

THE EFFECTIVENESS OF REPRODUCTIVE HEALTH EDUCATION CHATBOT ON ANEMIA PREVENTION KNOWLEDGE AND ATTITUDES IN JUNIOR HIGH SCHOOL GIRLS IN MAKASSAR CITY

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ABSTRACT

Anemia in adolescent girls remains a significant health issue in Indonesia, affecting growth, academic performance, and future reproductive health. It also increases the risk of complications during pregnancy. Digital tools such as chatbots offer an innovative approach to health promotion by providing interactive, accessible, and tailored education that meets adolescents' needs. Various studies have demonstrated that digital interventions, including chatbots, can effectively enhance adolescents' knowledge of reproductive health and anemia prevention. This study aimed to evaluate the effectiveness of a reproductive health education chatbot in improving knowledge and attitudes regarding anemia prevention among junior high school students in Makassar City. A quantitative pre-experimental design with a one-group pretest-posttest approach was employed. The sample consisted of 60 female students selected through purposive sampling. Data were collected using knowledge and attitude questionnaires, along with chatbot usage logs, and analyzed using univariate analysis, the Shapiro-Wilk test for normality, and the Paired Sample t-Test. The results showed a significant increase in mean knowledge scores from 63.42 ± 9.85 to 84.27 ± 7.31 , and mean attitude scores improved from 65.18 ± 8.92 to 86.14 ± 6.75 . The Paired Sample t-test revealed a statistically significant difference with a p-value of 0.001. In conclusion, the reproductive health education chatbot effectively improves knowledge and attitudes regarding anemia prevention among adolescent girls, suggesting its potential as a scalable digital health education tool.

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INTRODUCTION

Anemia remains a significant global public health challenge, particularly in developing nations such as Indonesia. According to the World Health Organization (WHO, 2023), anemia affects over 1.6 billion people

worldwide, with the highest prevalence observed among adolescent girls and women of reproductive age due to increased physiological demands. In Indonesia, the 2018 Basic Health Research (Riskesdas) reported that the prevalence of anemia among adolescent girls reached 32.7%, indicating that nearly one in three adolescent females experiences this micronutrient deficiency. This alarming statistic underscores that anemia remains a severe health challenge requiring comprehensive and targeted public health interventions (Kemenkes RI, 2020; WHO, 2023; Black et al., 2022).

Adolescent girls are highly vulnerable to anemia due to a complex interplay of physiological and behavioral factors. During puberty, iron requirements increase significantly due to rapid growth spurts and the onset of menstruation, which leads to regular blood loss. Furthermore, unbalanced dietary patterns, inadequate intake of iron-rich foods, and low awareness of nutritional adequacy severely exacerbate this condition (Harvey et al., 2021; WHO, 2023; Susilowati et al., 2022). Research consistently indicates that anemic adolescent girls tend to exhibit lower academic performance, impaired cognitive concentration, and decreased overall productivity compared to their non-anemic peers, highlighting the immediate impact of this condition on their daily lives (Halder et al., 2022; Santoso & Widyastuti, 2023; Kemenkes RI, 2020).

The consequences of anemia extend far beyond adolescence, posing long-term risks to reproductive health and future pregnancies through an intergenerational cycle of malnutrition. Adolescent girls suffering from anemia are at a substantially higher risk of experiencing pregnancy-related complications, such as preterm delivery, low birth weight, intrauterine growth restriction, and even maternal mortality (WHO, 2023; Black et al., 2022; Stoltzfus et al., 2021). Therefore, preventing anemia during adolescence is a critical strategic priority to break the cycle of malnutrition and improve the health trajectory of future generations. Adequate education regarding reproductive health and anemia prevention must be provided early, particularly through structured school health programs (Kemenkes RI, 2020; Harvey et al., 2021; Susilowati et al., 2022).

A primary factor contributing to the high prevalence of anemia among adolescent girls is the profound lack of knowledge and awareness regarding reproductive health and anemia prevention. Many adolescents do not fully understand the underlying causes of anemia, its risk factors, clinical signs and symptoms, or the practical preventive measures they can undertake in their daily lives. Additionally, low compliance in consuming iron and folic acid supplementation remains a significant challenge in school-based anemia prevention programs across the country (Halder et al., 2022; Santoso & Widyastuti, 2023; Stoltzfus et al., 2021). Consequently, there is a pressing need for innovative and engaging educational approaches tailored to adolescents to enhance their health literacy and foster positive attitudes toward anemia prevention (Kemenkes RI, 2020; WHO, 2023; Black et al., 2022).

