JPPIPA 12(10) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Improving Health Literacy and Problem-Solving Skills: The Effectiveness of Problem-Based Learning Through the HARVI Educational Website on the Topic of the Human Reproductive System

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Received: July 4, 2026
Revised: August 24, 2026
Accepted: October 12, 2026
Published: October 31, 2026

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DOI: 10.29303/jppipa.v12i10.15924

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Abstract: The human reproductive system topic in high school biology is directly relevant to adolescents' lives, requiring an approach that develops health literacy and problem-solving skills. Field conditions indicate both competencies remain in the "needs guidance" category due to teacher-centered instruction and lack of interactive digital media. This study determined the effectiveness of Problem-Based Learning (PBL) through the HARVI (Human Reproductive Hormones, HIV/AIDS, and Innovation) educational website on health literacy and problem-solving skills of 11th-grade students. Using a one-group pretest-posttest design, the study involved 35 students at SMA Negeri 1 Sungai Apit. The HARVI website integrates five stages of PBL syntax and presents contextual problems on the reproductive system and related disorders. Health literacy was measured across four dimensions within three domains, while problem-solving was measured using six indicators. Results showed health literacy rose to the high category (N-Gain 0.72) and problem-solving rose to the moderate category (N-Gain 0.651), with the Wilcoxon test confirming significant differences ($p < 0.001$). The website's effectiveness stems from its multi-format content and authentic case studies guiding students through problem identification, analysis, and solution evaluation. HARVI thus offers practical value for biology instruction as an adaptive, technology-based medium supporting Indonesia's Independent Curriculum (Kurikulum Merdeka).

Keywords: HARVI educational website; Health literacy; Human reproductive system; Problem-based learning; Problem-solving

Introduction

The topic of the human reproductive system in high school biology is directly relevant to the lives of adolescents because it covers complex biological, psychological, and social changes (Adolph, 2016). This material is abstract in nature, covering hormonal regulation, gametogenesis, fertilization, and reproductive system disorders including HIV/AIDS, and thus requires a deep conceptual understanding and the ability to analyze problems critically (Reza et al., 2023). However, teaching practices remain dominated by lecture-based methods that do not incorporate critical thinking, resulting in students primarily acting as passive recipients of information (Ghaleb, 2024).

Globally, low reproductive health literacy among adolescents is reflected in knowledge gaps, inappropriate health practices, and high rates of teenage pregnancy and sexually transmitted infections, where adolescents' limited understanding directly contributes to the emergence of risky health behaviors (Amanu et al., 2023). At the national level, reproductive health literacy among Indonesian adolescents remains in the moderate category, meaning they are not yet

How to Cite:
Kholifah, N., Listyorini, D., & Muntolib. (2026). Improving Health Literacy and Problem-Solving Skills: The Effectiveness of Problem-Based Learning Through the HARVI Educational Website on the Topic of the Human Reproductive System. *Jurnal Penelitian Pendidikan IPA*, *12*(10), 184–201. https://doi.org/10.29303/jppipa.v12i10.15924

fully able to access, understand, and make optimal use of health information (Wardiati et al., 2023). This situation is also reflected in local health service data: the Sungai Apit Community Health Center (Puskesmas) records a predominance of HIV/AIDS cases among young people due to inadequate reproductive health education and denial of the disease, while the Siak Regional General Hospital (RSUD) confirms a rise in similar cases, indicating that reproductive health literacy among adolescents remains low.

The results of a preliminary study at SMAN 1 Sungai Apit reveal a concerning situation. Students' average health literacy score was 47.9 and their problem-solving ability score was 43.9; both fell into the "needs guidance" category. Students face significant difficulties in understanding problems, planning solutions, and connecting biological concepts to reproductive health issues in daily life (Putri et al., 2023). The lack of relevant interactive learning materials further exacerbates this situation, leading to a decline in students' motivation to learn (Sekarwangi et al., 2021). These low achievement levels cannot be separated from the root cause: the lack of educational reinforcement received by students. Educational levels both at the individual and community levels help determine the quality of adolescents' reproductive health knowledge, including their understanding of HIV prevention and contraceptive use (Chamberlin et al., 2025). Such a knowledge gap, if not promptly addressed through consistent education, logically creates opportunities for the recurrence of risky behaviors among adolescents. This situation is all the more concerning given that low health literacy has also been shown to be associated with an increased risk of chronic diseases, as a result of weak disease-prevention behaviors among the individuals concerned (Rachmani et al., 2019).

The subject of the human reproductive system is not merely about memorizing biological concepts; rather, it encompasses aspects of reproductive health that are directly related to real-life decision-making among adolescents (Goldfarb & Lieberman, 2021). Teaching that relies solely on lectures has been shown to fail to develop students' critical thinking skills or health literacy (Aulia et al., 2025; Muliyadi et al., 2026), while misconceptions and delays in addressing reproductive health issues among adolescents are actually on the rise due to a lack of contextual and interactive education (Irfan et al., 2023). Therefore, this subject requires a teaching approach that encourages students to think critically, analyze health information, and formulate solutions systematically.

