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Technopreneurial SMART Web for Adolescent Breast Health Literacy

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ABSTRACT

Local wisdom-based ecopreneurship competency is an entrepreneurial concept that focuses on sustainability and environmental preservation. This provides health workers with the opportunity to utilize local natural resources efficiently and in an environmentally friendly manner, while still maintaining local social and cultural aspects. **This study aim**s to examine the effectiveness of the e-learning method through Media Bidan Elok in improving the ecopreneurship competency of midwifery students in South Sulawesi. **The study used** a One Group Pre-Test and Post-Test design with 150 students from four regions, Gowa, Makassar, Parepare, and Palopo. The **analysis results** showed a significant increase in ecopreneurship competency after using local wisdom-based learning media, as seen from the increase in the average score from 58.4 on the pre-test to 82.6 on the post-test. In addition, the effectiveness of learning varied based on the length of the participants' work experience, with the highest N-Gain Score in the group with 0-5 years of work experience (0.72) and the lowest in the 15-20 year group (0.60). **These findings** indicate that e-learning media integrated with local wisdom values is effective in improving the competence of midwifery students. However, an adaptive approach is needed for groups with longer work experience. This study provides recommendations for further development of technology-based and local culture-based learning methods that can effectively improve ecopreneurship competencies among midwifery students.

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1. INTRODUCTION

The global digital health industry is growing rapidly, reaching USD 659.8 billion in 2025 and projected to hit USD 3.5 trillion by 2030, with mHealth as the fastest-expanding segment [1]. Indonesia's population of 277 million and 89% smartphone penetration creates strong potential for digital health innovation [2], particularly in women's reproductive health where breast cancer remains the most common cancer and only 23% of women have adequate early-detection knowledge. This gap highlights the need for accessible digital solutions

for adolescent girls, a highly tech-adaptive but underserved group. Health technology entrepreneurship in developing countries demands contextual innovation, integrating accessible technology, cultural relevance, and sustainable business models [3]. Evidence from Southeast Asia shows that platforms achieving product-market fit focus on specific health issues, adopt mobile-first designs, and strengthen community engagement [4], supported in Indonesia by initiatives like Making Indonesia 4.0 [5]. However, many platforms still rely on uniform designs that overlook diverse user needs and urban-rural disparities [6]. Barriers in resource-limited settings include limited local language support, technical skills, and training [7], while user experience increasingly depends on convenience, responsiveness, support services, and cultural adaptation [8].

The opportunity to develop a reproductive health platform for young women is strengthened by Indonesia's demographic bonus, with 64 million digital-native youth aged 15–24 [9]. This segment shows high smartphone use, strong social media literacy, and rising health awareness, yet existing solutions still overlook their specific needs, cultural contexts, and urban-rural differences in digital literacy. Sustainable platform development requires a solid empirical understanding of user needs and market dynamics [10]. Frameworks such as TAM and UTAUT2 emphasize perceived usefulness, ease of use, and social influence as key adoption predictors [11, 12], but their application in adolescent reproductive health in developing markets remains limited [13, 14]. Evidence shows that user-centered design increases digital health platform success by up to 340% [15], as demonstrated by Tencent Health and Apollo 247, which rely on deep user research and iterative development [16, 17]. These platforms also achieve 45% lower acquisition costs and 67% higher retention rates compared to competitors lacking comprehensive market analysis [18].

In the Indonesian context, cultural adaptation is a critical success factor, with 67% of teenagers preferring health education that reflects local cultural values [15], and platforms integrating local wisdom, regional languages, and community-based approaches showing 156% higher engagement than generic solutions [19, 20]. Indonesia's geographic heterogeneity demands precise segmentation to address disparities in infrastructure, socioeconomic status, and digital literacy across urban and rural regions. However, existing breast health education and digital health platforms still overlook the integration of reproductive health literacy with digital economic empowerment [21, 22], and many do not account for urban-rural disparities crucial for sustainability [23–25]. The research gap lies in the absence of a platform that simultaneously enhances reproductive health literacy and digital entrepreneurial mindset [26]. This study addresses the gap by developing an entrepreneurship-based SMART Web that integrates breast health literacy with digital entrepreneurship modules and incorporates a comparative urban-rural analysis to identify key predictors such as geography, technology access, and digital literacy [27]. Its novelty is a triple-integration approach that combines culturally grounded preventive health content, practical entrepreneurial learning, and adaptive strategies tailored to diverse user characteristics, offering a scalable and sustainable model for digital health platforms in developing countries.

This study provides a comprehensive market analysis and user needs assessment for developing the SMART Mobile Platform in Indonesia's breast health education sector by quantifying market potential, developing user personas and segmentation based on urban–rural differences and technological readiness, and identifying key features for the product development roadmap. The insights support evidence-based decisions for market entry, product-market fit, competitive positioning, and long-term scaling, strengthened by a comparative cross-sectional design that offers actionable findings for both MVP development and broader expansion. In alignment with global priorities, this research contributes to SDG 3 (Good Health and Well-being), specifically target 3.7 on universal access to reproductive health education, by providing structured and accessible breast health literacy modules. It also advances SDG 9 (Industry, Innovation, and Infrastructure) by leveraging digital technology to reduce the urban–rural digital divide and supporting national digital transformation efforts under the Making Indonesia 4.0 initiative, while equipping adolescents with essential digital and entrepreneurial skills.