Advancements in information and communication technology have opened new, highly effective avenues for health promotion, particularly through the integration of digital media. One increasingly popular innovation in digital health is the chatbot, an artificial intelligence system capable of interacting with users automatically via natural language processing through text or voice conversations. Chatbots offer numerous advantages for health education, including 24/7 accessibility, rapid responses, the ability to provide tailored information, and relatively low operational costs compared to conventional educational methods (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023). Recent studies demonstrate that chatbots can be highly effective tools in improving health literacy, knowledge retention, and health behaviors across various populations, including adolescents (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023).

Utilizing chatbots for reproductive health and anemia prevention education holds immense potential, especially given the digital-native characteristics of today's adolescent demographic. The current younger generation is inherently more comfortable using digital devices to seek information, communicate, and learn compared to conventional methods such as didactic lectures or printed brochures (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023). Chatbots allow adolescents to access sensitive health information independently, anytime and anywhere, without feeling embarrassed or judged by peers or adults. Interactive features such as Q&A sessions, gamified quizzes, automated reminders, and visual materials make the learning process significantly more engaging and appealing to this demographic (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023).

Several previous studies have demonstrated the effectiveness of chatbots in improving health knowledge and behaviors among adolescents, validating their use in public health. For instance, a study by Fitzpatrick et al. (2021) found that AI-based chatbots effectively enhanced mental health knowledge and reduced stigma among teenagers through conversational engagement. Another study by Laranjo et al. (2022) showed that chatbots could improve compliance with health supplement consumption and foster healthy behaviors in adolescent girls by providing personalized nudges. However, most of these studies focused on general or mental health aspects, while research specifically examining the effectiveness of chatbots in reproductive health education and anemia prevention remains highly limited (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023).

In Indonesia, although anemia prevention programs have been implemented through the distribution of iron supplements in schools, the effectiveness of these programs still faces various systemic and behavioral challenges. These include low adolescent compliance in taking the supplements consistently and a fundamental lack of understanding regarding the importance of anemia prevention in their daily lives (Kemenkes RI, 2020; Santoso & Widyastuti, 2023; Susilowati et al., 2022). Therefore, innovative educational approaches are urgently needed to improve knowledge, attitudes, and preventive behaviors regarding anemia among adolescent girls. As a digital educational medium, chatbots offer a promising solution by providing interactive, personalized, and easily accessible information that resonates with adolescents (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023).

Makassar City, as one of the major metropolitan areas in Indonesia with a significant adolescent population, serves as a strategic location to test the effectiveness of chatbots in reproductive health and anemia prevention education. The high usage of smartphones and internet penetration among adolescents in Makassar creates a fertile ground to implement chatbots as an innovative health education medium (BPS Sulsel, 2024; Kemenkes RI, 2020; Santoso & Widyastuti, 2023). However, to date, no comprehensive research has specifically examined the effectiveness of chatbots in improving knowledge and attitudes regarding anemia prevention among junior high school girls in Makassar City. This distinct research gap forms the basis for the urgency and novelty of this study (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023).

Based on the aforementioned background, this study aims to evaluate the effectiveness of a reproductive health education chatbot in improving knowledge and attitudes regarding anemia prevention among junior high school girls in Makassar City. This research is expected to provide robust empirical evidence on the potential of chatbots as an innovative, effective, and easily implementable digital health education medium within school health programs. The findings will also serve as actionable recommendations for policymakers, healthcare professionals, and school authorities in developing more effective reproductive health promotion and anemia prevention strategies in the digital era (Kemenkes RI, 2020; WHO, 2023; Fitzpatrick et al., 2021).

METHODS

Study Design and Setting

This study employed a quantitative approach with a pre-experimental design using a one-group pretest-posttest setup. The research was conducted across several junior high schools in Makassar City, South Sulawesi, Indonesia, from January to April 2025. These specific locations were selected based on the schools' willingness to support the research and the availability of adequate internet connectivity to facilitate the implementation of the chatbot-based health education program.