The urgency of continuing to examine this issue is reinforced by a number of prior studies that, while making important contributions, ultimately leave the present gap unresolved. In the domain of problem-solving, PBL has been shown to significantly improve students' problem-solving skills and scientific literacy compared with conventional instruction (Lailis Indriani et al., 2023). A classroom action research study implementing PBL with its complete syntax — problem orientation, organizing group learning, individual and group investigation, developing and presenting results, and analyzing and evaluating the process — among vocational high school students in a Computer and Basic Networking course found consistent improvement in problem-solving ability across every action cycle (Hidayati & Wagiran, 2020). A mixed-methods study combining Paper-Based Problem Scenarios (PBPS) with the IPIE model (Identify, Plan, Implement, Evaluate) among high school biology students demonstrated significantly greater improvement in problem-solving than a control group (Nigussie et al., 2025). A correlational meta-analysis found that problem-solving ability correlates strongly and positively with student learning outcomes, although it was not focused on any single instructional model (Banawi et al., 2024). The integration of problem-based learning has likewise been shown to positively affect students' learning interest and problem-solving ability (Dewi et al., 2025). In the domain of health literacy, combining problem-based learning with digital, application-based collaborative mind mapping (PBL-CMM) produced a higher and more meaningful improvement in health literacy than conventional PBL or conventional instruction (Salim et al., 2025). A randomized controlled trial implementing a structured mental-health curriculum delivered by trained teachers, without any specific active-learning model, demonstrated a significant improvement in health literacy (Zeidabadi et al., 2025). Meanwhile, a blended-learning School-Based Community Learning Model that combined interactive digital health modules, peer group discussions, and community action projects grounded in Contextual Teaching and Learning and social constructivism also produced a significant improvement in health literacy (Leonita & Bagio Santoso, 2025).

However, closer examination of this body of work reveals a consistent gap: most previous studies developed instructional models and digital media as separate components rather than integrating them into a single system that accommodates the complete PBL syntax; where digital media were used, they typically served merely as a supplementary tool rather than as a learning environment that systematically embodies all

stages of PBL; and interactive, problem-based media specifically targeting health literacy on the topic of the Human Reproductive System remain scarce. This combination of gaps constitutes both the starting point and the novelty of the present study, which addresses a previously unexamined intersection by embedding contextual reproductive-health problems, digital learning resources, and the complete five-stage PBL process within a single, purpose-built platform. Scientifically, the study is expected to strengthen the theoretical foundation for applying an integrated PBL-based instructional strategy to develop health literacy and problem-solving skills simultaneously, extending prior research that has largely treated these two competencies in isolation.

To address this gap, this study developed the HARVI (Human Reproductive Hormones, HIV/AIDS, and Innovation) educational website using the Wix.com platform, which fully integrates the five stages of the PBL syntax (Arends, 2012). Unlike digital platforms used in prior research, which typically functioned as a supplementary repository of materials, HARVI was designed as a complete, self-contained learning environment: it combines multiple content formats — text, images, video, and audio — with authentic, contextual reproductive-health case studies, structured worksheets, and reflective questions, and integrates learning materials, tasks, and pretest–posttest assessment within a single platform accessible on both desktop and mobile devices (Cipto et al., 2022). This design directly embodies the theoretical relationship among PBL, HARVI, health literacy, and problem-solving: in the problem-orientation stage, students engage with authentic reproductive-health cases on HARVI, thereby exercising the access and understand dimensions of health literacy while identifying the contextual problem, the first indicator of problem-solving; in the stages of organizing and investigating, students search, appraise, and synthesize information from the website's resources, jointly developing the appraise dimension of health literacy and the ability to apply systematic problem-solving steps; and in the stages of developing, presenting, and evaluating solutions, students apply acquired knowledge to real decisions and evaluate and defend the solutions produced, corresponding to the apply dimension of health literacy and the concluding problem-solving indicators of solution evaluation and real-life application (Arends, 2012; Sørensen et al., 2013; Greenstein, 2012). Through this alignment, the HARVI-based PBL environment is conceptually designed to develop health literacy and problem-solving skills as two parallel outcomes of a single, unified instructional process rather than as separately trained competencies.

PBL was further deemed appropriate because it has been shown to encourage students to identify their own learning needs through independent inquiry and group discussion (Trullàs et al., 2022), to develop problem-solving skills through collaborative online tasks (Alshaye et al., 2023), and to improve literacy through information-seeking and evidence-based application (Komuhangi et al., 2025), consistent with 21st-century learning demands for innovative, student-centered approaches (Ge et al., 2025). Building on this background, the present study set out to examine how the HARVI-based Problem-Based Learning approach affects the health literacy and problem-solving skills of eleventh-grade students at SMA Negeri 1 Sungai Apit in the context of the Human Reproductive System material.

Method

This study is part of a broader Research and Development (R&D) project in which the HARVI (Human Reproductive Hormones, HIV/AIDS, and Innovation) educational website was developed and validated. The development stages of HARVI were carried out in an earlier phase of the R&D project and are not the focus of this article. This article specifically reports the implementation and effectiveness-testing phase of the R&D study.

The effectiveness-testing phase used a one-group pretest-posttest design, a type of pre-experimental design, selected because the objective was to test the effect of a single intervention (Problem-Based Learning through the HARVI website) on one group of students by comparing health literacy and problem-solving scores before and after the intervention.

The overall research procedure, from the development of HARVI to the testing of its effectiveness, is presented in Figure 1, adapted from the Lee and Owens (2004).R&D model. This article reports Stage 4 (Implementation) and Stage 5 (Evaluation), building on the HARVI product that was developed and validated in Stages 1-3.

The scientific contribution of HARVI lies in its full integration of all five PBL syntax stages into a single, comprehensive web-based learning environment for the Human Reproductive System topic — a combination not yet addressed by prior studies that applied PBL either in conventional classrooms or through standalone digital media. HARVI (built on Wix.com) consists of: a Home page (navigation and core features - Materi, Referensi, LKPD, pretest/posttest, and Ruang Diskusi); a User Guide page; an Introduction page (learning outcomes, process skills, and Pancasila Student Profile); a Materials page

divided into four sub-topics aligned with the eight meetings; an LKPD (worksheet) page with four structured worksheets; a Discussion Room with WhatsApp group links, comments, and search features; an Evaluation page for pretest/posttest; a Reference page linking to books and Google Scholar articles; and a Profile page. This integrated design allows contextual problem narratives, multimedia content, investigative tasks, and reflection activities to be delivered within one continuous digital PBL cycle.



