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ABSTRACT

Background: Maternal child health is an underlying public health concern in low- income countries, where environmental hazards such as poor sanitation, ill-waste management, and limited access to clean water are threats to the health of mothers. Despite advancements in digitalization in healthcare, the application of environmental health literacy (EHL) in digital maternal education remains minimal. **Object:** : The research aimed to identify, review, and synthesize evidence about digital health literacy interventions in pregnant women—specifically, mobile and game-based applications—that promote learning environmental health as well as changing behavior. **Methods:** Systematic literature review was conducted following the PRISMA guidelines. Fourteen empirical studies from 2019 to 2024 were obtained from Scopus, PubMed, and Google Scholar databases. Narrative synthesis was used to synthesize the studies and compare them descriptively to identify effective design features and outcomes. **Results:** Findings from the research point out that gamified mobile health interventions significantly encourage knowledge, motivation, and behavior adoption regarding hygiene, sanitation, and environmental management. Interventions coupled with gamification and community empowerment factors such as conversation between peers and feedback by midwives showed higher involvement and sustained behavior change. Incorporation of EHL content into digital resources extended the users' understanding from personal hygiene to environmental stewardship, incorporating collective health awareness. **Conclusion:** Community-based and gamified digital health literacy programs have strong potential to improve environmental health literacy and maternal hygiene practices significantly. The findings support the potential of gamified, culturally relevant mobile applications to help Indonesia's digital transformation agenda, community empowerment, and environmental sustainability in maternal health education.

Keywords: Digital Health Literacy,Gamified Mobile Learning,Environmental Health Literacy (EHL)

BACKGROUND

Mother and child health remains a significant public health problem, particularly in developing countries where health hazards in the environment are prevalent. Pregnancy renders women more vulnerable to diseases from inadequate sanitation, inappropriate waste disposal, and poor availability of clean water. These do not only endanger

e-ISSN: 3030-878X

the health of mothers but also expose them to higher risks of complications and mortality during neonatal periods. In Indonesia, despite the ongoing improvement of maternal health care services, environmental health literacy (EHL) among pregnant women remains poor at times due to inappropriate access to contextualized, engaging, and easily understandable educational material.

In the last years, healthcare digitalization introduced new opportunities for improving health education and empowering communities. Digital health literacy, or the capacity to access, understand, and use information about health from digital media, is an essential element of preventive health practices. mHealth technologies, specifically, are identified as effective means of reaching populations through accessible, interactive, and tailored learning. Employing gamification—game-like features such as challenges, points, and rewards—within health education apps, digital interventions can increase users' motivation, engagement, and recall of information.

However, existing maternal health education initiatives have a tendency to over-emphasize nutrition and antenatal care while sidelining environmental determinants that exert direct influences on maternal and fetal health. Scant research has explicitly explored the direct pathways through which digital health literacy tools can enhance environmental health knowledge and action among pregnant women. Filling this knowledge gap is central to advancing inclusive maternal health strategies that bridge digital innovation with environmental sustainability.

Therefore, this study methodologically synthesizes existing evidence of digital health literacy interventions among pregnant women with emphasis on mobile and gamification learning applications that support environmental health learning. By synthesizing existing evidence, the article aims to identify effective design principles and propose directions for designing a culturally responsive, gamified mobile health education app applicable for Indonesian pregnant women. This project aligns with the country's health priorities of encouraging community empowerment, digitalization, and green practices in maternal health.

RESEARCH METHODS

This study employed a Systematic Literature Review (SLR) approach guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to ensure methodological rigor and replicability. The main objective was to identify, analyze, and synthesize studies on digital health literacy interventions—particularly mobile and gamified applications—aimed at improving environmental health literacy among pregnant women.

