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The Impact of Digital Animated Flipbook on Knowledge and Adherence to Iron Supplementation: A Pre-Experimental Study Among Anemic Adolescent Girls

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Abstract

Anemia remains a significant public health problem among adolescent girls in Indonesia, with low adherence to weekly iron-folic acid supplementation (IFAS) programs. Innovative educational strategies are needed to improve both knowledge and adherence to supplementation. This study aimed to examine the effect of CEMARA animated flipbook education on knowledge and weekly iron supplement adherence among anemic adolescent girls. A pre-experimental one-group pretest-posttest design was used. The study involved 68 ninth-grade anemic girls from SMPN 03 Bukittinggi, Indonesia. Consecutive sampling was applied to recruit participants. The intervention consisted of the CEMARA animated flipbook, which was delivered over one month. During this period, the girls also received weekly monitoring of their iron tablet intake. Knowledge and adherence were measured using structured questionnaires, both of which had acceptable reliability (Cronbach's alpha = 0.812 for knowledge and 0.803 for adherence). Data analysis was performed using the Wilcoxon signed-rank test and Spearman's rank correlation test. The mean knowledge score increased from 12.90 ± 2.306 to 19.13 ± 1.683 ($p < 0.001$). The mean adherence score increased from 3.56 ± 1.028 to 5.84 ± 1.016 ($p < 0.001$). However, the correlation between knowledge improvement and adherence was weak and not statistically significant ($r = 0.171$; $p = 0.162$). CEMARA animated flipbook education significantly improved knowledge and weekly iron supplement adherence among anemic adolescent girls. However, increased knowledge was not significantly associated with adherence, indicating that behavioral and contextual factors may also influence supplementation practices.

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INTRODUCTION

Anaemia remains a major global public health concern, particularly among adolescent girls and women of reproductive age. The World Health Organization (WHO) estimates that nearly 30% of women aged 15–49 years worldwide are affected by anaemia, with iron deficiency being the most common cause (World Health Organization, 2024). Adolescence represents a critical period of rapid growth, increased nutritional requirements, and the onset of menstruation, all of which contribute to a heightened risk of iron deficiency anaemia (Srivastava et al., 2022). If left untreated, anaemia during adolescence can impair cognitive performance, reduce physical capacity, weaken immune function, and increase the risk of adverse maternal outcomes later in life, including preterm birth and low birth weight (Kassebaum et al., 2014; Stevens et al., 2022).

In Indonesia, anaemia among adolescents remains a significant public health challenge. National data from the Indonesian Health Survey (2023) indicate that the prevalence of anaemia among individuals aged 15–24 years is approximately 15.5% (Kementerian Kesehatan Republik Indonesia, 2024). To address this issue, the Indonesian government has implemented a weekly iron–folic acid supplementation (IFAS) program targeting adolescent girls through school-based delivery systems (Kementerian Kesehatan Republik Indonesia, 2023). However, despite improvements in program coverage, adherence to iron supplementation remains suboptimal. Previous studies have reported that factors such as side effects, misconceptions, forgetfulness, and lack of supervision significantly contribute to low adherence among adolescents (Benson et al., 2021; Mistry et al., 2022; Low et al., 2021).

Educational interventions are recognized as a key strategy to improve health knowledge and promote preventive behaviours among adolescents. The Cognitive Theory of Multimedia Learning suggests that combining visual and verbal information enhances comprehension and retention by engaging dual processing channels (Mayer, 2009). In line with this, recent studies have demonstrated that digital and multimedia-based educational interventions are more effective than conventional approaches in improving nutrition-related knowledge and engagement among adolescents (Hernandez et al., 2021; Chaudhary et al., 2022; Nguyen et al., 2023). Furthermore, school-based interventions integrating structured education with behavioural reinforcement have shown positive effects on both knowledge and adherence outcomes (Tamiru et al., 2017; Pasricha et al., 2021).

Despite these advances, previous studies on adolescent nutrition education have primarily focused on improving knowledge outcomes using conventional lectures, videos, or static digital materials (Hernandez et al., 2021; Chaudhary et al., 2022). Only a limited number of studies have evaluated behavioural outcomes such as adherence to iron supplementation, particularly among anaemic adolescent girls in school settings. Furthermore, existing interventions rarely integrate interactive multimedia elements with structured behavioural reinforcement or repeated monitoring strategies. Most prior studies also relied on passive educational delivery without allowing repeated user-controlled access to educational content.