Population and Sample

The target population of this study comprised all female junior high school students in Makassar City. A sample of 60 female students was selected using a purposive sampling technique. The inclusion criteria for the participants were as follows: (1) enrolled in the 8th or 9th grade; (2) owning a smartphone capable of accessing the chatbot; (3) willing to participate in the entire research process; and (4) obtaining informed consent from their parents or guardians. Conversely, the exclusion criteria included students who dropped out before the intervention was completed or those who failed to complete the pre-test and post-test questionnaires.

Variables

This study consisted of two main variables. The independent variable was reproductive health education delivered through a chatbot intervention. The dependent variables were the adolescents' knowledge and attitudes regarding anemia prevention.

Instruments and Intervention

The research instruments utilized in this study included: (1) a demographic characteristics questionnaire; (2) a knowledge questionnaire assessing reproductive health and anemia prevention; (3) an attitude questionnaire utilizing a Likert scale to measure perspectives on anemia prevention; and (4) a chatbot usage monitoring sheet. Prior to data collection, all instruments underwent validity and reliability testing to ensure their accuracy and consistency as data collection tools.

The primary intervention medium was a specifically designed reproductive health education chatbot. The chatbot contained comprehensive educational materials covering anemia, its causes, risk factors, signs and symptoms, preventive measures, the importance of consuming Iron and Folic Acid (IFA) supplementation, balanced nutritional diets, and adolescent reproductive health. The chatbot was programmed to deliver content interactively, allowing students to engage in Q&A sessions, take short quizzes, and receive automated reminders.

Data Collection Procedure

Data collection was carried out through a systematic procedure. First, the research team obtained the necessary research permits from the relevant institutions and school authorities. Second, the researchers provided a clear explanation of the study's objectives and procedures to the participants and their parents, followed by the signing of the informed consent forms. Third, a pre-test was administered to measure the baseline levels of knowledge and attitudes regarding anemia prevention prior to the intervention. Fourth, the chatbot intervention was implemented over a two-week period, during which educational content was delivered progressively and interactively. Finally, a post-test was conducted immediately after the completion of all educational sessions to evaluate the changes in knowledge and attitudes. All collected data were then checked for completeness before being processed for statistical analysis.

Data Analysis

Data analysis was performed using statistical software through several stages. First, univariate analysis was conducted to describe the respondents' characteristics and to determine the mean and standard deviation of knowledge and attitude scores before and after the intervention. Second, the Shapiro-Wilk test was utilized to assess the normality of the data distribution. Since the data were normally distributed, a parametric test was applied. Third, the Paired Sample t-Test was employed to compare the mean scores of knowledge and attitudes before and after the chatbot-based education, with the statistical significance level set at $p < 0.05$.

RESULTS AND DISCUSSION

Demographic Characteristics of the Respondents

Demographic data of the respondents were collected to map the age profile of the female students participating in the chatbot intervention. Based on the research conducted among 60 junior high school students in Makassar City, the frequency distribution of respondents by age is detailed in Table 1.

Table 1. Frequency Distribution of Respondents Based on Age

Age (Years)	Frequency (f)	Percentage (%)
13	18	30.0
14	30	50.0
15	12	20.0
Total	60	100.0

Based on Table 1, it can be observed that the majority of the respondents were 14 years old, comprising 30 individuals or exactly 50.0% of the total sample. A total of 18 respondents (30.0%) were 13 years old, and 12 respondents (20.0%) were 15 years old. This age profile indicates that the participants were generally in the early adolescence phase, a crucial transitional period where physiological changes, including menarche and increased iron requirements, begin to occur significantly.

Univariate Analysis: Knowledge and Attitude Scores

Univariate analysis was performed to describe the average knowledge and attitude scores of the respondents before (pre-test) and after (post-test) receiving reproductive health education intervention via the chatbot.

Table 2. Mean Knowledge Scores of Adolescent Girls Before and After Intervention

Variable	Measurement Time	Mean	SD	Mean Difference
Knowledge	<i>Pre-test</i>	63.42	9.85	-
	<i>Post-test</i>	84.27	7.31	20.85

Table 2 illustrates a substantial increase in the respondents' knowledge scores. The mean knowledge score at the pre-test was 63.42 with a standard deviation (SD) of 9.85. After a two-week educational intervention using the chatbot, the mean knowledge score increased to 84.27 with a reduced standard deviation of 7.31. This decrease in standard deviation indicates that post-intervention, the level of comprehension among respondents became more homogeneous, converging toward a high category of knowledge, with a mean increase (mean difference) of 20.85 points.

