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Empowering Indonesian Adolescents Through Digital Health Literacy: A Predictive Model for Breast Cancer Prevention Education Aligned with SDG 3

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Abstract. *Indonesia faces unique challenges with breast cancer affecting younger populations, necessitating early health literacy interventions among adolescents to achieve SDG 3.4 targets. To develop a predictive model identifying determinants of breast cancer literacy among Indonesian adolescents. A cross-sectional study was conducted from March-June 2025 in West Sulawesi Province. The sample comprised 58 female adolescents (ages 14-17) from high schools (n=26, 44.8%) and vocational schools (n=32, 55.2%). Data collection utilized validated online surveys measuring ten breast cancer literacy indicators. Binary logistic regression with backward elimination was performed using SPSS 25.0. Overall, 56.9% (n=33) demonstrated inadequate literacy levels, with only 43.1% (n=25) achieving adequate levels. Critical knowledge deficits were found in prevention strategies (1.7% correct) and risk factor identification (37.3% correct), contrasting with high awareness of medical follow-up procedures (96.6% correct). The logistic regression model (Nagelkerke R^2=0.618, Hosmer-Lemeshow p=0.512) identified four significant determinants: enrollment in high schools versus vocational schools (OR=4.3, 95% CI: 1.27-14.55, p=0.019), healthcare provider information sources (OR=7.3, 95% CI: 1.44-10.46, p=0.016), digital learning media utilization (OR=3.4, 95% CI: 1.13-10.46, p=0.031), and frequent health information-seeking behavior (OR=3.4, 95% CI: 1.01-11.66, p=0.048). This model enables targeted resource allocation for cancer prevention strategies supporting SDG 3.4, potentially reducing premature mortality through enhanced early detection behaviors among Indonesia's future generations.*

Keywords: *Adolescents, breast cancer literacy, breast self-examination, early detection, health education*

1. Introduction

Breast cancer constitutes a significant public health challenge globally, with particularly concerning implications for developing nations striving to achieve the United Nations Sustainable Development Goal 3 (SDG 3), which aims to ensure healthy lives and promote well-being for all. In Indonesia, this challenge manifests uniquely through earlier onset patterns, with the median diagnosis age of 48 years contrasting sharply with European countries' median of 68 years (Iskandarsyah et al., 2021). This epidemiological pattern—with 30% of Indonesian breast cancer cases occurring before age 40, compared to much lower rates in developed nations—underscores, underscores the critical importance of establishing preventive health behaviors during adolescence (Mardela et al., 2017).

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The concept of breast cancer health literacy extends beyond simple knowledge acquisition to encompass the comprehensive ability to obtain, process, evaluate, and apply health information for informed decision-making (Holden et al., 2021; Irma et al., 2023). Within the Indonesian context, this multifaceted construct becomes particularly crucial given the complex interplay between cultural beliefs, healthcare accessibility, and educational disparities that characterize the nation's health landscape. Research demonstrates that adolescent health literacy development directly influences adult health behaviors, making this life stage a critical intervention window for achieving long-term population health improvements (Woods-Townsend et al., 2023).

The alignment between breast cancer literacy initiatives and SDG 3, particularly target 3.4 which seeks to reduce premature mortality from non-communicable diseases by one-third by 2030, represents a strategic approach to sustainable health development (United Nations, 2015). By establishing robust health literacy foundations during adolescence, Indonesia can potentially alter the trajectory of breast cancer outcomes for future generations, contributing directly to national and global sustainable development objectives.

Despite growing international recognition of adolescent health literacy's importance, the Indonesian context presents unique challenges that remain inadequately addressed in existing literature. Research from comparable developing nations reveals concerning patterns—Koirala et al. (2016) found only 4.8% of Nepalese high school students possessed adequate breast cancer knowledge, while these findings suggest similar challenges may exist in Indonesia, though comprehensive empirical evidence remains limited. A localized study in Bandung by Nurleli et al. (2022) revealed that 53.1% of female adolescents demonstrated limited risk factor knowledge, with 99.2% exhibiting inadequate early detection behaviors. However, these fragmented findings fail to provide the comprehensive understanding necessary for developing targeted, evidence-based interventions.