Animated flipbooks represent a promising educational innovation because they integrate text, narration, visual animation, and interactive navigation within a user-friendly format that can be repeatedly accessed without continuous internet dependency. However, evidence regarding animated flipbook-based interventions for improving both knowledge and iron supplementation adherence among anaemic adolescents remains limited, especially in low- and middle-income countries such as Indonesia.

To address these gaps, this study developed and evaluated CEMARA a theory-based digital animated flipbook designed using Mayer's Multimedia Learning Theory and combined with weekly adherence monitoring. Unlike previous studies that mainly targeted knowledge improvement, the present study simultaneously evaluated both knowledge and weekly iron

supplement adherence among anaemic adolescent girls in a school-based setting.

METHOD

This study employed a pre-experimental one-group pretest–posttest design to evaluate the effect of the CEMARA animated flipbook on knowledge and weekly iron supplement adherence among anaemic adolescent girls. Although this design carries inherent limitations, including potential history, maturation, and Hawthorne effects due to the absence of a control group, it was considered appropriate for a preliminary evaluation of a school-based educational intervention where randomization was not feasible (Polit & Beck, 2021).

The study was conducted at SMPN 03 Bukittinggi, West Sumatra, Indonesia, between January and March 2025, involving ninth-grade adolescent girls who had experienced menarche and were diagnosed with mild anaemia (hemoglobin 10–11.9 g/dL) based on school health records. The sample size was calculated using the Lemeshow formula for paired measurements, with an additional 10% added to anticipate potential attrition, resulting in 68 participants recruited through consecutive sampling (Lemeshow et al., 1990). Inclusion criteria included adolescents aged 13.5–16 years with mild anaemia who were able to communicate effectively and provided informed consent, while those with other hematologic disorders, severe psychological conditions, or incomplete participation were excluded.

The intervention consisted of CEMARA a theory-based digital animated flipbook developed according to national anaemia prevention guidelines and Mayer's Cognitive Theory of Multimedia Learning. The flipbook integrated visual animation, narration, concise educational text, and user-controlled navigation to enhance cognitive engagement and knowledge retention. The intervention was delivered through two structured classroom sessions (30 minutes each), followed by weekly independent access via a digital link over one month.

In addition to educational exposure, participants underwent structured weekly adherence monitoring intended to reinforce supplement-taking behaviour and reduce forgetfulness. Monitoring was conducted through weekly follow-up and self-reported supplement intake tracking. Therefore, the observed outcomes in this study may reflect the combined influence of multimedia education and behavioural reinforcement strategies rather than the flipbook intervention alone.

Knowledge and adherence were measured using structured questionnaires administered before and after the intervention. Instrument reliability testing demonstrated acceptable internal consistency (Cronbach's alpha = 0.812 for knowledge and 0.803 for adherence). Prior to implementation, the questionnaires were reviewed by experts in adolescent health and health education to evaluate content validity and construct appropriateness.

The overall research procedure, including recruitment, baseline assessment, intervention, follow-up, and analysis, is illustrated in Figure 1. In addition, Figure 1 provides a visual representation of the educational content pillars and the structured 32-day intervention roadmap underlying the CEMARA flipbook implementation.

Ethical approval was obtained from the Faculty of Health Sciences, University of Indonesia (No. KET-284/UN2.F12.D1.2.1/PPM.00.02/2025), and written informed consent was secured from participants and their guardians in accordance with international ethical standards (World Medical Association, 2013).

Data were analysed using IBM SPSS Statistics version 29. Descriptive statistics were used to summarize participant characteristics and study variables. The Kolmogorov–Smirnov test indicated non-normal data distribution ($p < 0.05$), justifying the use of non-parametric tests (Ghasemi & Zahediasl, 2012). The Wilcoxon Signed Rank test was applied to assess differences between pretest and posttest scores, while Spearman's rank correlation was used to examine the relationship between changes in knowledge and adherence.