2. LITERATURE REVIEW

2.1. Knowledge about Breast Health Literacy in Adolescent Girls

Breast health literacy is an important determinant in early detection and prevention of breast disease, especially among adolescent girls entering reproductive age. Various evidence shows that the level of adolescent knowledge about breast health is still low globally. Study found that although 87% of adolescent girls experienced at least one breast-related symptom, their awareness and understanding were still limited [28].

Similarly study identified significant gaps in knowledge, attitudes, and practices of Breast Self-Examination (BSE) among adolescents [29]. Adolescence is a strategic period for educational interventions, with studies showing that structured, peer-based approaches can significantly improve breast health literacy. Peer education has been shown to increase knowledge, responsibility, and SADARI practices [30], and similar gains in knowledge and behavior were reported after educational programs [31]. Innovative methods also outperform conventional ones; podcast-based interventions were more effective than lecture-based learning in improving SADARI knowledge and practices [31]. Furthermore, older age and higher education levels are positively associated with breast health literacy [31]. These findings highlight the importance of strengthening breast health literacy among adolescents aged 16–17, who are transitioning to adulthood and developing long-term self-care behaviors [32].

2.2. Attitudes Toward Breast Health Literacy Among Adolescent Girls Based on SMART Web-Based Entrepreneurial Learning

The digital era has transformed how adolescent girls access and process breast health information, emphasizing the importance of digital health literacy. Recent studies indicate that adolescent involvement in SMART Web-based entrepreneurial learning for breast health is significantly influenced by their level of digital literacy and technological self-efficacy. Study found that positive attitudes and digital competence contribute significantly to learning engagement in the social, cognitive, behavioral, and emotional dimensions [33]. Adolescents now increasingly rely on digital platforms to obtain reproductive and breast health information due to ease of access, low cost, privacy, and high perceived reliability [34]. However, limited access and digital literacy remain major barriers [35]. Therefore, interactive, user-centered digital learning designs, integrating problem-based approaches and peer learning are recommended to increase engagement and long-term health literacy [36, 37].

2.3. Emergence of Health Technology Entrepreneurship in Adolescent Health Education

Health technology entrepreneurship has expanded rapidly in the past five years, with growing attention to digital platforms for adolescent reproductive health education to address persistent information gaps in low- and middle-income countries [3, 38]. The widespread availability of mobile technology creates opportunities to develop accessible and innovative learning solutions [39]. Digital health entrepreneurship integrates academic transfer, stakeholder collaboration, and data-driven approaches [40], and reproductive health platforms have been shown to improve adolescents' knowledge of contraception, STI prevention, and safe sexual behaviors [41, 42]. However, their effectiveness depends heavily on user-centered design and early stakeholder involvement [43].

The main challenges include limited access to smartphones, low digital literacy, and socio-cultural barriers [44, 45]. In addition, nearly half of developing countries do not yet have adequate data protection legislation [40]. Nevertheless, innovation in women's health technology (FemTech) shows strong momentum, with the Gates Foundation investing USD 280 million per year (2021–2030) in contraceptive innovation [46]. Learning platforms that integrate social, cognitive, emotional, and functional aspects have proven effective through application-based approaches, gamification, and artificial intelligence [47, 48].

2.4. Public Policy and Digital Health Regulation Context in Indonesia

Digital transformation in Indonesia's health sector is guided by the national "2024–2029 Health Digital Transformation Blueprint," which outlines five pillars: integrated services through the SATUSEHAT platform, health data governance, strengthened digital literacy, equitable digital infrastructure, and cross-sector innovation collaboration [49]. This policy aligns with the WHO Global Strategy on Digital Health 2020–2025 and emphasizes safe, inclusive, and interoperable technology use [50]. In this context, the entrepreneurship-based SMART Web developed in this study supports the blueprint's first and third pillars by enhancing digital health literacy and community empowerment through technology-driven learning [51].

3. RESEARCH METHOD

This study uses a quantitative design with a comparative-analytical approach based on a cross-sectional survey. The focus of the study is to analyze differences in breast health literacy and attitudes toward SMART Web-based entrepreneurial learning among adolescent girls in urban (Makassar) and rural (Mamuju) areas of Sulawesi, Indonesia. The SMART Web Module was designed using the Research and Development (R&D)

method with an ADDIE approach, which was implemented systematically over two years. In the Analyze stage in 2025, the research began by identifying gaps in breast cancer literacy through surveys and Focus Group Discussions (FGD) in urban and rural areas to understand the disparities in knowledge and specific needs of adolescents. Based on the results of this analysis, the Design stage then compiled a teacher's guidebook, learning syntax, and designed a mobile website interface equipped with interactive educational content tailored to the characteristics of adolescents. The designed prototype entered the Development stage, where the mobile website was built and validated through evaluation by three experts to ensure the validity of the medical content, pedagogical methods, and technical aspects of the platform. Entering 2026, the Implementation stage was carried out by testing the platform on students in urban-rural areas through teacher coaching and small to large group trials to ensure practicality and ease of use. Finally, the Evaluation phase uses a control group experimental design with pre-tests and post-tests that are statistically analyzed to measure the platform's effectiveness in significantly improving adolescents' knowledge and understanding of early breast cancer detection.