The evolution of cancer health literacy research over the past decade has revealed increasingly sophisticated relationships between literacy levels and health outcomes. Holden et al.'s (2021) systematic review established consistent correlations between low health literacy and adverse outcomes across the cancer care continuum. Building upon this foundation, recent studies employing validated instruments such as the European Health Literacy Survey Questionnaire-12 (HLS-EU-Q12) have uncovered complex patterns of literacy distribution that vary significantly across cultural and socioeconomic contexts (Samoil et al., 2021). These methodological advances highlight the importance of context-specific measurement approaches that account for local cultural nuances and educational systems.

The Indonesian sociocultural landscape presents particular complexities that influence health literacy development among adolescents. Qualitative research by Iskandarsyah et al. (2020) reveals persistent misconceptions characterizing cancer as a shameful condition linked to moral failings, creating substantial barriers to health information seeking and processing. Recent findings from Yogyakarta by Widjaja et al. (2023) demonstrate that while Indonesian women show familiarity with breast self-examination, awareness of clinical examination and mammography remains limited, suggesting differential literacy patterns across prevention modalities that require targeted educational approaches.

Health literacy determinants operate through multiple interconnected pathways, encompassing individual, social, and systemic factors (Dewi et al., 2023). International evidence increasingly points to the critical role of information source credibility, with healthcare provider communication emerging as a particularly influential factor in shaping

adolescent health understanding (Woods-Townsend et al., 2023). Additionally, the digital transformation of health information dissemination presents both opportunities and challenges, as adolescents navigate vast quantities of online content with varying accuracy and relevance (Irma et al., 2025; Irma & M. Sallo, 2025).

This study addresses critical gaps in current understanding by providing the first comprehensive analysis of breast cancer literacy determinants among Indonesian adolescents. Our research makes several novel contributions to the field: First, we employ a multidimensional literacy assessment framework that captures the complexity of health literacy beyond simple knowledge metrics. Second, we develop a predictive model that identifies actionable intervention targets for policy and practice. Third, we explicitly examine the role of digital media in shaping health literacy among Indonesia's digital native generation. Finally, we situate our findings within the broader sustainable development agenda, demonstrating how targeted health literacy interventions can contribute to achieving SDG 3 objectives.

The practical significance of this research extends to multiple stakeholder groups engaged in adolescent health promotion. For healthcare providers, our findings offer evidence-based guidance for tailoring health communication strategies to adolescent audiences. Educational policymakers can utilize our determinant analysis to inform curriculum development and resource allocation decisions. Public health practitioners gain insights into population segments requiring intensive literacy interventions. Most importantly, our predictive model provides a screening tool for identifying at-risk adolescents who would benefit most from targeted health literacy support.

Based on the identified research gaps and practical needs, this study aimed to: (1) comprehensively assess breast cancer literacy levels among Indonesian adolescents using a validated multidimensional framework; (2) identify and quantify demographic, institutional, information source, and behavioral factors influencing literacy levels; (3) develop a robust predictive model for early identification of adolescents at risk for low health literacy; (4) formulate evidence-based and culturally appropriate intervention recommendations that align with SDG 3 targets for reducing premature cancer mortality.

2. Methods

2.1. Research Design

This study employed a descriptive analytical design with a cross-sectional approach to comprehensively analyze breast cancer literacy levels among adolescents and identify the multifaceted factors influencing these literacy levels. The cross-sectional methodology was specifically selected to capture a comprehensive snapshot of literacy patterns while enabling simultaneous analysis of multiple predictor variables and their associations with literacy outcomes. This approach facilitated efficient data collection while maintaining methodological rigor in examining relationships between various predictive factors and achieved literacy levels.

2.2. Population and Sample

The study population comprised female adolescents aged 14-17 years attending secondary schools in West Sulawesi Province, Indonesia. This age range was selected based on developmental psychology evidence showing that mid-to-late adolescence is a critical period for health behavior formation that persists into adulthood.

Inclusion criteria were carefully defined to ensure sample homogeneity: female adolescents aged 14-17 years, currently enrolled in secondary education (high school or vocational school), possessing basic digital technology skills sufficient to access online surveys, and providing informed consent with parental permission for voluntary participation. Exclusion criteria were established to maintain data quality: adolescents with documented cognitive limitations affecting questionnaire comprehension and those lacking reliable internet access for digital platform participation.

The research sample consisted of 58 respondents selected using purposive sampling techniques based on institutional accessibility and school administration's willingness to facilitate student participation. The respondent distribution included 26 students from SMA Negeri 3 (44.8%) and 32 students from SMK Fatimah (55.2%). This sample size satisfied minimum requirements for logistic regression analysis with an adequate events per variable (EPV) ratio of approximately 6.25, considering the eight initial predictor variables analyzed in the model.