Statistical significance was set at $p < 0.05$ (Conover, 1999).

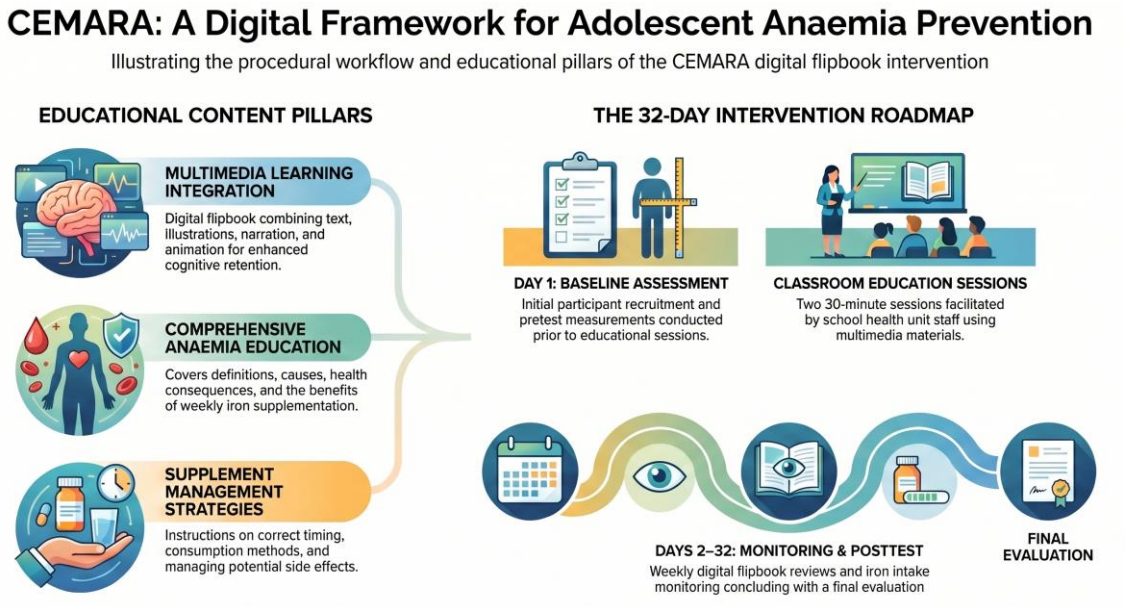

Figure 1. Flowchart of the Research Procedure

RESULT

Respondent Characteristics

Table 1. Distribution of Adolescent Girls' Characteristics by Nutritional Status and Menstrual Cycle

Variable	Category	n	%
Body Mass Index	Underweight	28	41.2
	Normal	37	54.4
	Overweight	1	1.5
	Obese	2	2.9
Menstrual Cycle	Polymenorrhoea	17	25.0
	Normal	48	70.6
	Oligomenorrhoea	3	4.4

Based on Table 1, a total of 68 anemic adolescent girls participated in this study. Most respondents had normal nutritional status based on body mass index (54.4%), while 41.2% were underweight. Regarding menstrual cycle characteristics, most respondents reported a normal menstrual cycle (70.6%), whereas 25.0% experienced polymenorrhea and 4.4% reported oligomenorrhea.

Table 2. Knowledge and Weekly Iron Supplement Adherence Before and After Intervention

Variable	Min	Max	Mean ± SD (Pretest)	Mean ± SD (Posttest)
Knowledge	6	21	12.90 ± 2.31	19.13 ± 1.68
Adherence	2	7	3.56 ± 1.03	5.84 ± 1.02

Based on Table 2, The mean knowledge score increased from 12.90 ± 2.31 before the intervention to 19.13 ± 1.68 after the intervention. Similarly, the mean weekly iron supplement

adherence score increased from 3.56 ± 1.03 at pretest to 5.84 ± 1.02 at posttest. These findings indicate an improvement in both knowledge and adherence following the CEMARA animated flipbook education.