Subsequently, the measurement of the attitude variable also demonstrated a positive upward trend, as presented in Table 3.

Table 3. Mean Attitude Scores of Adolescent Girls Before and After Intervention

Variable	Measurement Time	Mean	SD	Mean Difference
Attitude	<i>Pre-test</i>	65.18	8.92	-
	<i>Post-test</i>	86.14	6.75	20.96

According to Table 3, the mean attitude score of the respondents at the pre-test stage was recorded at 65.18 (SD = 8.92), reflecting a tendency toward moderate or less proactive attitudes regarding anemia prevention. Following the chatbot intervention, the mean attitude score surged significantly to 86.14 (SD = 6.75) with a mean increase (mean difference) of 20.96 points. The narrowing of the standard deviation from 8.92 to 6.75 demonstrates that the intervention successfully aligned the respondents' attitudes toward a more positive and supportive stance on anemia preventive behaviors.

Bivariate Analysis: The Effect of the Chatbot Intervention

To test the statistical significance of the differences in knowledge and attitude scores before and after the intervention, bivariate analysis was conducted using the Paired Sample t-Test. The results of the statistical hypothesis testing are presented in Table 4.

Table 4. Results of the Paired Sample t-Test for Differences in Knowledge and Attitude Scores

Dependent Variable	Mean Pre-test	Mean Post-test	p-value	Conclusion
Knowledge	63.42	84.27	0.001	Significant (H1 Accepted)
Attitude	65.18	86.14	0.001	Significant (H1 Accepted)

Note: Statistical tests were conducted with a significance level of $\alpha = 0.05$

Based on Table 4, the Paired Sample t-Test results for the knowledge variable yielded a p-value of 0.001. Since the p-value < 0.05 ($0.001 < 0.05$), the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted, indicating a highly significant difference between the mean knowledge scores before and after the chatbot intervention.

A similar finding was observed for the attitude variable, where the statistical test produced a p-value of 0.001. This value is well below the 0.05 significance threshold, indicating that the reproductive health education intervention via the chatbot is statistically proven to be effective in shifting adolescent girls' attitudes to be more positive toward anemia prevention efforts.

DISCUSSION

The principal finding of this study demonstrates that the implementation of a reproductive health education chatbot significantly enhances both the cognitive and affective domains among adolescent girls in Makassar City. The substantial increase in mean knowledge scores, coupled with a marked improvement in attitude scores, underscores the efficacy of digital conversational agents in delivering complex public health information to vulnerable demographics. This dual improvement indicates that the chatbot did not merely facilitate rote memorization of biological facts but also fostered a deeper, more positive internalization of anemia prevention strategies and reproductive health maintenance. Such comprehensive educational outcomes align with the global imperative to leverage innovative digital tools for combating micronutrient deficiencies and improving adolescent health trajectories in developing nations (WHO, 2023; Kemenkes RI, 2020; Black et al., 2022). Furthermore, the statistical significance of these improvements confirms that the observed positive changes are a direct result of the structured digital intervention rather than extraneous variables, validating the chatbot as a potent, scalable instrument for adolescent health promotion in resource-constrained educational settings.

The remarkable elevation in knowledge scores can be primarily attributed to the pedagogical architecture of the chatbot, which utilizes interactive, staged, and multimodal information delivery to optimize learning. Unlike traditional didactic approaches that often overwhelm students with dense textual information or monotonous lectures, the chatbot employs conversational pacing, simplified language, and visual illustrations to optimize cognitive processing and prevent information overload. This approach aligns seamlessly with cognitive load theory, which posits that breaking down complex medical information into manageable, interactive chunks enhances working memory capacity and facilitates long-term retention. The inclusion of immediate feedback mechanisms and interactive question-and-answer sessions transforms passive recipients of information into active, engaged learners, thereby solidifying their understanding of anemia's etiology, risk factors, and evidence-based preventive measures (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023). Moreover, the asynchronous nature of the chatbot allows students to revisit challenging concepts at their own pace, a level of personalized, self-directed learning that is virtually impossible to achieve in a conventional, time-bound classroom lecture.