Figure 1. R&D procedure, adapted from Lee et al. (2004)

The research subjects were 35 eleventh-grade students at SMA Negeri 1 Sungai Apit for the 2025/2026 academic year, selected using purposive sampling. The independent variable was Problem-Based Learning (PBL) through the HARVI educational website; the dependent variables were students' health literacy and problem-solving skills on the topic of the Human Reproductive System. Table 1 presents the PBL syntax integrated into the HARVI website.

Table 1. PBL Syntax on the HARVI Educational Website (Arends, 2012)

PBL Syntax	Learning Activity
Orient students to the problem	Students read contextual problem narratives related to the reproductive system, reproductive hormones, and HIV/AIDS presented on the HARVI website to spark curiosity
Organize students for study	Students form groups and define learning tasks based on the problems presented on the website
Guiding individual and group investigation	Students gather information from materials, worksheets (LKPD), videos, and scientific article links available on the HARVI website to find solutions
Develop and present artifacts and exhibits	Students compile and present the results of group discussions based on the investigations conducted
Analyze and evaluate the problem-solving process	Students reflect on the problem-solving process and evaluate the solutions that have been formulated

Learning was conducted over 8 face-to-face meetings, held twice a week for 4 weeks, totaling 20 lesson hours (900 minutes). Content was organized into four sub-topics matched to meeting pairs: Meetings 1-2 (reproductive organ structure and hormones), Meetings 3-4 (gametogenesis and menstrual cycle), Meetings 5-6

(fertilization, pregnancy, and childbirth), and Meetings 7-8 (reproductive disorders and prevention, including HIV/AIDS). Each meeting implemented the full five-stage PBL syntax in Table 1: (1) a contextual problem narrative was presented to orient students; (2) students were organized into groups and given the corresponding LKPD; (3) students investigated the problem using the website's materials, videos, and article links; (4) groups presented their findings; and (5) the class reflected on and evaluated the solutions with the teacher. Implementation fidelity was recorded through direct classroom observation across all 8 meetings.

Health literacy variables were measured across three aspects that integrate the four dimensions of health literacy (access, understand, appraise, apply) from the HLS-EU framework Sørensen et al. (2013), mapped onto three health-literacy domains: Healthcare, Disease Prevention, and Health Promotion (Table 2).

Table 2. Health Literacy Indicators (Sørensen et al., 2013)

Variables	Domain	health-literacy	Data Collection Technique
Health-literacy	Healthcare	Access & Understand (primary); Appraise & Apply (supporting): Ability to search for, obtain, and understand information on medical/health issues (organs, hormones, gametogenesis, menstruation, fertilization, pregnancy, childbirth) - Items No. 1-16, 27, 28	Multiple-choice test (problem-based model)
		Appraise (primary); Access, Understand, Apply (supporting): Ability to interpret and evaluate medical information - attitude statements No. 36-38, 41-43	Attitude questionnaire
		Apply (primary); Access, Understand, Appraise (supporting): Ability to make appropriate medical decisions and follow medical advice - Essay No. 51; Self-assessment questionnaire No. 55-57	Essay test (conceptual application) + self-assessment questionnaire
	Disease Prevention	Access & Understand (primary); Appraise & Apply (supporting): Ability to access and understand information on health risk factors (reproductive system disorders, HIV/AIDS) - Items No. 17-23, 29	Multiple-choice test (problem-based model)
		Appraise (primary); Access, Understand, Apply (supporting): Ability to evaluate information on health risk factors - attitude statements No. 33-34, 39, 44-46	Attitude questionnaire
		Apply (primary); Access, Understand, Appraise (supporting): Ability to make decisions to protect oneself from risk factors - Essay No. 52-53; Self-assessment questionnaire No. 58-61	Essay test (conceptual application) + self-assessment questionnaire
	Health Promotion	Access & Understand (primary); Appraise & Apply (supporting): Ability to update oneself and understand information on health determinants (social and physical environment) - Items No. 24-26, 30	Multiple-choice test (problem-based model)
		Appraise (primary); Access, Understand, Apply (supporting): Ability to evaluate information on social and environmental factors affecting health - attitude statements No. 35, 40, 47-50	Attitude questionnaire
		Apply (primary); Access, Understand, Appraise (supporting): Ability to make decisions and participate in collective action related to health promotion - Essay No. 54; Self-assessment questionnaire No. 62-64	Essay test (conceptual application) + self-assessment questionnaire

Table 3. Problem-Solving Indicators (Greenstein, 2012)

Variable	Indicator	Description	Instrument
Problem-solving	Identifying problems	Accurately explaining the contextual problem based on the information provided	Problem-based essay test
	Applying problem-solving steps	Using systematic steps and strategies to solve problems	Problem-based essay test
	Identifying solutions	Determining several relevant alternative solutions	Problem-based essay test
	Evaluating solutions	Analyzing and assessing the strengths and weaknesses of solutions	Problem-based essay test
	Maintaining solutions	Defending the best solution with logical reasoning	Problem-based essay test
	Applying solutions in real life	Applying solutions in the context of everyday life	Problem-based essay test

The problem-solving ability variable was measured using six indicators based on Greenstein (2012). Each indicator reflects a systematic stage in the problem-solving process, ranging from identifying a problem to applying a solution in real life. Measurements were conducted using problem-based essay tests tailored to the context of the Human Reproductive System topic (Table 3).

Content validity was established through two-stage expert judgment: an initial assessment by expert validators (material, media, and instructional-tool experts), followed by product revision, and a second-stage re-assessment. A product/instrument was considered adequately valid once the second-stage mean score reached the "valid" or "very valid" category.

Item validity was tested empirically using Pearson product-moment correlation between each item score and the total score, compared against the critical value at n = 35, alpha = 0.05 (r-table = 0.361). An item was declared valid if r-count > r-table. The interpretation categories are shown in Table 4.

Table 4. Item Validity Interpretation Criteria (Arifin, 2019)

r Value	Criteria
0.80 – 1.00	Very high
0.60 – 0.79	High
0.40 – 0.59	Moderate
0.20 – 0.39	Low
0.00 – 0.19	Very low

Reliability was estimated using Cronbach's alpha, interpreted using the criteria in Table 5. An instrument was considered reliable if its alpha coefficient fell in the "high" or "very high" category.