Table 3. Wilcoxon Signed Rank Test and Effect Size

Variable	Z	p-value	Effect Size (r)
Knowledge	−7.197	< 0.001	0.87
Adherence	−7.244	< 0.001	0.88

Based on Table 3, The Wilcoxon Signed Rank test demonstrated a statistically significant increase in knowledge scores after the intervention ($Z = -7.197$; $p < 0.001$). The calculated effect size was very large ($r = 0.87$), indicating a substantial impact of the intervention. Similarly, adherence scores significantly increased following the intervention ($Z = -7.244$; $p < 0.001$), with a very large effect size ($r = 0.88$).

While the statistical analysis yielded exceptionally large effect sizes for both knowledge ($r = 0.87$) and adherence ($r = 0.88$), these magnitudes must be interpreted with caution. The reliance on self-reported questionnaires inherently introduces social desirability bias. It is highly probable that participants, conscious of the study's objectives and the weekly monitoring by researchers or school authorities, may have overstated their adherence to iron supplementation and paid closer attention to the educational material to meet perceived expectations.

Furthermore, the Hawthorne effect likely contributed to these inflated scores, as the mere awareness of being observed and evaluated over the one-month period can temporarily alter participant behavior. Therefore, while the CEMARA animated flipbook demonstrated a positive educational impact, the absolute magnitude of the effect sizes reported in this study is likely overestimated due to these psychosocial biases. Future studies should integrate objective clinical biomarkers, such as changes in hemoglobin levels or direct pill counts, to corroborate self-reported adherence and provide a more accurate measure of the intervention's true efficacy.

Table 4. Correlation Between Knowledge and Adherence (n = 68)

Variables	r	p-value
Knowledge – Adherence	0.171	0.162

Based on Table 4, Spearman's rank correlation analysis showed a weak positive correlation between changes in knowledge and adherence ($r = 0.171$), which was not statistically significant ($p = 0.162$). Although both knowledge and adherence improved following the intervention, the increase in knowledge was not significantly associated with improved adherence.

DISCUSSION

The present study demonstrated a substantial improvement in adolescents' knowledge of anaemia following the CEMARA animated flipbook intervention, as reflected by a very large effect size ($r = 0.87$). This finding supports the Cognitive Theory of Multimedia Learning, which posits that integrating visual and verbal information enhances cognitive processing and retention (Mayer, 2009). Digital and interactive educational approaches have consistently been shown to improve adolescent engagement and comprehension, particularly in nutrition and health education contexts (Hernandez et al., 2021; Chaudhary et al., 2022; Nguyen et al., 2023). School-based interventions incorporating structured multimedia-supported delivery are generally more effective than conventional lecture-based methods in improving knowledge outcomes (Tamiru et al., 2017; Nguyen et al., 2024). The repeated access and interactive features embedded within the CEMARA flipbook may have

contributed to greater cognitive engagement and information retention among participants.

In addition to improving knowledge, this study also observed a significant increase in weekly iron supplement adherence (r = 0.88). However, these findings should be interpreted cautiously because the pre-experimental one-group pretest–posttest design does not allow strong causal inference. The observed improvements may not solely reflect the effect of the animated flipbook itself but may also be influenced by repeated monitoring, increased participant awareness, and the structured school environment during the intervention period. Nevertheless, the findings suggest that combining multimedia-based education with behavioural reinforcement strategies may positively support adherence behaviour among adolescents.

Behavioural change theories emphasize that knowledge alone is insufficient to produce sustained behavioural change without environmental support and repeated reinforcement (Ajzen, 1991; Bandura, 2004). In this study, weekly monitoring may have strengthened adherence by reinforcing perceived benefits and increasing accountability regarding supplement intake. This finding aligns with previous evidence showing that adherence to iron supplementation among adolescents is often inconsistent due to side effects, forgetfulness, lack of supervision, and low motivation despite adequate program availability (Benson et al., 2021; WHO, 2023; Low et al., 2021). Interventions integrating education with behavioural reinforcement and structured monitoring have demonstrated greater effectiveness than passive supplementation strategies alone (Fernandez-Gaxiola & De-Regil, 2019; Pasricha et al., 2021; Salam et al., 2013).