2.3. Data Collection Technique

Data collection was conducted through structured online surveys using the Google Forms platform during March-June 2025 in Mamuju Regency, West Sulawesi Province. The decision to employ online data collection methods was based on several methodological advantages: broad geographic reach within the study region, enhanced respondent autonomy allowing participation according to individual schedules, reduced social desirability bias through anonymous submission, and minimized interviewer effects on response patterns.

Prior to data collection, extensive coordination with school administrations was undertaken. This process involved obtaining formal research permits, conducting orientation sessions with school counselors who served as liaison personnel, and establishing communication protocols to ensure student safety and data confidentiality. The response rate reached 87.9% of initially invited students, with a 100% completion rate for all returned questionnaires, indicating strong engagement and instrument acceptability.

2.4. Research Instrument

The research instrument comprised a comprehensively designed structured questionnaire consisting of two main sections: respondent characteristics and breast cancer literacy measurement.

The respondent characteristics section systematically collected: demographic data (age, school type), primary health information sources (categorized as healthcare providers, internet/social media, or family), learning media preferences (classified as digital versus conventional), and frequency of health information seeking (measured on a four-point scale: very frequently, frequently, occasionally, rarely).

The breast cancer literacy section utilized an instrument systematically adapted from the Breast Cancer Awareness Scale - Indonesia (BCAS-I) with modifications to ensure age-appropriateness for adolescent populations. This instrument measured 10 distinct breast cancer literacy components: (1) understanding of breast cancer as a disease entity, (2) knowledge of at-risk age groups for breast cancer, (3) comprehension of breast self-examination (BSE) procedures, (4) awareness of optimal BSE timing, (5) recognition of early signs of breast cancer, (6) identification of breast cancer risk factors, (7) understanding of breast cancer prevention strategies, (8) capacity for family BSE education, (9) knowledge of

mammography, and (10) appropriate follow-up actions upon discovering breast abnormalities.

Each component was assessed using multiple-choice questions with one scientifically correct answer. Content validity was rigorously evaluated through a Delphi process involving an expert panel comprising three public health specialists with expertise in adolescent health and two oncology practitioners with experience in cancer education. Instrument reliability was tested using Kuder-Richardson 20 (KR-20) for dichotomous data, yielding a reliability coefficient of 0.78, indicating good internal consistency suitable for research purposes.

2.5. Research Variable Construction

1. Outcome Variable

Breast cancer literacy was operationalized through composite scores derived from 10 validated indicators. Each indicator was dichotomously scored with 1 for correct answers and 0 for incorrect answers. Total literacy scores were calculated as percentages of correct answers from all indicators (potential range 0-100%).

For logistic regression analysis purposes, the outcome variable was dichotomized into two categories based on evidence-based cut-off points established in health literacy research literature. Respondents with total scores ≥70% were categorized as achieving "high literacy" (code 1), while respondents with total scores <70% were categorized as demonstrating "low literacy" (code 0). The 70% threshold was selected based on international standards for functional health literacy and previous validation studies in Southeast Asian populations (Mardela et al., 2017).

2. Predictor Variables

Predictor variables were selected based on theoretical frameworks and empirical evidence: (1) respondent age (continuous variable measured in years), (2) school type (binary: high school=1, vocational school=0), (3) primary health information sources (categorical with three levels: healthcare providers, internet/social media, family as reference), (4) digital learning media preference (binary: yes=1, no=0), and (5) frequency of health information seeking (ordinal with three collapsed categories: very frequently/frequently, occasionally, rarely as reference).

3. Individual Knowledge Level Categorization

For descriptive analysis of each literacy indicator, we applied standard knowledge level categories according to Arikunto (2013), which have been widely validated in Indonesian educational research contexts. Knowledge levels were stratified into three categories based on the percentage of respondents answering correctly: Good (76-100%), Sufficient (56-75%), and Poor (≤55%). This classification system provides meaningful thresholds for identifying areas requiring targeted educational intervention.

2.6. Data Analysis

Data analysis was conducted in two sequential and complementary stages to comprehensively address the research objectives.