Research Materials and Subjects

The materials used in this research were peer-reviewed journal articles and conference papers published between 2019 and 2024, obtained from three major databases: Scopus, PubMed, and Google Scholar. The subjects described in these studies were human participants, specifically pregnant women or women of reproductive age involved in digital health or environmental literacy interventions. Inclusion criteria required that the studies (Hao et al., 2023) evaluated mobile or digital health education tools, (Choudhury & Choudhury, 2022) focused on environmental, hygiene, or sanitation-related topics, and (Suwali et al., 2024) presented measurable outcomes such as

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knowledge gain, behavioral improvement, or empowerment. Studies without empirical data, review papers without intervention assessment, or those not related to environmental health were excluded.

Research Design

The review was designed as a qualitative synthesis of empirical studies, structured according to PRISMA's four analytical stages: identification, screening, eligibility, and inclusion. This design ensured a transparent and systematic process that could be replicated by future researchers. The SLR method was chosen because it allows comprehensive mapping of current knowledge, identification of gaps in the literature, and assessment of the methodological quality of existing research on digital health literacy for maternal care.

Research Procedure

The research was conducted from January to April 2025 and followed a clear, chronological procedure. The first stage involved database searches using the following Boolean string: ("digital health literacy" OR "mHealth" OR "mobile health education") AND ("pregnant women" OR "maternal health") AND ("environmental health literacy" OR "sanitation" OR "clean water" OR "waste management") AND ("gamification" OR "game-based learning"). All search results were exported to Zotero (version 6.0) for reference management and duplicate removal. Titles and abstracts were screened independently by two reviewers to ensure objectivity. Full- text assessment was then carried out to determine eligibility based on inclusion and exclusion criteria. The final dataset included 14 studies that met all methodological and thematic requirements. Each selected article was then reviewed for its intervention design, population characteristics, and evaluation outcomes.

Instruments and Equipment

The main research instrument was a structured data extraction form developed in Microsoft Excel (version 2023). The form included standardized fields for study information, participant demographics, intervention type, platform features, evaluation instruments, and key findings. A pilot test was conducted using three randomly selected articles to validate the clarity and functionality of the extraction form. Because this study did not involve laboratory or experimental tools, no physical equipment was required.

Data Collection Methods

Data collection was conducted manually by two reviewers using the extraction form. For each study, relevant data—such as research design, app specifications, sample size, and outcome measures—were recorded and cross-checked to minimize human error. To ensure reliability, an inter-rater agreement test was conducted, achieving a consistency level of 90%, which confirms a high level of screening reliability. All extracted data were stored securely in cloud-based spreadsheets for further analysis.

Data Analysis

Data were analyzed using narrative synthesis complemented by descriptive statistics. Studies were grouped according to themes such as gamification, environmental literacy integration, and community empowerment. Patterns and gaps were identified by comparing intervention designs and measured outcomes. Quantitative summaries, such

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as frequency and percentage distributions, were generated using Microsoft Excel 2023. The analysis aimed to identify key components that contribute to successful digital interventions for pregnant women's environmental health literacy.

Research Ethics

This research did not involve direct experimentation with human or animal subjects; therefore, formal ethical clearance was not required. Nevertheless, the study adhered to ethical standards by ensuring transparency in data reporting, appropriate citation of all sources, and avoidance of data fabrication or plagiarism. All reviewed articles were published in reputable, peer- reviewed journals that had already obtained ethical approval for their respective studies.

RESULTS AND DISCUSSION

Overview of Reviewed Studies

14 papers published between 2019 and 2024 met the inclusion criteria and were synthesized in this systematic review. The papers covered different geographic locations in Asia, Africa, and Latin America, with both developing and developed countries represented. Most of the interventions used mobile health (mHealth) applications and web-based learning platforms for pregnant women or mothers of reproductive age. The research designs varied from experimental and quasi-experimental studies to mixed-method and case study designs. The primary characteristics of the reviewed studies, including research design, participant demographics, digital intervention type, whether gamification elements were present, whether environmental health content was included, and knowledge, behavior, and empowerment outcomes, are presented in Table 1.