Table 5. Reliability Interpretation Criteria

Alpha Value	Criteria
≥ 0.90	Very high
0.70 – 0.89	High
0.50 – 0.69	Moderate
0.30 – 0.49	Low
< 0.30	Very low

Pretest-posttest data were analyzed in three steps. First, a prerequisite normality test was conducted using the Shapiro-Wilk test (suitable for a small-to-moderate single-class sample) at alpha = 0.05: data were considered normally distributed if the significance value exceeded 0.05, and not normally distributed if it was 0.05 or below.

Second, hypothesis testing followed a decision rule based on the normality result: if both pretest and posttest data were normally distributed, the parametric Paired-Samples T-Test was used; if either distribution deviated from normality, the nonparametric Wilcoxon Signed-Rank Test was used instead. The null hypothesis (no significant difference between pretest and posttest) was rejected if the significance value (Sig. 2-tailed) was below 0.05.

Third, the N-Gain Score was calculated to determine the category of improvement in students' health literacy and problem-solving skills, using the formula: N-Gain = (Posttest score - Pretest score)/ (Maximum score - Pretest score), following Hake (1998) interpretation criteria in Table 6.

Table 6. N-Gain Score Interpretation Criteria

N-Gain value	Category
$g < 0.30$	Low
$0.30 \leq g \leq 0.70$	Moderate
$g > 0.70$	High

Result and Discussion

Validity, Reliability, and Practicality of the HARVI Educational Website and Research Instruments

Three content experts, three media experts, three learning-tool experts, and three instrument experts (the same panel assessed both the health literacy instrument and the problem-solving instrument) from the Graduate Program in Biology Education at Universitas Muhammadiyah Metro and Universitas Negeri Malang evaluated the website and both instruments across two validation stages. The content experts assessed content adequacy, content feasibility, presentation standards, and language; the media experts assessed accuracy, feasibility, usefulness, and propriety, referring to Jayakumar et al. (2013) and Kusumaningrum and the learning-tool experts assessed the learning objectives/flow and the Human Reproductive System teaching module based on BSKAP Standard No. 046/H/KR/2025, Sørensen et al. (2013), and Greenstein (2012); and the instrument experts assessed substance, construction, and language/readability for both the health literacy instrument and the problem-solving instrument. All five components reached the "very valid" category after revision (Table 7).

Revisions requested by the content experts (contextual examples, more coherent presentation, standard Indonesian spelling) and by the media experts (image relevance, animation quality, layout, and integration of health-literacy and problem-solving content) were accommodated prior to the second-stage assessment, consistent with the view that expert validators provide not only evaluative scores but also constructive input that refines a digital product before it is used in the field (Laia et al., 2021; Mukni et al., 2025). Three biology teachers — one from SMA Negeri 1 Martapura and two from SMA Negeri 1 Sungai Apit, all teaching at the grade level appropriate to the material — validated the practicality of the website in the classroom in a single stage, because the initial assessment had already reached the "very valid" category and required no further revision. The practitioners assessed content feasibility, presentation, language, design/graphics, and ease of use (usability) (Table 8).

Table 7. Expert Validation Results for the HARVI Website and Research Instruments (Content, Media, Learning-Tool, and Instrument Components)

Validator	Stage 1 Mean Score	Stage 1 Category	Stage 2 Mean Score	Stage 2 Category
Content experts (content, feasibility, presentation, language)	95.8	Very valid	100	Very valid
Media experts (accuracy, feasibility, usefulness, propriety)	91	Very valid	100	Very valid
Learning-tool experts (objectives/flow, teaching module)	85	Valid	100	Very valid
Health-literacy instrument experts (substance, construction, language)	98.3	Very valid	99	Very valid
Problem-solving instrument experts (substance, construction, language)	97	Very valid	100	Very valid

Table 8. Biology Education Practitioners' Validation of the HARVI Website

Aspect	Practitioner 1	Practitioner 2	Practitioner 3	Mean	Category
Content feasibility	100	100	100	100	Very valid
Presentation	100	100	90	97	Very valid
Language	100	83	100	94	Very valid
Design and graphics	100	90	90	93	Very valid
Ease of use	100	92	75	89	Very valid
Overall mean				95	Very valid

Overall, the near-maximum scores obtained from every group of validators indicate that the HARVI website met the criteria for a valid PBL medium and was ready for classroom use before it was used to collect the pretest–posttest data reported below, thereby also addressing the reviewer's note that this evidence had not previously appeared in the Results section. The validity and reliability of the two measurement instruments themselves — the health literacy instrument and the problem-solving instrument — are reported separately in §2 and §3, immediately before the corresponding effectiveness results, so that the psychometric evidence for each instrument sits alongside the variable it measures.

PBL through the HARVI Website Improves Health Literacy

The health literacy instrument combined a 30-item multiple-choice cognitive test (with access and understand as the primary dimensions), a 20-item attitude questionnaire (with appraise as the primary dimension), and a 4-item conceptual application essay accompanied by a 10-item self-assessment questionnaire (with apply as the primary dimension). Item validity was tested empirically using the Pearson product-moment item–total correlation against the

critical value for n = 35 at α = 0.05 (r-table = 0.361), and reliability was estimated using Cronbach's α coefficient (Arifin, 2019). Every item in all three instrument components exceeded the r-table threshold, and all three components reached the "very high" reliability category (Table 9).

Implementation of the Problem-Based Learning (PBL) model using the HARVI educational website on the topic of the human reproductive system was shown to improve the health literacy of Grade XI students at SMA Negeri 1 Sungai Apit. This improvement was reflected in all four health literacy dimensions (access, understand, appraise, apply), measured according to the framework of Sørensen et al. (2013), as described in the Methods section. Mean scores increased across all dimensions from pretest to posttest: the "access" dimension rose from 59 to 86, "understand" from 51 to 80, "appraise" from 69 to 97, and "apply" from 55 to 85. The "appraise" dimension showed the largest gain, while "understand" showed the smallest. The overall mean score rose from 59 at pretest to 87 at posttest (Figure 2).