Stage 1: Descriptive Analysis

Descriptive analysis was performed to systematically characterize respondent profiles and breast cancer literacy levels for each indicator. Respondent characteristic data were

analyzed using frequency distributions and percentages with 95% confidence intervals where appropriate. Literacy levels for each indicator were calculated as percentages of respondents answering correctly, then categorized according to the validated Arikunto (2013) standards. Central tendency measures (mean, median) and dispersion indices (standard deviation, range) were computed for continuous variables. The descriptive analysis results were presented in clearly formatted frequency and percentage tables to facilitate interpretation of literacy distribution across various breast cancer knowledge domains.

Stage 2: Logistic Regression Analysis

Binary logistic regression analysis was conducted to identify factors significantly influencing adolescent breast cancer literacy levels. Prior to multivariate modeling, preliminary analyses were conducted including: bivariate analysis using chi-square tests to assess individual relationships between each predictor variable and the outcome, and correlation analysis to detect potential multicollinearity among predictor variables.

The multivariate analysis employed the backward elimination method with a significance level of $\alpha=0.05$ to determine variables retained in the final model. Model building proceeded systematically: initial inclusion of all theoretically relevant predictors, stepwise removal of non-significant variables based on likelihood ratio tests, and retention of variables with p-values <0.05 or those demonstrating important confounding effects.

Logistic regression assumptions were rigorously evaluated: (1) linearity of the relationship between logit and continuous variables was assessed using Box-Tidwell transformation, (2) independence of observations was ensured through study design, (3) absence of multicollinearity among predictor variables was confirmed using variance inflation factors (VIF<5), and (4) adequacy of sample size was verified using the 10 events per variable rule.

Model quality was evaluated using multiple complementary criteria: (1) Nagelkerke R^2 to measure the proportion of variability explained by the model, (2) Hosmer-Lemeshow test to examine goodness-of-fit with $p>0.05$ indicating acceptable calibration, and (3) -2 Log Likelihood to measure overall model fit with lower values indicating better fit. Additionally, model discrimination was assessed through the area under the receiver operating characteristic (ROC) curve, with values >0.7 indicating acceptable discrimination.

2.7. Data Processing and Management

Data collected through Google Forms were systematically exported to Microsoft Excel format for initial cleaning and coding. The data cleaning process followed a standardized protocol: identification and handling of missing values using appropriate imputation methods where justified, detection of outliers through box plot analysis, and verification of inconsistent responses through logical checks. The cleaned data were then imported into SPSS version 25.0 for statistical analysis. Each analysis stage was documented in a detailed audit trail to ensure reproducibility and transparency of research processes. All data were stored securely with password protection and access limited to the research team.

3. Results and Discussion

3.1. Result

3.1.1. Respondent Characteristics

This study involved 58 female adolescents with a mean age of 15.9 years (SD=1.02) and an age distribution ranging from 14-17 years. The majority of respondents were 16 years old (n=24, 41.4%) and 17 years old (n=19, 32.8%), while respondents aged 14 and 15 years comprised 12.1% (n=7) and 13.8% (n=8), respectively. This age distribution reflects the typical enrollment pattern in Indonesian secondary education. Based on school type, the respondent distribution showed 26 students from SMA Negeri 3 (44.8%) and 32 students from SMK Fatimah (55.2%), providing representation from both academic and vocational educational tracks.

Analysis of health information source patterns revealed important insights into adolescent information-seeking behaviors. A total of 34.5% (n=20) of respondents primarily obtained health information from healthcare providers, 41.4% (n=24) from internet/social media, and 24.1% (n=14) from family sources. Regarding learning media preferences, 65.5% (n=38) of respondents expressed preference for digital learning media, while 34.5% (n=20) still showed a preference for conventional methods. Health information seeking frequency indicated that 27.6% (n=16) of respondents frequently/very frequently sought information, 44.8% (n=26) occasionally, and 27.6% (n=16) rarely sought health information, suggesting variable engagement with health-related content.

3.1.2. Breast Cancer Literacy Levels per Indicator

Comprehensive breast cancer literacy measurement results revealed a markedly heterogeneous distribution across different knowledge domains. Analysis using Arikunto (2013) categorization provided an illuminating overview of Indonesian adolescent literacy levels, highlighting specific areas of strength and critical knowledge gaps.