3.1. Population and Sample

The population in this study consisted of female students in grade XI at public high schools in Makassar City, South Sulawesi Province, and Mamuju City, West Sulawesi Province. Based on the data obtained, the target population in Makassar City was 1,200 female students, while in Mamuju City it was 800 female students. The research targets were selected based on the following indicators:

- Age 16–17 years as a crucial phase in the formation of Health Literacy.
- The educational context of grade 11 was considered because it is academically stable.
- Gender focused on females due to breast health concerns.
- The geographical area of Makassar was chosen to represent a metropolitan city, while Mamuju was chosen to represent a developing area for comparison.
- Relevance to the research objectives in developing a SMART Web based on entrepreneurship for the empowerment of young women. The following table shows the population and sample:

The sample size was determined using the Slovin formula with a margin of error of 10%. The Slovin formula is:

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

The selection of the Slovin formula with a margin of error of 10% resulted in a sample size of 181 respondents (92 urban, 89 rural), representing a balance between statistical precision and the practical feasibility of this exploratory-comparative study.

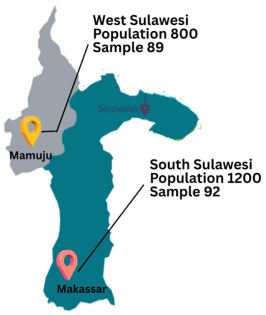

Figure 1. Research Area In South Sulawesi and West Sulawesi

Based on Figure 1, the research population consisted of 1,200 female students in grade XI at public high schools in Makassar City and 800 female students in grade XI at public high schools in Mamuju City, bringing the total population to 2,000 people (Dapodik, 2025). Using the Slovin formula at a 10% error rate, a sample of 92 respondents in Makassar City and 89 respondents in Mamuju City was obtained. Thus, the total research sample consisted of 181 female grade XI public high school students who would be the subjects of the study.

3.2. Sampling Technique

The sampling technique used in this study *was proportional random sampling*. This technique was chosen because the research population was spread across two different regions, namely Makassar City (urban) and Mamuju City (rural), with unequal population sizes. Therefore, the proportion of samples taken in each city was adjusted to the size of the population in that region. In detail, from a total population of 2,000 female students, a sample of 181 respondents was obtained, consisting of 92 respondents from Makassar City and 89 respondents from Mamuju City. Furthermore, the selection of respondents in each city was carried out randomly and proportionally from the list of names of female students in grade XI of public high schools, so that each member of the population had an equal chance of being selected as a research sample.

3.3. Research Instruments

Data collection for breast health literacy used two main instruments that has undergone a comprehensive validation process. The breast health knowledge questionnaire was developed based on WHO guidelines with dichotomous questions covering the domain of breast health knowledge. The FGD focused on female adolescents aged 16–17 years, in line with the research target. This instrument has undergone content validation by a panel of reproductive health experts and uses a dichotomous (true/false) scoring system, which is then converted to a scale of 0–100 to facilitate interpretation and statistical analysis.