Table 9. Empirical Item Validity and Reliability of the Health Literacy Instrument (n = 35, r-table = 0.361)

Instrument Component	Number of Items	Item r Range	Validity Category	Cronbach's α	Reliability Category
Cognitive test (access & understand; multiple choice)	30	0.607–0.848	High–Very high	0.964	Very high
Attitude questionnaire (appraise)	20	0.610–0.732	High	0.923	Very high
Conceptual application essay (apply)	4	0.835–0.960	Valid	0.929	Very high
Self-assessment questionnaire (apply)	10	0.608–0.781	Valid	0.847	Very high

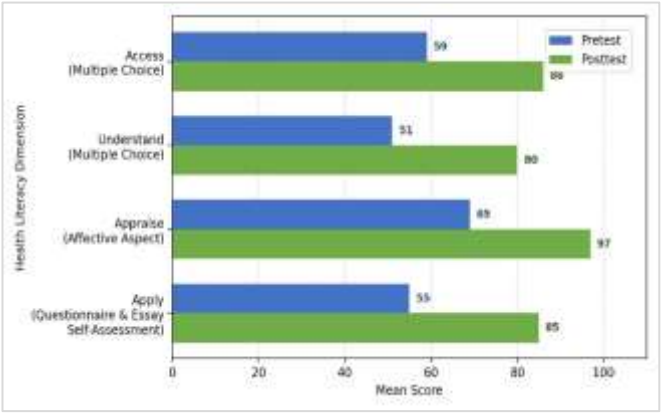


Figure 2. Comparison of pretest and posttest health literacy scores by dimension

Before hypothesis testing, the Shapiro–Wilk test was used to check the normality assumption for the pretest and posttest health literacy scores. Pretest scores were normally distributed (W = 0.967; p = 0.362), whereas posttest scores deviated from normality (W = 0.892; p = 0.002); the nonparametric Wilcoxon Signed-Rank test was therefore used for hypothesis testing (Table 10).

The Wilcoxon Signed-Rank test showed a statistically significant difference between the pretest and posttest health literacy scores (Z = −5.159; p < 0.001), so H_0 was rejected (Table 11). Because a nonparametric test was used, the effect size was calculated using the matched-pairs rank-biserial correlation rather than Cohen's d, which assumes normally distributed difference scores. The analysis yielded r = −1.00 (95% CI [−1.00, −1.00]), the maximum attainable magnitude, meaning that all 35 students shifted from pretest to posttest in the same direction wiwithout exception — a result classified as a very large effect under conventional benchmarks for the rank-biserial correlation (|r| ≥ 0.5 = large).

Table 10. Normality Test Results for Health Literacy Scores (Shapiro–Wilk, α = 0.05)

Data	N	Mean	SD	Shapiro–Wilk (W)	p (normality)	Distribution
Pretest	35	58.77	11.93	0.967	0.362	Normal
Posttest	35	87.83	8.09	0.892	0.002	Not normal

Table 11. Wilcoxon Signed-Rank Test and Effect Size for Health Literacy Scores

Variable	N	Z	p (Wilcoxon)	Decision (α = 0.05)	Rank-biserial r (95% CI)
Health literacy: pretest – posttest	35	−5.159	< 0.001	H_0 rejected	−1.00 (−1.00, −1.00)

Based on N-Gain scores, all dimensions achieved a mean of 0.72, which falls into the high category. The highest N-Gain score was found in the "appraise" dimension (0.90) and the lowest in "understand" (0.59). The N-Gain distribution showed fairly wide variation: 57.14% of students fell into the high category, 42.86% into the medium category, and none (0%) into the low category (Table 12). These results indicate that the intervention produced not only a statistically significant difference but also a substantive, evenly

distributed improvement in health literacy across all (Xu et al., 2023).

Table 12. Distribution of N-Gain Categories for Health Literacy

N-Gain Category	Score Range	Number of Students	Percentage
High	$g \geq 0.7$	20 students	57.14%
Medium	$0.3 \leq g < 0.7$	15 students	42.86%
Low	$g < 0.3$	0 students	0%
Total		35 students	100%

The four dimensions did not improve uniformly, and this pattern of gains can be explained by the specific cognitive demands each dimension places on students and by which stage of the PBL syntax targets those demands. The "access" dimension improved because the problem-orientation stage of PBL confronted students with an authentic reproductive-health case from the first session onward, which functioned — in constructivist terms — as a trigger that activated prior knowledge and created a need to seek new information rather than simply receive it passively, consistent with the constructivist view underlying the HARVI website's design, in which students actively interpret, relate, and construct new understanding from their existing knowledge and experience (Doyan et al., 2026; Qin et al., 2022). Students then sought that information independently through the learning materials, videos, and reference links on the HARVI website, so the skill being trained was genuinely an information-seeking skill practiced in a meaningful context rather than a technical exercise detached from a real problem. Strengthening health literacy early on through this kind of meaningful learning experience lays the foundation for a sustainable healthy lifestyle later in life (Okan et al., 2020).

The "understand" dimension improved through the organizing-and-inquiry stage of PBL, yet recorded the lowest N-Gain (0.59) among the four dimensions. This is consistent with the function of the Discussion Forum as a social space for negotiating meaning: students reconstructed concepts in their own words, questioned what they had not yet mastered, and corrected one another's misconceptions about reproductive hormones, gametogenesis, and the menstrual cycle — a socially mediated and externalized process of cognitive restructuring, rather than mere information retrieval, consistent with the constructivist principle underlying the HARVI website that new understanding is built through interpretation and interaction with others rather than through passive reception of information (Qin et al., 2022). Restructuring existing misconceptions takes longer than acquiring new facts, because learners must first become aware of the conflict between their prior beliefs and new evidence before a new, stable schema can form, which plausibly explains why "understand" lagged behind the other three dimensions despite receiving the same eight sessions of exposure. This is consistent with the view that the ability to understand health information depends on the cognitive and social skills that shape an individual's motivation to process health knowledge personally and reflectively (Juvinyà-Canal et al., 2020).