Table 1. Distribution of Breast Cancer Literacy Levels per Indicator Among Indonesian Adolescents (n=58)

Indicator	Correct (%)	Incorrect (%)	Category
Definition of Breast Cancer	71.3	28.7	Sufficient
Age at Risk of Breast Cancer	30.5	69.5	Poor
Definition of BSE	72.9	27.1	Sufficient
Time to Perform BSE	59.3	40.7	Sufficient
Early Signs of Cancer	33.9	66.1	Poor
Cancer Risk Factors	37.3	62.7	Poor
Breast Cancer Prevention	1.7	98.3	Poor
Clinical Breast Examination	30.5	69.5	Poor
Mammography	61	39	Sufficient
Follow-up on Lumps	96.6	3.4	Good

Source : Primary Data 2025

The literacy level distribution revealed a deeply concerning pattern with a pronounced dominance of the poor category (50% of indicators), followed by the sufficient category (40% of indicators), and only one indicator (10%) achieving the good category. Most notably, the indicator with the highest literacy was follow-up actions upon discovering lumps (96.6%), demonstrating encouraging awareness about the importance of medical consultation when detecting breast abnormalities. Conversely, the indicator with the lowest literacy was breast

cancer prevention (1.7%), indicating a critical gap in understanding preventive strategies that could significantly impact future cancer incidence.

3.1.3. Literacy Level Categorization for Determinant Analysis

Based on composite literacy scores calculated from 10 indicators, respondents were systematically categorized using the established 70% cut-off point. The categorization results showed 25 respondents (43.1%) achieved high literacy (scores ≥70%) while 33 respondents (56.9%) demonstrated low literacy (scores <70%). This distribution indicates that the majority of adolescents still require comprehensive intervention to meaningfully improve their breast cancer literacy.

The mean total literacy score was 54.8% (SD=18.3%) with a range of 20%-90%. The median score was 55%, further confirming that more than half of the respondents fell below the adequate literacy threshold. The score distribution showed slight negative skewness (-0.34), suggesting a concentration of scores below the mean. This categorization was subsequently used as the binary outcome variable in logistic regression analysis to identify key determinants of breast cancer literacy.

Table 2. Logistic Regression Model Summary for Breast Cancer Literacy Determinants

Statistics	Value
-2 Log Likelihood	54.267
Cox & Snell R^2	0.456
Nagelkerke R^2	0.618
Hosmer-Lemeshow Test	$\chi^2 = 7.234$, $p = 0.512$

Source : Primary Data 2025

The logistic regression model demonstrated excellent predictive performance with a Nagelkerke R^2 of 0.618, indicating that 61.8% of the variability in breast cancer literacy could be explained by the variables in the model. The Hosmer-Lemeshow test yielded a p-value of 0.512 (>0.05), demonstrating good model calibration and no significant evidence of lack of fit. The area under the ROC curve of 0.823 indicated excellent discrimination ability, while the overall classification accuracy of 75.9% suggested strong predictive capacity.

Table 3. Binary Logistic Regression Results for Predictors of Breast Cancer Literacy

Predictor Variable	B	SE	Wald	df	Sig	Exp(B)	95% cl
Constant	-3.247	1.124	8.339	1	0.004	0.039	
Age	0.186	0.213	0.762	1	0.383	1.204	0.784-1.827
School Type (High School vs. Vocational)	1.456	0.623	5.467	1	0.019	4.298	1.265-14.546
Information Source			7.892	2	0.019		
1. Internet/Social Media	0.745	0.721	1.069	1	0.301	2.107	0.513-8.660
2. Healthcare Providers	1.987	0.826	5.789	1	0.016	7.297	1.443-10.455

Digital Learning Media	1.234	0.567	4.731	1	0.031	3.434	1.128-10.455
Information Search Frequency Health				2	0.015		
1. Frequent/Very Frequent	1.234	0.623	3.923	1	0.048	3.434	1.012-11.656
2. Occasional	0.567	0.534	1.128	1	0.288	1.763	0.619-5.023

Source : Primary Data 2025

The multivariate logistic regression analysis identified four statistically significant determinants influencing breast cancer literacy among Indonesian adolescents. School type emerged as an important institutional factor (p=0.019), with high school students demonstrating a 4.3 times greater likelihood of achieving high literacy compared to vocational school students (95% CI: 1.27-14.55). Healthcare provider information sources emerged as the strongest predictor (OR=7.3; 95% CI: 1.44-10.46; p=0.016), underscoring the critical importance of access to credible medical information. Digital learning media utilization contributed significantly (OR=3.4; 95% CI: 1.13-10.46; p=0.031), confirming the effectiveness of technology in adolescent health education. Frequent health information seeking behavior also showed significant influence (OR=3.4; 95% CI: 1.01-11.66; p=0.048), indicating that active information-seeking behavior strongly correlates with better literacy outcomes.