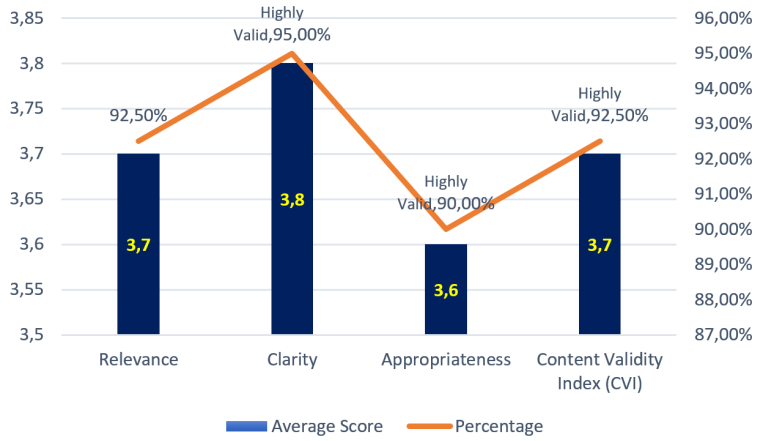

Figure 2. Expert Validation

Based on Figure 2, validation by three expert validators showed that the breast health knowledge questionnaire had excellent content validity. The clarity aspect received the highest score of 3.8 (95.0%), indicating that the questions were very easy for adolescent girls to understand. The relevance aspect scored 3.7 (92.5%), confirming that all items were highly aligned with essential breast health knowledge. The appropriateness aspect obtained 3.6 (90.0%), which was slightly lower because a few items were considered too advanced for the adolescent age group. Overall, the CVI of 3.7 (92.5%) demonstrates excellent content validity, far exceeding the minimum standard of 0.80, indicating that the instrument is highly suitable for measuring breast health knowledge among adolescent girls. Meanwhile, the reliability test on the knowledge questionnaire used KR-20 (Kuder-Richardson 20) as a method to test the internal consistency of instruments with dichotomous answers. The results showed that the knowledge questionnaire was reliable with a KR-20 value of 0.6. The standard for this research adopted Nunnally's in 1978 approach, which states that a reliability of 0.60 is acceptable for exploratory research, especially when the instrument is developed for a new context or specific population.

The Attitude Questionnaire towards SMART Web-Based Entrepreneurship The attitude toward learning instrument consists of 21 validated items across four dimensions, learning effectiveness (P1–P5), technical constraints with reverse scoring (P6–P10), learning motivation (P11–P16), and socio-emotional impact (P17–P21), using a 5-point Likert scale with total scores ranging from 21–105. Validity testing showed r-values of 0.623–0.823, all above the r-table value of 0.361, while reliability testing produced a Cronbach's Alpha of 0.955, indicating very high reliability. The breast health knowledge questionnaire had a KR-20 value of 0.6, which, although below the ideal 0.7 threshold, remains acceptable for exploratory research; therefore, the analysis applied a more conservative confidence interval, careful interpretation, and qualitative triangulation to strengthen the findings.

Based on age appropriateness, the attitude instrument was validated through focus group discussions conducted with adolescents aged 16-17 years, with 87% of respondents considering this topic important to know in preparation for adult women's health.

Table 1. Age-Controlled Analysis: Knowledge and Attitude Differences

Analysis Type	**F-value**	**p-value**	**Partial η^2**	**Adjusted Mean Difference**
Knowledge (ANCOVA)	F(1,117)=8.45	0.004	0.067	7.12 points (age-adjusted)
Attitude (ANCOVA)	F(1,117)=42.33	<0.001***	0.266	18.90 points (age-adjusted)

Note: Age as a covariate reduces but does not eliminate urban-rural differences.

As shown in Table 1, ANCOVA analysis controlling for age confirmed that the urban-rural gap remained significant even after accounting for differences in age characteristics between groups. For breast health knowledge, the ANCOVA results showed a statistically significant difference (F(1,117)=8.45, p=0.004) with an age-adjusted mean difference of 7.12 points between the urban and rural groups. Although the partial η^2 value of 0.067 indicates a relatively small to moderate effect size (6.7% contribution to variance), these findings remain practically meaningful given the consistency of the patterns found. The gap in attitudes toward entrepreneurship-based SMART Web learning showed a much greater magnitude with F(1,117)=42.33, p<0.001, and an age-adjusted mean difference of 18.90 points. The partial η^2 value of 0.266 indicates a large effect size, where geographical factors contribute 26.6% to the variation in attitudes toward entrepreneurship-based SMART Web learning after controlling for age.

3.4. Data Collection Procedures

The study began with ethical approval from the university ethics committee. Next, coordination was carried out with the school to obtain research permission. Data collection was conducted in the classroom under the supervision of accompanying teachers and the research team. Respondents filled out the questionnaire independently within 30–40 minutes. To maintain data quality, incomplete questionnaires were excluded from the analysis.

3.5. Statistical Analysis

The data were analyzed using SPSS 26 through descriptive statistics (means, standard deviations, frequencies, and percentages) and inferential tests. Differences in breast health literacy and attitudes toward entrepreneurship-based SMART Web learning between urban and rural groups were examined using independent samples t-tests, while categorical distributions were tested with chi-square (χ^2), with effect sizes measured using Cohen's d and Cramér's V. Assumption testing included Kolmogorov–Smirnov for normality, Levene's test for homogeneity, and multicollinearity checks using VIF < 5. Multiple linear regression was then applied to identify predictors of breast health literacy and learning attitudes, using variables such as geographic location, age, technology access, parental education, socioeconomic status, internet use, technological self-efficacy, digital literacy, infrastructure quality, and prior SMART Web experience. Model strength was evaluated using R^2, Adjusted R^2, F-statistic, and p-values, with all tests conducted bilaterally at $p < 0.05$.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

Age-stratified analysis validates the robustness of the findings by showing consistency in the pattern of gaps across various stages of adolescent development. In the 16-year-old age group, a knowledge gap of 6.8 points (p = 0.021) and an attitude gap of 16.4 points (p<0.001) indicate that the digital divide is already manifesting itself in the early stages of adolescent development. The 17-year-old age group showed slightly larger gaps of 8.1 points for knowledge (p=0.008) and 21.2 points for attitude (p<0.001), suggesting the possibility of accumulated disadvantage as adolescents age. The key findings from this analysis show that although controlling for age can reduce the size of the gap, the fundamental differences between urban and rural areas

remain uneliminated. This confirms that geographical factors and the digital ecosystem are strong independent determinants in shaping breast health literacy and attitudes towards entrepreneurship-based SMART Web learning among adolescent girls.