The "appraise" dimension achieved both the highest posttest score and the highest N-Gain (0.90) among the four dimensions. HARVI's design paired the Discussion Forum with links to scientific articles as comparison material, repeatedly requiring students to select, organize, and integrate information from more than one channel of representation (text, images, video, and peer discussion) before deciding whether a claim could be trusted. This pattern of gains is consistent with evidence that actively engaging students with multiple sources of content, rather than having them passively receive a single account, improves the quality and contextualization of their (Bavishi et al., 2022), and this plausibly explains why the dimension most directly training comparative and evaluative processing showed the largest gain. The ability to judge the validity of information is at the core of health literacy; good health literacy is characterized not only by increased knowledge but also by the ability to evaluate and apply that information in health-supportive attitudes and behaviors (Pleasant et al., 2020).

The "apply" dimension developed through the work-production-and-reflection stage of PBL. Through tiered worksheets, students not only answered conceptual questions but also formulated solutions to reproductive-health cases and presented them in class — for example, in the form of posters covering topics ranging from fertilization to childbirth. This sequence reflects an emphasis on placing responsibility for translating knowledge into a concrete product on the learner rather than the teacher, moving knowledge from the level of understanding toward real-world practice, consistent with the fourth stage of the PBL syntax, in which students are guided to develop and present their work as a form of applying the information they have learned (Arends, 2012).

Not every PBL-based health-literacy intervention produces gains of this magnitude, and this comparison

is informative about which design features matter. Salim et al. (2025) found that combining PBL with collaborative mind mapping in a digital application produced a higher and more meaningful improvement in health literacy than conventional PBL or conventional instruction alone, suggesting that the medium through which PBL is delivered — not the model alone — helps determine how far health literacy gains can progress; this is broadly consistent with the present study, in which the persistent, revisitable HARVI website plausibly supported the more effortful "understand" and "appraise" dimensions further than a shorter or non-digital implementation might have. Suwono et al. (2023) likewise showed that PBL in biology instruction is empirically associated with higher health literacy, but their quasi-experimental design measured students' perceptions of the PBL process rather than directly comparable pre–post competency gains, illustrating how differences in research design — not just the intervention itself — can produce different forms of evidence for the same claim. Linking this to the broader observation that the advantage of PBL over conventional instruction is most consistently seen in durable, applied learning rather than in brief or single-exposure knowledge gains (Schmidt et al., 2011), these comparisons suggest that intervention duration (eight sessions), medium type (an integrated, revisit able website rather than a one-off paper scenario), and instructional context (a biology classroom embedding all five PBL stages, rather than a stand-alone health module) are the most plausible factors underlying the relatively high N-Gain observed in this study.

This improvement in health literacy is also closely tied to the HARVI website's character as a structured yet flexible digital medium. Organizing the material progressively from subtopics 1–2 through 7–8, complemented by images, videos, and contextual case studies such as hormonal disorders, vaginal discharge, and HIV/AIDS, allowed students to revisit sections they had not yet mastered without being constrained by class time — an arrangement that kept the amount of new information presented at any one time manageable for students without overwhelming their capacity to process it, so that their attention and effort remained available for genuine learning. This is consistent with findings that digital media designed around student needs can support self-paced independent learning (Camel et al., 2020), while also increasing learning engagement through greater motivation and participation (Januarti et al., 2024; Mukni et al., 2025). The improvement in health literacy is thus the product of an integration between PBL design and technological features that synergistically guide students through the four health-literacy dimensions in a sequential, mutually reinforcing way, while also addressing the need to strengthen adolescents' digital health literacy, as demonstrated by website-based educational platform implementations for senior high school students (Wiguna et al., 2025).

PBL through the HARVI Website Improves Problem-Solving Skills

Problem-solving ability was measured using a six-item problem-based essay test corresponding to Greenstein's (2012) six indicators. Item validity was again tested using the Pearson item–total correlation against r-table = 0.361 (n = 35), and reliability was estimated using Cronbach's α. All six items correlated significantly with the total score, and the instrument reached the "very high" reliability category (Table 13).

Table 13. Empirical Item Validity and Reliability of the Problem-Solving Instrument (n = 35, r-table = 0.361)

Instrument Component	Item–Total r Range	Validity Category	Cronbach's α	Reliability Category
Problem-based essay test (6 indicators)	0.681–0.911 (all $p < 0.001$)	Valid	0.883	Very high

In addition to health literacy, implementation of PBL through the HARVI website also had a positive effect on students' problem-solving skills related to the Human Reproductive System. Problem-solving skill was measured using six indicators developed by Greenstein (2012), ranging from identifying the problem to applying the solution in real life. Mean scores increased across all indicators: identifying the problem rose from 44.3 to 75.0; applying problem-solving steps from 44.3 to 77.1; identifying solutions from 42.9 to 78.6; evaluating solutions from 35.7 to 76.4; maintaining solutions from 35.7 to 73.6; and applying solutions in real life from 38.6 to 74.3. The evaluating-solutions and maintaining-solutions indicators recorded the highest percentage gains (114% and 106%, respectively), while identifying the problem showed the smallest gain (69%). The overall mean score rose from 40.34 at pretest to 78.37 at posttest (Figure 3).

The Shapiro–Wilk test showed that, unlike the health-literacy posttest, both the pretest ($W = 0.939$; $p = 0.053$) and posttest ($W = 0.942$; $p = 0.063$) distributions for problem-solving were normal (Table 14). To keep the analysis consistent across both study variables, the nonparametric Wilcoxon Signed-Rank test was nevertheless applied to problem-solving, following the same test used for health literacy.