3.2. Discussion

3.2.1. Breast Cancer Literacy Patterns: Reconciling Awareness with Knowledge Deficits

The dichotomous pattern observed in this study—high awareness of medical follow-up procedures coupled with profound deficits in preventive knowledge—represents a critical challenge for health education in Indonesia. This paradox extends beyond simple knowledge gaps to reflect deeper structural issues in how health information is communicated and processed within the Indonesian educational and healthcare systems.

The finding that breast cancer prevention knowledge reached only 1.7% correct responses demands urgent attention, particularly when contextualized within global evidence demonstrating that 30-40% of breast cancers are preventable through lifestyle modifications (Bleyer et al., 2020). This knowledge deficit becomes even more concerning when compared with findings from other developing nations. Research by Kandasamy et al. (2024) in Saudi Arabia reported 77.6% of women had poor BSE knowledge, yet even this concerning figure substantially exceeds the prevention knowledge levels observed in our Indonesian sample. Ben El-Fakir et al. (2024) documented moderate knowledge levels among 48.25% of Moroccan female students, suggesting that Indonesia faces particularly acute challenges in health literacy development.

The contrast between high follow-up awareness (96.6%) and low prevention knowledge (1.7%) suggests that Indonesian health education has successfully conveyed reactive health behaviors while failing to establish proactive prevention understanding. This pattern may reflect cultural tendencies toward curative rather than preventive healthcare orientations, a phenomenon documented across Southeast Asian health systems (Iskandarsyah et al., 2020). Furthermore, the emphasis on crisis response over prevention in health messaging may inadvertently reinforce passive health behaviors among adolescents,

who learn to seek help only after problems manifest rather than actively preventing disease occurrence.

3.2.2. Institutional Determinants: Educational System Disparities and Their Implications

The significant literacy advantage observed among high school students (OR=4.3) compared to vocational school students reveals fundamental disparities in Indonesia's dual-track education system. This finding gains additional significance when interpreted through Bourdieu's framework of cultural capital accumulation, which posits that educational institutions differentially transmit knowledge and competencies based on their institutional missions and resource allocations (Bhattacharyya et al., 2020).

Indonesian high schools (SMA) allocate substantially more curriculum time to natural sciences, including biology and health topics, compared to vocational schools (SMK) which prioritize technical skill development. This curriculum imbalance creates systematic disadvantages for vocational students in developing health literacy, potentially perpetuating health inequalities into adulthood. The implications extend beyond individual health outcomes to workforce productivity and national development, as vocational school graduates often enter physically demanding occupations where health knowledge becomes particularly crucial.

International comparisons reinforce the significance of these educational disparities. Woods-Townsend et al. (2023) demonstrated that comprehensive health curricula in UK schools significantly improved adolescent health literacy across socioeconomic strata. Similarly, research from Finland, which integrates health education across all secondary education tracks, shows minimal literacy disparities between academic and vocational students (Dadaczynski et al., 2024). These examples suggest that Indonesia's educational disparities are not inevitable but rather reflect policy choices that could be reformed to promote health equity.

3.2.3. Healthcare Provider Influence: The Power of Credible Information Sources

The emergence of healthcare provider information as the strongest predictor (OR=7.3) underscores the irreplaceable value of professional health communication in shaping adolescent understanding. This finding aligns with Social Cognitive Theory's emphasis on observational learning from credible models, where healthcare providers serve as authoritative sources who can contextualize complex medical information for adolescent comprehension levels (Julian et al., 2020).

However, the practical implications of this finding must be considered within Indonesia's healthcare access constraints. With only 34.5% of respondents reporting healthcare providers as their primary information source, substantial barriers exist to leveraging this powerful literacy determinant. Geographic disparities in healthcare provider distribution, with rural areas experiencing severe shortages, mean that many Indonesian adolescents lack regular access to professional health guidance. Additionally, cultural factors including gender preferences for female providers when discussing breast health may further limit access for some adolescents.