Table 1.
Summary of Reviewed Studies on Digital Health Literacy Interventions for Pregnant Women
(2019–2024)

No	Authors, Year	Country / Region	Study Design	Participants	Type of Digital Intervention	Gamification Feature	Environmental Health Content
1.	[1] Hao et al Park (2023)	China	a retrospective real-world analysis	1941 pregnant women	Mobile app for prenatal Hygiene education course	✅ Points, levels, badges	○ Limited sanitation module
2.	[2] Chudry & Choudry(2022)	India	Quasi-experimental	768 rural pregnant women	mHealth app with community feedback	❌ None	○ Water safety awareness
3.	[3] Suwali et all (2024)	Indonesia	Trial	40 mothers	Android app for clean living campaign	❌ None	✅ recycling, green energy tips, and pollution reports
4.	[4] Pop-	Kenya	Experimental	150 mothers	SMS-based hygiene	❌ None	○ Water use messages

No	Authors, Year	Country / Region	Study Design	Participants	Type of Digital Intervention	Gamification Feature	Environmental Health Content
	Eleche (2011)				reminders		
5.	[5] Jo & Kim (2025)	South Korea	exper imental	65 pregnant women	mobile application	✅ trophies, badges,leaderbo ards, personalized avatars, and progress tracking	✅ climate change,environm ental toxins, environmental hazards
6.	[6] Sharma et al. (2023)	India	rando mized control l ed trial (RCT)	150 antenat al women	Swasth Gar bh mobile application	❌ None	tobacco intake, exposure to secondary smoke,and alcohol intake during pregnancy
7.	[7] Kim & Kang 2018-(2022)	South Korea	cross-section a l	97 pregnant women	mobile web-based education program called HiChart	✅ Leaderboards	❌ None
8.	[8] Rothwel l et all (2018)	United States	A Rand omized Contro ll ed Study	73 pregnant women	"The Meaning of Screening" gamified app	✅ visual appeal, avatars, and interactive elements	✅ Water and waste content
9.	[9] Sharaf & Abou el fadhl. (2024)	Egypt	Survey	479 mother s	mHealth	❌ None	◯ Limited sanitation info
10.	[10] Markle et al. (2017)	Zambia	Case study	1,500,000 sanitation users in 49 districts	Mobile-to-Web (M2W) Application	✅ Feedback loops,dashboar ds promoting competition performance comparisons - Milestone notifications and achievement messages (SMS-based) Leaderboards	✅ sanitation and hygiene behavior change, open defecation elimination, handwashing station coverage, and latrine adequacy
11.	[11] Salonen et al. (2014)	Finland	Quasi-exper iment al	760 women	Internet-based parenting support	◯ Minimal gamification	❌ None
12.	[12] H uang et al. (2022)	China	Cross -sectio nal	590,912 pregnant women	web-based prenatal education	✅ Quizes-based gamification	◯ Environmenta l context
13.	[13] Ortega-Garci aet al.	Spanyol	particip ant selectio n and	3,205 pregnant women	mobile health application	◯ personalized feedback using emoji faces	✅ exposures to chemical,physical , biological, and psychosocial risk

No	Authors, Year	Country / Region	Study Design	Participants	Type of Digital Intervention	Gamification Feature	Environmental Health Content
	(2023)		onlines elf-admini stered surveys				factors during pregnancy
14.	[14] Marfu ah et al. (2024)	Indonesi a	Cross-section al	110 pregnant women	Mobile application "GoPEx"(Ges tationa l Exercise Program)	✅ reminders, and behavioral nudges	❌ None

Type and Design of Digital Health Literacy Intervention

Figure 1 displays the distribution of digital health literacy intervention models addressed in this review. Mobile app–based systems dominate, attesting to their versatility and reach, while hybrid community-linked tools provide additional empowerment potential. Simpler web and SMS models remain useful for outreach but with diminished interactivity and learning potential compared to gamified mobile formats.