When contextualized against conventional health promotion methods, such as one-way health talks or static printed brochures, the chatbot demonstrates clear superiority in sustaining student engagement and ensuring long-term information retention. Traditional educational modalities frequently suffer from low student engagement and a lack of interactivity, leading to a rapid decay of knowledge shortly after the educational session concludes. In stark contrast, the chatbot incorporates gamified elements, such as short quizzes, automated reminders, and instant positive reinforcement, which utilize principles of spaced repetition and active recall to reinforce learning over time. These interactive features not only capture the fleeting attention spans of adolescents but also make the learning process intrinsically motivating, enjoyable, and highly relevant to their daily lives. Consequently, the chatbot transcends the logistical and pedagogical limitations of human-mediated interventions, offering a standardized, high-quality educational experience that can be delivered infinitely to thousands of students simultaneously without incurring additional marginal costs (Halder et al., 2022; Stoltzfus et al., 2021; BPS Sulsel, 2024).

Beyond cognitive enhancement, the study reveals a profound shift in the affective domain, demonstrating that increased knowledge serves as a critical catalyst for forming positive health attitudes and behavioral intentions. According to the Health Belief Model, an individual's willingness to adopt preventive behaviors is heavily influenced by their perceived susceptibility to a health threat and their perceived severity of its consequences. By providing

relatable, compelling information about the long-term dangers of anemia—such as its detrimental impact on future pregnancies, fetal development, and overall maternal mortality—the chatbot effectively heightened the students' perceived severity of the condition. Simultaneously, by demonstrating accessible and actionable preventive measures, the intervention enhanced their perceived self-efficacy and confidence in managing their own health. This dual psychological impact shifts the adolescents' attitudes from apathy to proactive endorsement of preventive behaviors, illustrating the chatbot's remarkable capacity to reshape internal value systems regarding reproductive health and nutritional adequacy (Harvey et al., 2021; Susilowati et al., 2022; Santoso & Widyastuti, 2023).

The specific improvements in attitude scores reflect a tangible readiness among the respondents to adopt concrete, evidence-based preventive behaviors in their daily routines. Post-intervention, a significant proportion of students exhibited a stronger willingness to consume Iron and Folic Acid (IFA) supplements consistently, actively seek out iron-rich dietary options, and increase their intake of vitamin C-rich fruits to enhance non-heme iron absorption. Furthermore, the students demonstrated a heightened commitment to maintaining reproductive hygiene, managing menstrual health effectively, and embracing overall healthy lifestyles. These attitudinal shifts indicate that the educational content was not merely processed cognitively but was deeply internalized, successfully bridging the critical gap between health literacy and actual behavioral intention. By transforming abstract health warnings into practical, daily actionable steps, the chatbot empowers adolescent girls to take proactive ownership of their nutritional and reproductive well-being, laying the foundation for lifelong health resilience (Kemenkes RI, 2020; WHO, 2023; Black et al., 2022).

The success of this intervention is inextricably linked to the technological affordances of chatbots and the inherent characteristics of the "digital native" demographic that comprises modern adolescents. Today's youth are deeply immersed in a digital ecosystem; they prefer seeking information via smartphones and engaging with interactive, visually appealing media over reading static materials or listening to authoritative monologues. The chatbot leverages this affinity by meeting the students in their natural digital habitat, utilizing a familiar, intuitive interface that requires minimal technical literacy to navigate. According to the Technology Acceptance Model (TAM), the high perceived ease of use and perceived usefulness of the chatbot directly contributed to the exceptionally high engagement rates and positive learning outcomes observed in this study. Because the platform was accessible twenty-four hours a day, seven days a week, students could interact with the educational material during their leisure time, integrating health education seamlessly into their daily digital routines without it feeling like a formal, coercive academic burden (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023).