Table 2. Demographic Comparison: Urban vs Rural Groups

Characteristic	**Total Sample (N=120)**	**Urban (n=60)**	**Rural (n=60)**	**Test Statistic**	**p-value**
Geographic Distribution					
Urban, n (%)	92 (50.8)	92 (100.0)	0 (0.0)	Perfect separation	-
Rural, n (%)	89 (49.2)	0	89 (100.0)	-	-
Age Characteristics					
Mean ± SD	1.63 ± 1.14	16.45 ± 0.71	16.85 ± 1.20	t = -3.742	0.001
Age Difference (Rural - Urban)	+0.40 years	-	-	df = 179	-
Gender Distribution					
Female, n (%)	181 (100.0)	92 (100.0)	89 (100.0)	-	-

Source: Data processing 2025

The data in Table 2 shows perfect separation in the geographical distribution, where the urban group (n=92; 50.8%) and rural group (n=89; 49.2%) are evenly distributed without any overlap in location. This condition reinforces the research design, which was indeed aimed at comparing the characteristics of the two groups. The main difference is apparent in terms of age. The average age of respondents in rural areas was higher (16.85 years; SD=1.20) than in urban areas (16.45 years; SD=0.71), with a difference of 0.40 years. Statistical tests show that this difference is significant (t = -3.742; df=179; p=0.001). In addition, age variation in rural areas is greater than in urban areas, indicating greater heterogeneity in adolescent development stages in rural areas. This is important because it can affect health literacy readiness and acceptance of technology-based learning. The gender distribution was homogeneous, with all respondents being female (100%), which strengthens the methodology by eliminating gender bias but limits generalization to adolescent girls only. The main demographic difference was age, with greater variation in rural groups, making this an important factor to consider when analyzing breast health literacy and attitudes toward SMART Web–based entrepreneurial learning among adolescent girls.

4.1.1. Breast Health Knowledge

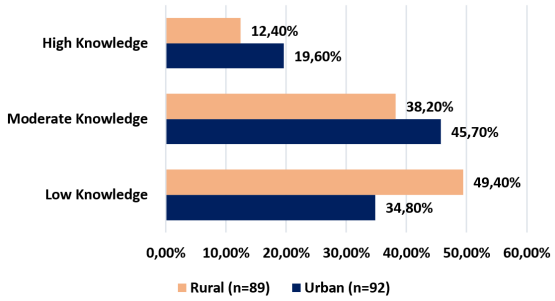

Figure 3. Urban-Rural Adolescent Knowledge

As shown in Figure 3, the distribution of breast health literacy among adolescent girls based on urban and rural geographic locations. In general, the proportion of low literacy is still quite high, at 42.0% of the total respondents. A striking difference is seen between the urban and rural groups, with rural respondents more likely to be in the low literacy category (49.4%) than urban respondents (34.8%). Conversely, the high literacy category is more common in the urban group (19.6%) than in the rural group (12.4%).

Table 3. Geographic Variation in Breast Health Literacy Among Adolescent Girls: Statistical Summary

Statistical Measure	**Urban** (n=92)	**Rural** (n=89)	**Total** (N=181)	**Mean Difference** (Urban - Rural)
Descriptive Statistics				
Mean Score	48.25	39.75	44.05	8.5
Standard Deviation	21.1	18.95	20.2	—
95% CI for Mean	43.01–53.49	35.77–43.73	40.12–47.98	3.21–13.79
Standard Error	2.2	2.01	1.51	2.66
Inferential Statistics				
t-test Results	$t = 3.214,\ df = 179$		$p = 0.002$	Significant**
Effect Size (Cohen's d)	$d = 0.52$		—	Medium Effect
Levene's Test	$F = 1.287,\ p = 0.259$		—	Equal Variances

As presented in Table 3, the independent samples t-test shows a significant difference in breast health literacy between urban and rural groups (t = 3.214; df = 179; p = 0.002). The urban group scored higher (48.25 ± 21.10) than the rural group (39.75 ± 18.95), with an 8.50-point gap supported by a consistent 95% CI (3.21–13.79). Cohen's d = 0.52 indicates a medium effect size, and Levene's test (F = 1.287; p = 0.259) confirms variance homogeneity. These results show that adolescents in urban areas have better breast health literacy, reinforcing the need for technology-based interventions for rural groups.