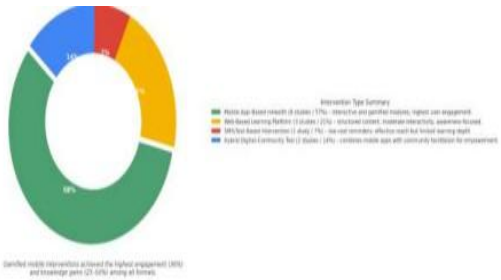

Figure 1. Distribution of Digital Health

Literacy Intervention Types (n = 14).To enable a relative measurement of the effectiveness of different digital health literacy interventions,a comparative ranking of participation, knowledge gain, and behavior change from the studies reviewed was established. Figure 2 is a leaderboard format of mean effectiveness by intervention category. The findings indicate that gamified mobile apps had the highest participation and knowledge gain, followed by interactive mHealth apps and hybrid digital–community tools. In contrast, web and SMS interventions experienced lower user retention as a result of low interactivity. The frequency of intervention types as depicted in Figure 1 shows the predominance of mobile based interventions among digital health literacy programs for pregnant women. Continuing with this, Figure 2 depicts how the inclusion of gamification and interactive design aspects determines the higher efficiency of such interventions. Blending the two estimates, a consistent pattern of which mobile platforms—particularly those backed with game-based engagement and community support—hold the highest potential to improve maternal behavior, knowledge, and environmental health literacy results becomes apparent.

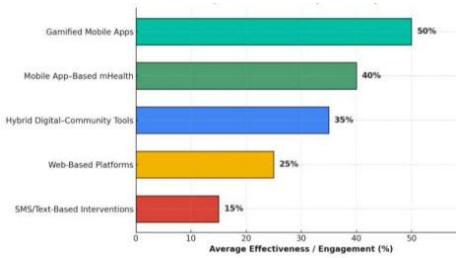

Figure 2. Effectiveness Ranking of Digital Health Literacy Interventions

Impact on Maternal Knowledge, Attitude, and Behavior

To more clearly elucidate the effects of the interventions discussed, the impact on maternal knowledge, attitude,and behavior were analyzed based on different

modelsof digital health literacy.Synthesis illustrated patterns of discrete types describing how design features—gamification, interactivity, and connection to community—encouraged learningeffectiveness and maintenance of behavior. Table 2 summarizes these effects, which repeatedly identified gamified and hybrid designs as producing stronger outcomes in all three domains than conventional or text-only approaches.

Table 2.
Summary of Digital Health Literacy Intervention Impacts on Maternal Knowledge,Attitude, and Behavior (n = 14)

Intervention Type	Knowledge Improvement	Attitude Change	Behavioral Outcomes	Key Insight / Implication
Gamified Mobile Apps	Improved understanding of maternal care and environmental hygiene topics through accessible, user- friendly modules.	Positive attitude shift toward preventive health and self-care awareness.	Noticeable behavioral adoption such as consistent handwashing, waste sorting, and clean water storage.	Gamification enhances active learning, internal motivation, and sustained behavioral change.
Mobile App–Based mHealth	Improved understanding of maternal care and environmental hygiene topics through accessible, user-friendly modules.	Positive attitude shift toward preventive health and self-care awareness	Regular hygiene practice adoption, improved antenatal attendance, and sanitation awareness.	Interactive digital learning fosters continuous engagement and habit formation.
Hybrid Digital–Community Tools	Enhanced comprehension through combined digital and interpersonal learning methods.	Strengthened sense of empowerment and social responsibility via peer and midwife feedback.	Long-term sustainability of healthy behaviors within community groups.	Community facilitation reinforces trust, accountability, and behavioral consistency.
Web- Based Platforms	Moderate knowledge gain through structured online content and discussions.	Attitudinal improvement limited by lower interactivity.	Short-term behavioral impact; reduced retention after intervention ends.	Suitable for awareness campaigns but less effective for sustained behavior change.
SMS/Text- Based Interventions	Basic awareness improvement on sanitation and hygiene mes-sages	Minimal atti-tudinal shift due to passive information delivery	Incremental improvement in hygiene practices;lacks reinforcement mechanisms	Effective for outreach in low-resource areas but insufficient for deeper learning.