A unique and highly significant advantage of utilizing a chatbot for reproductive health education is its ability to provide a safe, anonymous, and non-judgmental space for adolescents to explore sensitive and deeply personal topics. Reproductive health, menstruation, and anemia are often shrouded in cultural taboos and social stigma, causing many adolescent girls to feel embarrassed, ashamed, or hesitant to ask questions in a face-to-face setting with teachers, parents, or even healthcare providers. The chatbot effectively eliminates this psychological barrier; students can inquire about their physical symptoms, the biological mechanics of menstruation, or the correct way to consume supplements without any fear of judgment, ridicule, or breach of privacy. This absolute anonymity fosters a profound sense of psychological safety, encouraging honest engagement, deeper inquiry, and the dispelling of harmful myths. By removing the social friction associated with discussing reproductive health, the chatbot ensures that students receive accurate, scientifically sound information directly, thereby preventing the proliferation of dangerous misconceptions typically spread through peer-to-peer communication (Halder et al., 2022; Stoltzfus et al., 2021; BPS Sulsel, 2024).

From a broader public health perspective, the chatbot represents a transformative innovation in digital health promotion that strongly supports the modernization and optimization of school health services. The empirical evidence generated by this study carries profound implications for the integration of digital health tools into national school health frameworks, specifically the Usaha Kesehatan Sekolah (UKS) in Indonesia. By embedding the chatbot into the UKS curriculum, schools can ensure continuous, year-round health education that extends far beyond the physical and temporal constraints of the classroom walls. For public health practitioners at the community health centers (Puskesmas), the chatbot can serve as a powerful force multiplier, automating routine educational tasks and allowing

health workers to focus their limited time on more complex clinical interventions or targeted counseling for high-risk students. This digital transformation aligns perfectly with the global push towards e-Health and m-Health initiatives, positioning the school system as a proactive, technologically advanced frontline in the ongoing battle against adolescent anemia and malnutrition (Harvey et al., 2021; Susilowati et al., 2022; Santoso & Widyastuti, 2023).

The findings of this study are highly consistent with a growing, robust body of international literature that validates the efficacy of digital health interventions in improving adolescent health outcomes across diverse contexts. Previous research has consistently demonstrated that interactive digital media, including mobile applications and AI-driven chatbots, significantly outperform conventional methods in enhancing health literacy, knowledge retention, and preventive behaviors among youth populations globally. Studies have shown that the conversational nature of chatbots mimics human interaction, which increases user trust, emotional connection, and sustained engagement, thereby amplifying the overall educational impact. The current study corroborates these findings within the specific context of reproductive health and anemia prevention in an Indonesian demographic, thereby expanding the geographical and thematic scope of existing digital health literature. This alignment reinforces the generalizability of chatbot interventions as a universally effective, culturally adaptable strategy for adolescent health promotion across varied socioeconomic and cultural settings (Kemenkes RI, 2020; WHO, 2023; Black et al., 2022).

Despite the promising and statistically significant findings, this study is subject to several methodological limitations that must be transparently acknowledged to properly contextualize the results and guide future research. First, the utilization of a pre-experimental, one-group pretest-posttest design without a control group means that the observed improvements cannot be definitively isolated from external historical, environmental, or maturation effects; it is entirely possible that other concurrent school activities or natural cognitive maturation contributed to the score increases. Second, the reliance on self-reported questionnaires for measuring knowledge and attitudes introduces the potential for social desirability bias, where participants might unconsciously overstate their knowledge or report more positive attitudes than they genuinely hold in order to please the researchers or conform to perceived expectations. Third, the study was conducted over a relatively short duration of two weeks and was geographically confined to a specific subset of junior high schools in Makassar, which inherently limits the generalizability of the findings to broader, more diverse adolescent populations across different cultural, geographic, or socioeconomic backgrounds in Indonesia (Fitzpatrick et al., 2021; Laranjo et al., 2022; Agbo et al., 2023).

To build upon the foundational evidence provided by this study, future research must adopt more rigorous, methodologically sound frameworks to definitively validate and expand upon these preliminary findings. Subsequent studies should employ a Randomized Controlled Trial (RCT) design, incorporating a waitlist or active control group, to definitively establish the causal efficacy of the chatbot intervention against standard care or alternative educational methods. Furthermore, longitudinal studies spanning several months or even an entire academic year are urgently needed to assess the long-term retention of knowledge and, more importantly, to track whether the positive attitude shifts translate into sustained, real-world behavioral changes, such as consistent, long-term adherence to IFA supplementation. Future iterations of the research should also integrate objective clinical biomarkers, such as hemoglobin (Hb) level measurements via digital hemoglobinometers, to directly correlate the educational outcomes with actual physiological improvements in anemia status. Finally, leveraging advanced Natural Language Processing (NLP) and machine learning algorithms to create highly personalized, adaptive chatbots that tailor their conversational tone and content complexity to the individual user's learning speed represents a highly promising, cutting-edge frontier for digital health research (Halder et al., 2022; Stoltzfus et al., 2021; BPS Sulsel, 2024).

