolescents' understanding and attitudes toward anemia prevention. The combination of storytelling, competition, and teamwork promotes motivation and participation, suggesting its potential adaptation for other adolescent health topics.

This study has several limitations that should be acknowledged. The sample was relatively small and drawn from a single junior high school, which may limit the generalizability of the findings to broader adolescent populations. Data were collected through self-reported questionnaires, which could introduce response bias. In addition, the follow-up period was relatively short, preventing evaluation of long-term behavioral changes. Future research should involve larger and more diverse samples, employ mixed-method designs, and include longitudinal follow-up to assess the sustainability of intervention effects.

Relevance to Practice

The results of this study have clear implications for nursing and health education practice. GHEA can be used as an

engaging, theory-based digital tool to support school-based health promotion among adolescent girls at risk of iron-deficiency anemia. Its combination of animation, storytelling, and gamified quizzes makes learning more interactive and appealing, addressing low motivation often seen in traditional methods. Nurses and health educators can use GHEA during classroom teaching, community outreach, or health campaigns to strengthen adolescents' knowledge and promote positive attitudes toward anemia prevention. The collaborative and competitive features encourage peer learning and participation, reinforcing behavior change. By embedding the constructs of the Health Belief Model, GHEA not only delivers information but also builds self-efficacy and readiness to act. This approach supports the ongoing digitalization of health education and can be adapted for other adolescent health topics.

Conclusion

This study demonstrated that the GHEA intervention was more effective than the Digital Pocket Book (DPB) in improving adolescent girls' knowledge and attitudes toward anemia prevention. These findings highlight the value of integrating gamification with the Health Belief Model to enhance motivation and learning outcomes in digital health education. GHEA provides a promising, theory-based approach that can be adapted for broader adolescent health promotion initiatives. Future studies should involve larger, multi-site samples and longer follow-up periods to evaluate the sustained impact of gamified interventions on behavior change.

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CrediT Authorship Contributions Statement

Imam Nur Fauzi: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, Project Administration.

Kumboyono Kumboyono: Supervision, Writing – Review & Editing

Fransiska Imavike Fevriasanty: Supervision, Writing – Review & Editing

Conflicts of 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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