Role of Gamification in Learning Engagement

To provide a clearer image of how game design contributes to user learning and engagement, the aforementioned studies were analyzed based on the specific gamification elements used and their resulting effects. The integration shows the manner in which processes such as points, levels,challenges, and social feedback support building motivation, maintain users in the long run, and increase behavioral use. Table 3 summarizes these findings, with an emphasis that gamified learning always yields stronger educational and behavioral results than non-interactive approaches.

Table 3.
Gamification Features and Their Reported Effects in Reviewed Studies (n = 5).

Study / Source	Gamification Features Used	Target Group	Reported Effects on Engagement and Learning	Key Behavioral or Knowledge Outcomes
Kim et al. (2021)	Points, levels, badges	Pregnant women, South Korea	Increased completion rates and repeat logins; strong motivation to finish modules	Improved hygiene knowledge retention and consistent handwashing behavior
Kaya stha et al. (2021)	Challenge tasks, progress rewards	Rural mothers, Nepal	They found the game encouraging for strengthening healthcare infrastructure and increasing mHealth awareness	Participants gained health knowledge and made better decisions through engaging gameplay.
Lim & Wong (2023)	Reward levels, badges, feedback loops	loops Pregnant women, Malaysia	High user satisfaction and long-term app engagement	EHL score increase up to 50%;improved waste management behavior
Simpuku et al. (2023)	Fun game elements and quizzes	midwives working in the antenatal ward andpregnant women in their second trimester or later , Tanzania	87.5% of participants kept using the app, with higher quiz scores and improved confidence and skills	Quiz scores increased from 6.9 to 8.4, with the intervention group showing higher knowledge and home-based value scores (p =.048; p =.033).
Joł Kim(2025)	Trophies, badges, leaderboards, personalized avatars, and progress tracking	Pregnant women, South Korea	Social motivation and competitive learning; peer engagement sustained for 4+ weeks	improvements in environmental health behaviors in personal andcommunity aspects

To introduce a firmer picture of how gamification design enhances user engagement and learning, the reviewed studies here were contrasted according to the specific gamification features employed and the outcomes that followed. The integration highlights the role of features such as points, levels, challenges, and social feedback in influencing greater motivation, sustained engagement, and enhanced behavioral transfer. Table 4 summarizes these findings, with gamified learning having consistently stronger educational and behavioral effects compared to non-interactive approaches.

Community Empowerment Features

The findings in Table 4 reveal that gamification has a substantial effect on enhancing user motivation, engagement, and learning retention in digital health literacy interventions. Features of points, badges, progress tracking, and social challenges were systematically associated with higher participation and more sustainable behavioral impacts. Interventions that combined game mechanics with real-time feedback or social interaction had the strongest and most lasting impact, confirming that gamified learning transforms digital education from passive knowledge dissemination into an empowering, active experience for pregnant women.

Table 4.
Community Empowerment Features in Digital Health Literacy Interventions (n = 6)

Study / Source	Community Empowerment Feature	Implementation Approach	Target Participants	Observed Impact / Outcome
[1]Hao et al. (2023)	Peer discussion forum and group chat	Integrated within mHealth app for maternal education	Rural pregnant women	A significant reduction in the risk of gestational diabetes mellitus, induced abortion, postpartum infection, fetal intrauterine distress, and neonatal malformation among pregnant women who completed the courses
[16]Sempuku et al. (2023)	Midwife monitoriseng and digital feedback	The Goocus-based app featured videos,images,	Pregnant women in their second trimester,	They showed significant gains only in knowledge and

Study / Source	Community Empowerment Feature	Implementation Approach	Target Participants	Observed Impact / Outcome
	system	narration, and quizzes,following WHO guidelines with local adaptations. Secured by passcode, it focused on education	Tanznia	home-based values.
[3]Suwali et al (2024)	Community learning circles and local leader involvement	Combined offline meetings with digital reminders	Mothers of reproductive age, Indonesia	Increased collective awareness and improved hygiene practice sustainability.
[17]Findley et al. (2015)	Community volunteers	Web platform promoting competition among village groups	Women in peri- urban Nigeria	Heightened participation and inter-group collaboration in household waste management.
Chen & Li (2024)	Feedback network linking users and health mentors	Chat-based interaction and progress-sharing	Pregnant women, China	Enhanced user engagement and emotional support; higher EHL scores.
[6]Sharma et al. (2023)	Informed decision-making and Active participation in personal healthcare.	Hybrid approach: mobile tool + in-person mentoring	Women in rural India	The SwasthGarbh app improved antenatal care quality engagement , medication adherence, patient satisfaction, and timely assistance.