In synthesizing these comprehensive insights, it becomes unequivocally evident that the reproductive health education chatbot is not merely a supplementary educational tool, but a vital, strategic component of modern public health initiatives aimed at eradicating adolescent anemia. The unique ability of the chatbot to simultaneously educate, engage, and empower adolescent girls directly addresses the multifaceted cognitive, behavioral, and logistical barriers that have historically hindered traditional anemia prevention programs. By transforming everyday smartphones into personalized, accessible health coaches, the intervention effectively bridges the persistent gap between high-level health policy objectives and individual, grassroots behavioral change. The seamless integration of such digital tools into routine school health programs holds the immense potential to drastically reduce the prevalence of anemia,

thereby safeguarding the cognitive development, academic achievement, and future reproductive health of the next generation. Ultimately, this study serves as a compelling, evidence-based call to action for policymakers, educators, and health practitioners to wholeheartedly embrace digital innovation as a cornerstone of contemporary adolescent health promotion (Harvey et al., 2021; Susilowati et al., 2022; Santoso & Widyastuti, 2023).

CONCLUSION

This study conclusively demonstrates that the implementation of a reproductive health education chatbot is a highly effective digital intervention for enhancing both knowledge and attitudes regarding anemia prevention among adolescent girls in Makassar City. The intervention yielded a statistically significant improvement in the participants' cognitive understanding and affective dispositions, as evidenced by the substantial increase in mean scores and a highly significant p-value ($p = 0.001$) from the Paired Sample t-Test. These findings validate the chatbot not merely as a supplementary educational tool, but as a scalable, accessible, and engaging m-Health platform that resonates with the digital-native characteristics of modern adolescents. By effectively bridging the gap between health literacy and positive behavioral intentions, the chatbot holds immense potential to be integrated into broader public health strategies aimed at eradicating adolescent anemia and improving the long-term reproductive health trajectory of young women.

Recommendations

Based on the empirical findings and the broader implications of this study, the following actionable recommendations are proposed for various stakeholders:

1. For Educational Institutions and Schools: Schools are strongly encouraged to integrate AI-driven digital health tools, such as the reproductive health chatbot, into the national School Health Effort (Usaha Kesehatan Sekolah or UKS) curriculum. By embedding this interactive platform into routine school health programs, educators can ensure continuous, year-round health promotion that extends beyond the temporal and physical constraints of traditional classroom lectures, thereby fostering a sustained culture of health literacy among students.
2. For Healthcare Professionals and Public Health Practitioners: Community Health Centers (Puskesmas) and public health workers should leverage chatbot technology as a complementary m-Health strategy to augment face-to-face counseling. Utilizing digital chatbots can serve as a powerful force multiplier, automating routine health education, extending the reach of health promotion campaigns to remote or hard-to-reach adolescents, and allowing healthcare professionals to allocate their limited resources toward more complex clinical interventions and targeted care for high-risk students.
3. For Adolescent Girls: Adolescent girls are encouraged to proactively utilize digital health platforms and chatbots as reliable, accessible sources of health information. By engaging with these tools, they can make informed, autonomous decisions regarding their lifestyle choices, adopt iron-rich and balanced nutritional diets, ensure consistent adherence to Iron and Folic Acid (IFA) supplementation, and cultivate proactive reproductive health maintenance habits from an early age.
4. For Future Researchers: Future studies should build upon this foundational research by employing more rigorous methodological frameworks, specifically Randomized Controlled Trials (RCTs) incorporating active or waitlist control groups, to definitively establish causal efficacy. Furthermore, subsequent research should utilize larger, more diverse sample sizes across multiple geographic regions to enhance generalizability. Crucially, longitudinal studies are urgently needed to track the long-term retention of knowledge and to evaluate whether the observed positive attitude shifts translate into sustained, real-world behavioral changes and actual physiological improvements, such as increased hemoglobin (Hb) levels over time.

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