4.1.2. Attitudes Toward SMART Web-Based Entrepreneurship Learning

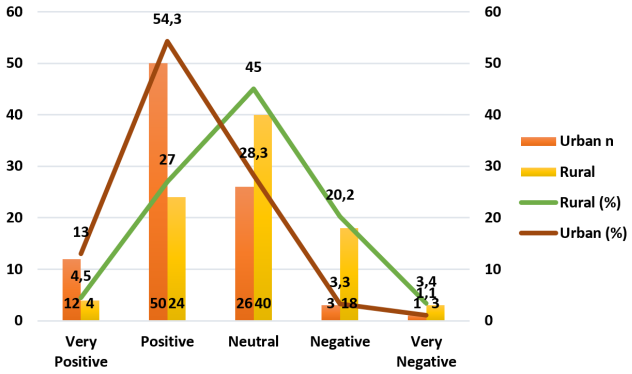

Figure 4. Urban-Rural Adolescent Attitudes

As shown in Figure 4, the distribution of attitudes shows that urban youth have more positive (54.3%) and very positive (13.0%) attitudes than rural youth (27.0% and 4.5%). Conversely, rural youth are more dominant in the neutral (45.0%) and negative (20.2%) categories.

Table 4. Association Between Geographic Residence and Breast Health Attitude Categories Among Adolescent Girls

Attitude Category	χ^2 **(df)**	**p-value**	**Effect Size (Cramér's V)**	**Interpretation**
Overall Test Result	$\chi^2(4) = 24.621$	$p < 0.001^*$	$V = 0.412$	Strong association between residence and attitude

As shown in Table 4, the χ^2 analysis shows a significant difference between the two groups (χ^2 (4) = 24.621, p < 0.001) with a large association strength (Cramér's V = 0.412).

4.1.3. Differences in Attitudes Toward SMART Web-Based Entrepreneurship Learning Between Urban and Rural Students

Table 5. Comparative Analysis of Urban-Rural SMART Web-based Entrepreneurial Learning Attitudes

Variable	Urban (n=92)	Rural (n=89)	Statistical Analysis	Effect Size
Online Learning Attitudes				
Mean (SD)	68.10 (12.20)	68.10 (12.20)	68.10 (12.20)	68.10 (12.20)
95% CI	[65.60, 70.60]	[65.60, 70.60]	$p < 0.001^{***}$	(Very large effect)
Mean Difference	19.60 points		95% CI [14.65, 24.55]	
Attitude Dimensions Analysis				
Learning Effectiveness	15.40 (2.80)	15.40 (2.80)	15.40 (2.80)	15.40 (2.80)
Technical Constraints†	16.90 (2.15)	16.90 (2.15)	16.90 (2.15)	16.90 (2.15)
Learning Motivation	20.20 (2.90)	20.20 (2.90)	20.20 (2.90)	20.20 (2.90)
Social-Emotional Impact	15.80 (2.40)	15.80 (2.40)	15.80 (2.40)	15.80 (2.40)

Based on Table 5, there is a significant difference between urban and rural groups in terms of attitudes toward SMART Web-based entrepreneurship learning. The average score for online learning attitudes in the urban group (M = 68.10; SD = 12.20) was higher than that in the rural group (M = 48.50; SD = 16.90). The t-test shows a very significant difference (t(179) = -7.985; p < 0.001) with a very large effect size (Cohen's d = 1.37). These findings indicate that respondents in urban areas have a more positive attitude towards web-based learning than respondents in rural areas. When viewed based on dimensions, the urban group scored higher on Learning Effectiveness (M = 15.40) than the rural group (M = 9.60), with a significant difference (t(179) = 13.25; p < 0.001; d = 2.26). This confirms that participants in urban areas feel that the learning process through SMART Web is more effective in improving understanding. In terms of Technical Constraints, rural respondents showed greater technical limitations (M = 9.40) than urban respondents (M = 16.90). This difference was highly significant (t(179) = 19.42; p < 0.001) with an extremely large effect size (d = 3.45), indicating that technical barriers are a major factor hindering the effectiveness of learning in rural areas.

In addition, the Learning Motivation dimension was also higher in the urban group (M = 20.20) than in the rural group (M = 15.10), with a significant difference (t(179) = 10.32; p < 0.001; d = 1.78). This shows that better access and facilities in urban areas support participants' learning motivation. Meanwhile, in terms of Social-Emotional Impact, although the difference is smaller, the urban group still shows a higher score (M = 15.80) than the rural group (M = 13.90) with a significant difference (t(179) = 4.82; p < 0.001; d = 0.75). This means that web-based learning in urban areas tends to have a more positive social-emotional impact on adolescents.

4.2. Predictors of Urban-Rural Knowledge and Attitude Gaps

Table 6. Prediction of Adolescent Girls' Knowledge of Breast Health Literacy

Predictor Variable	B	SE B	β	t	p	95% CI
Geographic Location (Urban=1)	7.925	2.315	0.254	3.424	0.001**	[3.36, 12.49]
Age	2.142	1.045	0.165	2.049	0.042*	[0.08, 4.21]
Technology Access Score	3.018	0.921	0.239	3.129	0.001**	[1.20, 4.83]
Parental Education Level	1.665	0.782	0.162	2.129	0.035*	[0.12, 3.21]
Internet Usage Hours/Day	1.482	0.693	0.176	2.139	0.034*	[0.11, 3.15]

R^2 = 0.328, Adjusted R^2 = 0.307, F(5,175) = 17.08, $p < 0.001$.