The contrast between healthcare provider effectiveness (OR=7.3) and internet/social media ineffectiveness (p=0.301) reveals critical insights about information quality versus quantity. While 41.4% of respondents relied primarily on digital sources, these platforms failed to significantly improve literacy, suggesting that unguided digital information

consumption may be insufficient or even counterproductive for complex health topics. This finding challenges assumptions about digital natives' ability to effectively navigate online health information without professional guidance or digital health literacy training.

3.2.4. Digital Learning Media: Bridging Traditional Gaps Through Technology

The significant contribution of digital learning media preference (OR=3.4) to literacy outcomes demonstrates technology's potential for democratizing health education access. This finding gains particular relevance given that 65.5% of respondents preferred digital learning platforms, indicating strong acceptability among Indonesian adolescents. The effectiveness of digital media likely stems from multiple mechanisms including multimedia engagement, self-paced learning opportunities, and the ability to revisit complex information repeatedly (Liu et al., 2025).

However, the distinction between general internet use and structured digital learning media requires careful consideration. Our findings suggest that purposeful engagement with educational digital content differs fundamentally from passive social media consumption. This distinction aligns with Cognitive Load Theory, which demonstrates that well-designed multimedia learning optimizes information processing through dual-channel engagement while poorly structured digital content can overwhelm cognitive capacity (Dadaczynski et al., 2024).

The Indonesian context presents unique opportunities for digital health education expansion. With rapidly increasing smartphone penetration reaching even rural areas, mobile health (mHealth) applications could potentially overcome geographic and resource barriers to health education. However, successful implementation requires addressing digital literacy disparities, ensuring content cultural appropriateness, and developing quality assurance mechanisms for digital health information.

3.2.5. Information-Seeking Behavior: Active Engagement as a Literacy Catalyst

The significant association between frequent health information seeking and higher literacy (OR=3.4) reinforces Information Processing Theory's premise that repeated exposure and active engagement enhance knowledge retention and application (Yamashita et al., 2020). This finding suggests that fostering curiosity and proactive health information seeking during adolescence could yield long-term benefits for health literacy development.

However, only 27.6% of respondents reported frequent health information seeking, indicating substantial room for improvement. This low engagement level may reflect multiple barriers including lack of awareness about health information importance, absence of engaging health content targeted at adolescents, or cultural factors that discourage adolescent girls from actively seeking information about bodily health. The gender dimension becomes particularly salient given Indonesian cultural norms that may characterize breast health discussions as inappropriate for unmarried young women.

International evidence suggests that peer education and social learning approaches can effectively stimulate health information seeking among adolescents. Programs that train adolescent peer educators to disseminate health information within their social networks have shown success in various cultural contexts, potentially offering a culturally appropriate strategy for Indonesia (Woods-Townsend et al., 2023).

3.2.6. Implications for Achieving SDG 3: A Multi-Level Intervention Framework

The study findings provide crucial evidence for developing targeted interventions that directly contribute to SDG 3.4's objective of reducing premature NCD mortality by one-third by 2030. Given Indonesia's young breast cancer demographic profile, improving adolescent health literacy represents a strategic investment in preventing future cancer burden.

At the policy level, our findings support several priority interventions aligned with sustainable development principles:

First, curriculum reform to address the literacy gap between high school and vocational students becomes imperative. This could involve developing a core health literacy curriculum mandatory across all secondary education tracks, ensuring that vocational students receive equivalent health education despite their technical focus. Such reform would directly support SDG 4 (Quality Education) while contributing to SDG 3 health objectives.

Second, strategic deployment of healthcare providers for school-based health education could maximize the impact of this powerful literacy determinant. Regular health professional visits to schools, particularly in underserved areas, could provide structured health education while building trust between adolescents and healthcare systems. This approach aligns with SDG 3.8's universal health coverage objectives by extending preventive health services to adolescent populations.

Third, development of quality-assured digital health education platforms specifically designed for Indonesian adolescents could leverage technology's demonstrated effectiveness. These platforms should incorporate cultural sensitivity, age-appropriate content, and interactive features that promote active engagement rather than passive consumption. Such digital initiatives support SDG 9 (Innovation and Infrastructure) while advancing health literacy objectives.

Fourth, community-based interventions that stimulate health information seeking through peer education and social mobilization could address the low engagement levels observed. Training adolescent health champions who can disseminate accurate information within their peer networks could create sustainable health promotion mechanisms that persist beyond formal intervention periods.