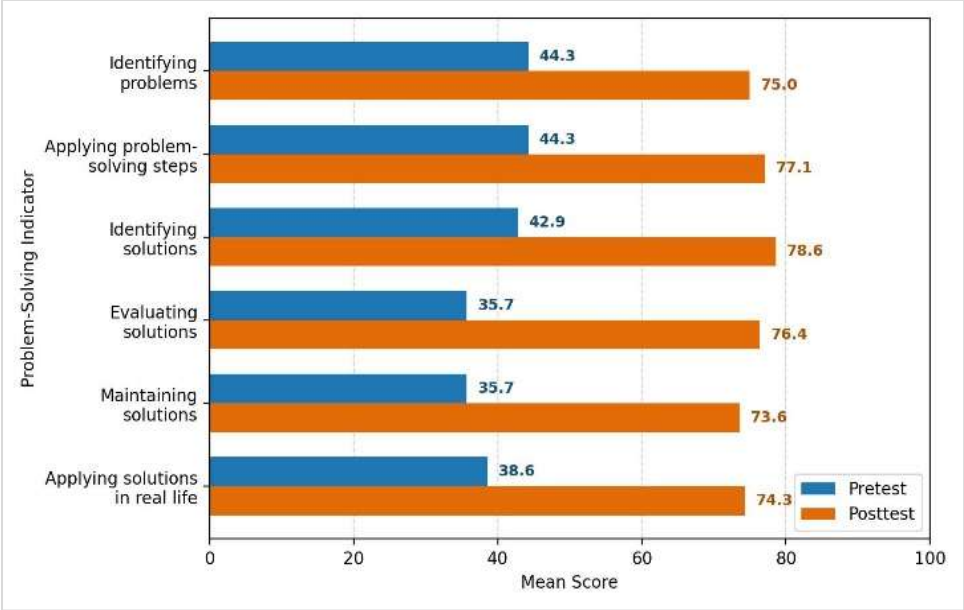


Figure 3. Comparison of pretest and posttest problem-solving scores by indicator

Table 14. Normality Test Results for Problem-Solving Scores (Shapiro–Wilk, α = 0.05)

Data	N	Mean	SD	Shapiro–Wilk (W)	p (normality)	Distribution
Pretest	35	40.34	12.3	0.939	0.053	Normal
Posttest	35	78.37	14.03	0.942	0.063	Normal

As with health literacy, the Wilcoxon Signed-Rank test confirmed a significant difference between the problem-solving pretest and posttest scores ($Z = -5.159$; $p < 0.001$), so H_0 was rejected (Table 15). The matched-pairs rank-biserial correlation of $r = -1.00$ (95% CI [−1.00, −1.00]) — the same maximum magnitude obtained for health literacy, and classified as a very large effect under conventional benchmarks — confirms that all 35 students (35 of 35) showed a score increase without exception.

Table 15. Wilcoxon Signed-Rank Test and Effect Size for Problem-Solving Scores

Variable	N	Z	p (Wilcoxon)	Decision (α = 0.05)	Rank-biserial r (95% CI)
Problem-solving: pretest – posttest	35	−5.159	< 0.001	H_0 rejected	−1.00 (−1.00, −1.00)

Based on N-Gain scores, all students showed improved problem-solving ability with a mean N-Gain of 0.651 (median = 0.597), which falls into the medium category. N-Gain values ranged from 0.333 (lowest) to 1.000 (highest), indicating that every student improved, albeit at differing rates. The N-Gain category distribution (Table 16) shows that 40% of students (14 students) fell into the high category and 60% (21 students) into the medium category, while no students (0%) fell into the low category. The absence of students in the low category indicates that the problem-based learning approach used was able to reach all students, including those with relatively low prior knowledge.

This finding is consistent with the view that problem-solving is a higher-order thinking skill that can be developed gradually through a process of internalization facilitated by group discussion and repeated problem-solving practice (Belland et al., 2011).

Table 16. Distribution of N-Gain Categories for Problem-Solving Ability

N-Gain Category	Score Range	Number of Students	Percentage
High	$g > 0.7$	14 students	40%
Medium	$0.3 \leq g \leq 0.7$	21 students	60%
Low	$g < 0.3$	0 students	0%
Total		35 students	100%

Nevertheless, the predominance of students in the medium category indicates that most students still faced challenges in optimally transferring the concepts they had learned to new problem-solving situations,

particularly in evaluating and maintaining solutions, which demand higher-order thinking skills (HOTS), specifically in analyzing, evaluating, and constructing solutions for complex problems (Affandy et al., 2024). The intensity of students' involvement in group discussion also affected the rate of improvement in this skill, given that discussion, collaboration, and reflection in learning play an important role in helping students build understanding of a problem and refine the problem-solving strategies they use (Xu et al., 2023); accordingly, the eight learning sessions tended to yield better results for students who were more actively engaged in group discussion than for other students.

The improvement in the "identifying the problem" indicator developed in line with the problem-orientation stage of PBL, which opened every session by presenting an authentic reproductive-health case. In inquiry-based-learning terms, this presentation functioned as an authentic trigger that prompted students to identify what they did not yet know and to seek it out, consistent with the view that presenting students with an ill-structured, real-world problem is what drives the entire PBL learning process from the outset (Hmelo-Silver, 2004), consistent with evidence that structuring problem-based learning around authentic real-world issues can increase students' motivation to engage with the material (Mengyao et al., 2025); students became accustomed to identifying the core of a problem before moving to the resolution stage, rather than guessing at an answer directly without understanding the context of the case at hand.