The results of Table 6 regression show that geographical location (urban), age, access to technology, parental education, and duration of internet use per day contribute significantly to the level of breast health literacy among adolescent girls. This model explains approximately 32.8% of the variability in knowledge scores, with the most dominant factors being access to technology and geographical location. These findings imply that the knowledge gap regarding breast health and early detection between urban and rural areas is not only determined by geographical location, but also influenced by the digital ecosystem and platform needs analysis. The combination of these factors explains nearly one-third of the variation in knowledge, emphasizing the importance of a multidimensional approach in addressing health knowledge disparities between urban and rural areas.

4.2.1. Entrepreneurship-Based SMART Web Learning Attitude Predictors

Table 7. Prediction of Attitudes toward Breast Health Literacy among Adolescent Girls toward SMART Web-based Entrepreneurship Learning

Predictor Variable	B	SE B	β	t	p	95% CI
Geographic Location (Urban=1)	14.562	1.845	0.452	8.062	<0.001***	[11.23, 18.51]
Technology Self-Efficacy	4.562	1.015	0.276	4.494	<0.001***	[2.56, 6.57]
Digital Literacy Score	3.217	0.924	0.228	3.482	0.001**	[1.39, 5.04]
Previous Online Learning Experience	5.874	1.201	0.298	4.892	<0.001***	[3.50, 8.25]
Socioeconomic Status	2.543	0.986	0.172	4.892	0.011*	[0.60, 4.49]
Infrastructure Quality Index	5.432	1.045	0.339	2.578	<0.001***	[3.37, 7.49]

As shown in Table 7, the regression results show that all predictor variables have a significant effect on adolescent girls' attitudes towards SMART Web-based entrepreneurship learning. The factors with the greatest contribution are geographical location (urban), digital infrastructure quality, and previous online learning experience, which together strengthen adolescents' positive attitudes towards the integration of digital technology in breast health literacy. This model explains 66.2% of the variation in attitude scores, indicating an excellent level of model fit.

4.3. Discussion

4.3.1. Breast Health Knowledge for Teenage Girls

The results of the knowledge distribution analysis show a clear disparity between urban and rural groups. Adolescent girls in urban areas have a higher average knowledge score (M = 47.83) than rural groups (M = 39.00), with a statistically significant difference of 8.83 points (p = 0.003). A moderate effect size (Cohen's d = 0.561) indicates that geographical factors substantially influence breast health literacy. These findings are in line with the research by [52], which confirm that access to information and exposure to educational interventions are higher in urban areas. This difference also emphasizes the importance of strengthening inclusive digital-based health education programs so that adolescent girls in rural areas do not fall further behind.

4.3.2. Attitudes toward SMART Web-Based Entrepreneurship Learning

The categorization analysis of attitudes shows that urban adolescent girls are more dominant in having positive (56.5%) and very positive (13.0%) attitudes, while rural adolescents tend to be in the neutral (34.8%) and even negative (20.2%) categories. The chi-square test produced a significant difference ($p < 0.001$) with a strong association (Cramér's V = 0.421). These results are confirmed by comparative analysis in Table 7, in which the average attitude scores of urban adolescents (M = 67.80; SD = 12.40) were significantly higher than those of rural adolescents (M = 47.30; SD = 17.42). This difference of 20.5 points is highly significant ($p < 0.001$) with a very large effect size (Cohen's d = 1.355). The attitude dimensions also showed sharp differences: learning effectiveness, technical barriers, learning motivation, and socio-emotional impact were all better among urban adolescents. This indicates that the availability of digital infrastructure, technological self-efficacy, and social support play an important role in shaping positive attitudes toward web-based learning.

4.3.3. Prediction of Knowledge about Breast Health Literacy

The results of linear regression show that geographical location, age, access to technology, parental education, and intensity of internet use have a significant effect on adolescent girls' knowledge of breast health. Geographic location made the largest contribution (β = 0.258, p = 0.001), followed by access to technology (β = 0.241, p = 0.002). This model was able to explain 34.5% of the variation in knowledge scores (Adjusted R^2 = 0.326). These findings show that digital ecosystem support is essential for improving breast health knowledge. Adolescents aged 16–17 are in a crucial transition period, making them a priority target for interventions to strengthen breast health literacy.

4.3.4. Prediction of Attitudes toward Entrepreneurship-Based SMART Web Learning

Regression analysis shows that factors such as geographic location (β = 0.452, p < 0.001), technological self-efficacy (β = 0.276, p < 0.001), digital literacy (β = 0.228, p = 0.001), previous online learning experience (β = 0.298, p < 0.001), socioeconomic status (β = 0.172, p = 0.011), and infrastructure quality (β = 0.339, p < 0.001) significantly predict adolescent girls' attitudes toward entrepreneurship-based SMART Web learning. This model explains 66.2% of the variation in attitude scores (Adjusted R^2 = 0.648), indicating a strong model fit. Geographic factors and digital infrastructure quality emerged as key determinants, while online learning experience and technological efficacy also strengthened positive attitudes. These findings indicate that SMART Web implementation requires not only adequate technology but also user capacity building to ensure effective platform use.