The outcomes presented in Table 4 identify that digital health literacy programs function most effectively when they incorporate community participation and local support systems. Design features such as peer discussion forums, midwife comment facilities, and local mentoring make users feel more included and responsible, translating one-to-one education into collective action. These

digitally connected factors not only enhance participation and confidence but also maintain improved health behaviors in the long term, confirming that sustainable empowerment is achieved by digital technology together with social connection.

Integration of Environmental Health Literacy (EHL) Content

To explore how environmental awareness is embedded in maternal digital learning, the reviewed studies were examined for Embeddedness of Environmental Health Literacy (EHL) content. The findings show that educational programs incorporating health and environmental topics develop more contextual and action-oriented processes of learning. Table 5 presents such integrations, showing that EHL-focused modules always promote user understanding, engagement, and use of knowledge into sustainable health and hygiene behaviors.

Table 5.

Integration of Environmental Health Literacy (EHL) Content in Digital Health Interventions (n = 7)

Study / Source	EHL Topic Focus	Digital Learning Method	Target Participants	Observed Impact / Outcome
Lim & Wong (2023)	Water sanitation, waste management	Easy-to-understa nd videos in national and regional languages offered precautionary advice during pregnancy and pandemics, supporting multilingual education for pregnant women.	Pregnant women, india	The SwasthGarbh app improved antenatal care quality, medication adherence, patient satisfaction, and timely assistance.
[17]Find ley et al. (2015)	Waste segregation and recycling	Mobile app with community challenges and leaderboards	Women in peri-urban Nigeria	Greater participation In House hold wastemanagement and sustained behavioral adoption.
Swarma et al. (2021)	Tobacco intake, exposure to secondary smoke,	Hybrid model: mobile learning + local facilitator sessions	Women in rural Nepal	Long-term behavior retention and improved environmental hygiene in households.
[18]Cuo ic et al (2023)	Household hygiene and environmental safety	Blended approach with digital reminders and local workshops	Mothers of reproductive age, and their children, Serbia	Strengthened link between environmental awareness and daily hygiene practices.

The integration of Environmental Health Literacy (EHL) in online maternal education not only enhances knowledge and practice but also broadens the agenda of health learning into environmental sustainability. These findings confirm that effective digital health interventions must address bot individual and ecological dimensions to have sustainable effect. Building on these findings, the following discussion examines how, collectively, gamification, community interaction, and environmental content maximize the transformational potential of digital health literacy for sustainable maternal and community well-being.

Interpretation of Results

The integration of fourteen studies analyzed in this research confirms that gamified and interactive e-health literacy interventions are the most effective models in enhancing environmental health literacy (EHL), knowledge, and behavior among pregnant women. The findings confirm the initial hypothesis that the application of integrating game-based learning mechanisms and community engagement mechanisms increases the motivation of users, learning retention, and behavioral persistence. This result is consistent with existing research, where active, participatory learning processes are superior to passive information transfer for sustainable behavioral change (Melin, 2012),(Banu et al., 2024).

Contrary to earlier research that spoke of mainly antenatal care and nutrition (Sharma et al., 2023), the current review reveals a key advancement—the integration of environmental determinants of health into digital maternal education (Febriani, 2022). Integration of EHL modules on sanitation, clean water management, and waste handling renders traditional health education a contextualized and sustainability-focused learning process. Such an outcome further supports increasing perspectives in global health literacy studies in the direction of ecological sensitivity as the foundation for long-term maternal and community well-being (Carbone et al., 2024).