Despite improvements in both knowledge and adherence, the correlation between these variables was weak and not statistically significant (r = 0.171; p = 0.162), highlighting the complex and multidimensional nature of adolescent health behaviour. This finding is consistent with behavioural frameworks suggesting that knowledge does not automatically translate into behavioural compliance (Glanz et al., 2015; Michie et al., 2018). Adherence behaviour among adolescents is shaped by multiple contextual determinants, including family supervision, peer influence, cultural perceptions regarding supplement consumption, school support systems, and individual motivation. In some cultural settings, iron tablets may be perceived as medication only for illness or pregnancy, potentially reducing adolescents' willingness to consume them regularly. Family encouragement and teacher involvement may also play important roles in shaping adherence behaviour among school-aged adolescents.

Field observations in this study further supported these interpretations, revealing that practical and physiological barriers such as nausea, gastric discomfort, unpleasant taste, and forgetfulness frequently undermined adherence despite adequate knowledge. Similar findings have been reported in previous studies identifying side effects and negative physical experiences as major contributors to non-adherence in iron supplementation programs (Galloway et al., 2002; De-Regil et al., 2013; Hurrell et al., 2010). Additionally, adherence may decline outside structured environments where supervision and reinforcement are limited. Therefore, improving adolescent adherence to iron supplementation likely requires not only educational interventions but also supportive social and environmental systems that facilitate sustained behavioural adoption.

Collectively, these findings have important implications for midwifery and school health practice. Multimedia-based educational interventions such as CEMARA may serve as supportive tools to improve adolescent engagement and awareness regarding anaemia prevention. However, their effectiveness may be enhanced when integrated with broader behavioural and environmental support systems, including family involvement, teacher supervision, peer support, and structured monitoring mechanisms. This approach aligns with global public health strategies aimed at reducing anaemia prevalence and improving adolescent nutrition outcomes in low- and middle-income countries (Bhutta et al., 2013; Black et al., 2021; Keats et al., 2024).

Nevertheless, this study has several limitations. The absence of a control group limits the ability to establish definitive causal relationships between the intervention and observed outcomes. Reliance on self-reported adherence measures may also introduce social desirability and reporting bias. Furthermore, the relatively short intervention duration may not adequately capture long-term adherence behaviour. Future studies employing randomized controlled designs, larger sample sizes, objective adherence indicators, and longer follow-up periods are recommended to strengthen causal inference and evaluate long-term intervention effectiveness.

CONCLUSION

CEMARA animated flipbook education was associated with improvements in both anaemia-related knowledge and weekly iron supplement adherence among anaemic adolescent girls. These findings suggest that multimedia-based educational approaches combined with structured monitoring may support adolescent engagement and adherence within school-based health programs.

However, the findings should be interpreted cautiously because the pre-experimental design without a control group limits the ability to establish strong causal relationships between the intervention and observed outcomes. In addition, the absence of a significant correlation between knowledge improvement and adherence indicates that adolescent health behaviour is multifactorial and may also be influenced by contextual determinants such as supervision, family support, social environment, and perceived barriers to supplement consumption.

Nevertheless, this study highlights the potential role of interactive digital educational media as supportive tools within school-based iron supplementation programs and adolescent reproductive health strategies. Future studies employing controlled experimental designs, longer follow-up periods, and objective adherence measurements are recommended to strengthen causal inference and evaluate long-term effectiveness.

SUGGESTION

Digital educational media such as the CEMARA animated flipbook should be integrated into school-based iron supplementation programs to enhance knowledge and adherence among adolescent girls. Strengthening supervision through collaboration between school health units, midwives, and families is recommended to support sustained supplement intake. Future studies should employ controlled experimental designs with larger samples and objective adherence measures to better evaluate long-term effectiveness and behavioural determinants.

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CONFLICTS OF INTEREST

The authors confirm that there are no conflicts of interest related to this study.

AUTHOR CONTRIBUTIONS

Indah Putri Ramadhanti contributed to conceptualization, methodology development, supervision, data collection, and manuscript

drafting. Desri Nova H contributed to methodology refinement, data validation, and manuscript review. Kholilah Lubis contributed to data collection and data management. Debby Ratno Kustanto contributed to data analysis, interpretation of results, and critical revision of the manuscript. Aini Mulia Hidayat contributed to literature review, data documentation, and manuscript editing. All authors have read and approved the final version of the manuscript.

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