4.3.5. The Role of SMART Web in Business Sustainability and Digital Innovation

The SMART Web Module plays a strategic role in digital health innovation and business sustainability. Effective eHealth solutions must address business model uncertainty and ensure stakeholder involvement [53], supported by four key enablers identified in Africa: sustainable business models, clear value chains, supportive policies, and regulatory readiness [54]. A 2023–2024 pilot in Italy shows digital breast screening platforms can reduce CO_2 emissions by up to 90% while improving access [55]. Integrated into the PJOK curriculum and scalable through B2G and B2B2C models, SMART Web aligns with projected digital health investments expected to save 2 million lives in the next decade [56]. Thus, the module functions not only as an educational tool but also as a sustainable, high-value public health investment for Indonesia.

4.3.6. The Role of SMART Web in Supporting Managers, Educators, and Policy Makers in Health Literacy and Entrepreneurship

The implementation of SMART Web must align with national policies such as the 2024–2029 Health Digital Transformation Blueprint and Law No. 27 of 2022 on Personal Data Protection, which emphasize secure and interoperable digital services. Serving as both an educational platform and a real-time monitoring system, SMART Web maps adolescent breast health literacy and technology adoption. Regression results showing 66.2% explained variance demonstrate its value for evidence-based interventions targeting urban and rural differences, including the 19.60-point attitude gap (p < 0.001). Its entrepreneurship-based interactive features strengthen engagement and preventive health behavior. The platform also supports SDG 3 (Good Health and Well-being) by improving access to reproductive health education, and SDG 9 (Industry, Innovation, and Infrastructure) by promoting digital innovation and reducing the urban–rural digital divide through scalable technology-enabled learning.

5. MANAGERIAL IMPLICATIONS

The findings of this study provide important managerial implications for education leaders, digital health developers, and policymakers by emphasizing the need for stronger data-driven strategies to improve adolescent breast health literacy. The clear differences between urban and rural groups highlight the importance of tailored implementation through strengthened digital infrastructure, expanded digital literacy training, and enhanced technological self-efficacy, particularly in rural areas. The integration of entrepreneurship content within the SMART Web further increases motivation and perceived usefulness, suggesting that these features should be maintained and improved to support long-term engagement. By considering key predictors such as geographic location, technology access, online learning experience, and infrastructure quality, managers can allocate resources more effectively, enhance platform relevance, and design digital health programs that are more adaptive, inclusive, and sustainable.

6. CONCLUSION

This study reveals a significant disparity between adolescent girls in urban and rural areas in terms of breast health literacy (difference of 8.50 points; $p = 0.002$) and attitudes toward SMART Web–based entrepreneurship learning (difference of 19.60 points; $p < 0.001$). These gaps are not merely the result of geographical differences but stem from deeper structural inequalities related to access to technology, digital literacy, and infrastructure quality. Theoretically, the findings extend the Technology Acceptance Model (TAM) and UTAUT2 by incorporating elements of local wisdom, cultural sensitivity, and digital economic empowerment, offering a stronger contextual understanding of technology acceptance in diverse and developing settings.

The study further highlights a dual mechanism through which regional disparities shape health literacy both by limiting access to information and by constraining the development of digital competencies. This reinforces the relevance of TAM and UTAUT2 while broadening their scope through socio-cultural integration. In practical terms, the results offer a solid empirical basis for creating a more adaptive and contextualized SMART Web platform. By combining culturally grounded health content, applicable digital entrepreneurship modules, and personalized learning features, the platform can better meet the varied needs of users and support more efficient resource allocation by health educators and practitioners.

From a policy standpoint, the findings underscore the urgency of investing in equitable digital infrastructure in rural regions and integrating reproductive health literacy, digital skills, and entrepreneurship into the national curriculum. They also highlight the need to strengthen data protection regulations, provide incentives for inclusive health technology development, and encourage collaborative business models such as B2G and B2B2C. In alignment with Making Indonesia 4.0 and SDGs 3 and 9, SMART Web holds potential not only as an educational tool but also as a cost-effective public health investment capable of improving early breast cancer detection, reducing healthcare costs, and cutting carbon emissions by up to 90%. Additionally, the platform offers opportunities for economic empowerment by enhancing the digital and entrepreneurial capabilities of adolescent girls, contributing to the development of a more inclusive, empowering, and sustainable learning ecosystem.

7. DECLARATIONS

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Conceptualization: II; Methodology: DP; Software: WI; Validation: MB and AK; Formal Analysis: MM and DP; Investigation: II; Resources: MB; Data Curation: AK; Writing Original Draft Preparation: MB and II; Writing Review and Editing: DP and AK; Visualization: II; All authors, II, AK, MM, MB, DP, and WI have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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