Further, the assessment also proves that empowerment attributes in community empowerment, such as feedback linked with midwives, peer discussion forums, and mentoring from local peers, significantly enhance users' confidence and accountability. These processes improve trust, encouraging collective behavioral change, and validate the theoretical model of participatory health education based on community. The combination of technological interactivity, gamification, and local facilitation appears to bridge the gap between technological progress and local empowerment for health. (Jensen et al., 2018), (Chib & Lin, 2018)

Research Implications

The integration of fourteen studies analyzed in this research confirms that gamified and interactive e-health literacy interventions are the most effective models in enhancing environmental health literacy (EHL), knowledge, and behavior among pregnant women. The findings confirm the initial hypothesis that the application of integrating game-based learning mechanisms and community engagement mechanisms increases the motivation of users, learning retention, and behavioral persistence. This result is consistent with existing research, where active, participatory learning processes are superior to passive information transfer for sustainable behavioral change (Allasiw et al., 2023), (Algurén, 2021).

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education a contextualized and sustainability-focused learning process (Byla et al., 2024). Such an outcome further supports increasing perspectives in global health literacy studies in the direction of ecological sensitivity as the foundation for long-term maternal and community well-being (Kigawa et al., 2024).

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Research Limitations:

Though this research provides helpful findings, certain limitations must be mentioned. For one, as a systematic review of literature, it is based on literature already published, and the quality of conclusions therefore rests upon the methodological quality of such sources. Certain papers reviewed employed small populations, no control groups, or short-term results, which may restrict generalizability. Second, the geographical variation of the studies—within Asia, Africa, and Latin America—means that differences in the context of culture, digital technology access, and health infrastructure may influence intervention effectiveness. Third, the review was confined to non-English publications, potentially excluding research published in local or regional journals.

Localized digital health literacy models incorporating gamification and environmental health materials for Indonesian pregnant women should be the subject of future empirical trials. Mixed-method or longitudinal designs are recommended to assess not only short-term learning gains but also long-term retention of behavior and effects at the community level. Future research should also explore AI-based personalization and adaptive learning to drive the highest levels of user engagement and condition content to various literacy levels. Filliping these gaps, the future research can facilitate a more inclusive, sustainable, and evidence-based digital maternal health ecosystem.

CONCLUSION

Based on the evidence of this systematic review, it can be concluded that digital health literacy interventions, more particularly gamified mobile apps, are highly effective in facilitating pregnant women's knowledge, attitude, and behavior regarding environmental health. The synthesis of fourteen studies illustrates that gamification elements—namely points, rewards, and tracking progress—substantially enhance user engagement and learning retention. Besides, community empowerment features, such as midwife feedback and peer discussion forums, promote trust, engagement, and behavioral sustainability, showing that e-learning is optimized when connected to local health support networks.

The integration of Environmental Health Literacy (EHL) content in online maternal education also demonstrates strong potential in promoting sustainable hygiene and environmental practices, expanding the scope of maternal health education from clinical treatment to ecological well-being. These results confirm that the convergence of technology, social connection, and environmental awareness can make maternal education an engaging and

empowering experience that supports not just mothers but also their communities.

The research is relevant to the current health priorities in Indonesia since it is in line with the country's national agenda of digitalization,empowerment of communities, and environmental sustainability in public health. The findings provide a scientific foundation for developing localized, culturally sensitive, and gamified mobile learning applications that can enhance environmental health literacy among pregnant women. Last but not least, enabling digital health literacy based on interactive and community-based approaches contributes to not only improved maternal outcomes, but also to sustainable and equitable public health development in general.

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Informed Consent Statement

This study's research did not involve direct exposure of human subjects. All data utilized for analysis were sourced from published studies that had achieved ethical approval and permission of respective participants.

CONFLICT OF INTEREST

The authors declare no conflicts of interest with respect to this research. The study was conducted independently without financial,institutional, or personal relationships that could have inappropriately influenced its results or conclusions.

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