3.2.7. Study Limitations and Future Research Directions

While this study provides valuable insights into Indonesian adolescent breast cancer literacy, several limitations warrant consideration. The relatively modest sample size (n=58) and geographic concentration in West Sulawesi Province limit generalizability to Indonesia's diverse adolescent population. Future research should employ larger, nationally representative samples to validate these findings across different cultural and socioeconomic contexts.

The cross-sectional design, while efficient for identifying associations, cannot establish causal relationships between determinants and literacy outcomes. Longitudinal studies tracking literacy development from early to late adolescence would provide crucial insights into how health literacy evolves and which interventions most effectively promote sustained improvement.

The reliance on self-reported measures may introduce social desirability bias, particularly given cultural sensitivities around breast health discussions. Future research could incorporate objective literacy assessments, behavioral observations, or experimental designs to validate self-reported findings.

Additionally, this study did not examine several potentially important determinants including family education levels, socioeconomic status, or exposure to cancer within social networks. These factors may moderate or mediate the relationships identified, warranting investigation in future research.

The exclusive focus on female adolescents, while appropriate for breast cancer literacy, leaves questions about male adolescent health literacy and their potential role as future partners and fathers in supporting women's health. Inclusive approaches examining both genders could provide insights into comprehensive community-based health promotion strategies.

Conclusions

This pioneering study provides critical evidence about breast cancer literacy among Indonesian adolescents and its determinants, offering direct pathways for achieving SDG 3.4 targets in reducing premature cancer mortality. The research revealed a concerning literacy landscape with only 43.1% of adolescents achieving adequate literacy levels, while the mean score of 54.8% confirms widespread knowledge deficits that could perpetuate Indonesia's early-onset breast cancer burden into future generations.

The paradoxical pattern of high medical follow-up awareness (96.6%) contrasted with critically low prevention knowledge (1.7%) highlights fundamental gaps in current health education approaches. This disparity suggests that while Indonesian health systems have successfully communicated reactive health behaviors, they have failed to establish proactive prevention understanding—a deficit with profound implications for long-term cancer burden reduction.

Our robust predictive model (Nagelkerke R^2=0.618; ROC AUC=0.823) identified four actionable determinants that provide clear intervention targets. The educational disparity between high school and vocational students (OR=4.3) demands urgent curriculum reform to ensure health literacy equity across educational tracks. The powerful influence of healthcare provider information (OR=7.3) underscores the need for strategic deployment of health professionals in adolescent education. Digital learning media's effectiveness (OR=3.4) offers scalable solutions for reaching Indonesia's geographically dispersed adolescent population. The importance of active information seeking (OR=3.4) highlights opportunities for peer-based interventions that stimulate health curiosity.

These findings directly inform evidence-based strategies for achieving sustainable development objectives. By addressing identified literacy determinants through targeted multi-level interventions—including curriculum standardization, healthcare provider engagement, digital platform development, and peer education programs—Indonesia can potentially alter the trajectory of breast cancer outcomes for future generations. The predictive model developed provides policymakers and practitioners with a screening tool for identifying at-risk adolescents requiring intensive literacy support, enabling efficient resource allocation in resource-constrained settings.

This research contributes significantly to global health literacy scholarship by providing the first comprehensive analysis of breast cancer literacy determinants among Indonesian adolescents. The findings challenge assumptions about digital natives' health information processing capabilities while confirming the irreplaceable value of professional health communication. Most importantly, this study demonstrates that achieving SDG 3 health objectives requires addressing educational inequities, leveraging technology

thoughtfully, and fostering active health engagement from adolescence—investments that will yield dividends in reduced cancer burden and improved population health for decades to come.

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This research contributes to improving adolescent health literacy in Indonesia, and we hope that the findings will benefit future breast cancer prevention and early detection efforts among Indonesian youth.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this article. This research was conducted independently without any commercial, financial, or personal relationships that could potentially influence the research design, data collection, analysis, interpretation of results, or manuscript preparation. No funding or financial support was received from pharmaceutical companies, medical device manufacturers, or other commercial entities related to breast cancer screening, diagnosis, or treatment. The authors have no financial interests, employment relationships, consultancy arrangements, stock ownership, or other financial stakes in any organization that may gain or lose financially from the publication of this manuscript. Additionally, there are no personal relationships with individuals or organizations that could inappropriately influence this work. The research was conducted solely for academic and scientific purposes to contribute to the understanding of breast cancer literacy among Indonesian adolescents and to inform evidence-based health education interventions.

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