The improvement in "applying problem-solving steps" was linked to the student-organizing stage of PBL. At this stage, students were guided through structured worksheets to devise a solution plan and divide roles within their group. Functionally, the worksheet acted as a scaffold that offloaded part of the planning burden from students working alone, allowing them to focus their effort on formulating the solution itself rather than on organizing the task, and is consistent with evidence that PBL instructional materials based on e-modules significantly improve students' problem-solving skills compared with PBL without structured instructional materials (Hadira et al., 2024). This habit of formulating a strategy before acting strengthened students' logical reasoning when confronting complex reproductive-health problems.

The improvement in identifying solutions is consistent with the individual-and-group investigation stage, which encouraged students to explore information from various sources before settling on alternative solutions, an exercise in which students, rather than the teacher, decided which sources needed to be consulted and when their search was sufficient. The availability of article links and additional references on the HARVI website gave students the opportunity to consider more than one possible answer, so that they did not rush to settle on a single solution without comparing it against other relevant information.

The most striking improvement, in the evaluating-solutions and maintaining-solutions indicators, reflects the low pretest scores on both indicators (35.7), which confirms that the ability to judge the appropriateness of a solution and construct an argument was the most evident initial weakness among students — unsurprising, given the teacher-centered instruction described in the Introduction, which had previously given students very little opportunity to practice analytical or argumentative thinking. The work-development-and-presentation stage of PBL specifically trains both of these skills, because students not only produce a solution but also present it and answer questions from peers and the teacher, a retrieval-and-elaboration cycle consistent with the evaluating- and maintaining-solutions indicators, which require students to weigh all alternatives before determining the most appropriate solution to a problem (Greenstein, 2012). The experience of defending one's position before an audience prompts students to reconsider the basis of their reasoning, thereby building the ability to support an argument with relevant evidence through direct experience; because both indicators started from the lowest baseline, their large percentage gains (114% and 106%) still brought the class only to a medium absolute posttest level (76.4 and 73.6), a point returned to below in the discussion of the overall problem-solving N-Gain.

The improvement in applying solutions in real life was driven by the reflection stage that HARVI consistently presented in the form of reflective questions at the end of every session. These questions guided students to connect the solutions they had formulated to everyday reproductive-health situations, such as preventing sexually transmitted infections or recognizing warning signs in the menstrual cycle, consistent with evidence that a problem-based learning cycle of identifying, analyzing, and resolving problems can effectively facilitate the transfer of theoretical knowledge into practical application (Shi et al., 2025). This practice of linking learning outcomes to real-world contexts is what determines whether the problem-solving skills trained in the classroom can be transferred into students' lives or remain merely an academic skill.

The medium, rather than high, N-Gain obtained in this study is broadly consistent with the wider PBL literature, which finds that the advantage of PBL is

most consistent for durable applied learning outcomes and less consistent for short-term or single-session designs (Schmidt et al., 2011). Studies that measure problem-solving after a single or very brief PBL exposure, or in more heterogeneous samples with a wider spread of prior ability, generally report smaller or more variable gains than the eight-session, single-class implementation used in this study; the relatively homogeneous ability range within a single class, guided throughout the study by the same teacher and case materials, plausibly also contributed to the convergent positive gains observed across all 35 students, a pattern that may be harder to replicate in larger, more heterogeneous samples or across multiple classes or schools. A further design-related factor is that the problem-solving instrument in this study was specifically designed to reflect the PBL syntax taught through HARVI, maximizing alignment between what was taught and what was tested; studies using more generic or standardized problem-solving instruments not explicitly aligned with the intervention content would be expected to show more conservative gains. These considerations — intervention duration, sample homogeneity, and alignment between the instrument and the intervention — are revisited in the Limitations subsection below.

Overall, these findings confirm that PBL is effective in developing problem-solving skills not because it presents many practice items, but because it places students within a continuous sequence of thinking experiences: identifying the problem, gathering information, formulating a solution, and finally discussing and defending that solution before the group, consistent with evidence that inquiry-based problem-solving training combined with small-group discussion significantly improves critical-thinking and decision-making skills (Ahmady & Shahbazi, 2020). The HARVI website, which accommodates this entire sequence within a single platform, allowed this systematic thinking process to be practiced continuously, thereby producing a demonstrable and verifiable improvement in students' problem-solving skills related to the Human Reproductive System, both statistically and conceptually.

Although both variables improved significantly, the magnitude of improvement differed: health literacy reached a high N-Gain category (0.72), while problem-solving reached only the medium category (0.651), a difference of roughly 0.07 on the N-Gain scale that was fairly consistent across dimensions and indicators, and therefore cannot be attributed solely to measurement error. There are three complementary explanations for this difference.

First, the two constructs sit at different cognitive levels. Most of the health-literacy dimensions — particularly access and apply — rely on the ability to locate, understand, and directly use information that the HARVI website had already made readily available, whereas the most lagging problem-solving indicators (evaluating and maintaining solutions) demand higher-order thinking skills: analyzing multiple alternatives, weighing evidence, and defending a judgment (Affandy et al., 2024). Higher-order cognitive operations are inherently more effortful and slower to consolidate than the comprehension-level operations that dominate health literacy, so a comparable amount of learning time produced a smaller relative improvement in this more demanding construct. Second, the two constructs differ in the type of knowledge transfer they require. Health-literacy items were assessed on reproductive-health content largely identical to what students had just learned on the HARVI website, primarily requiring near transfer from recently learned material to a highly similar context; the problem-solving posttest, by contrast, required students to apply what they had learned to new, contextualized cases, a form of far transfer that is consistently more difficult to achieve and slower to develop than near transfer.

Third, complex problem-solving skills generally require longer, more deliberate practice to become reliable than information-literacy skills do; the PBL literature also finds that its benefits are most pronounced for durable applied learning measured over a longer period, rather than for immediate post-intervention gains (Schmidt et al., 2011), so the eight sessions used in this study may have been sufficient to bring health literacy into the high category but only brought problem-solving to the threshold of that category.

This is supported by the pretest data itself: the problem-solving indicators demanding the highest level of analytical thinking (evaluating and maintaining solutions) started from the lowest baseline score (35.7) among all indicators measured across both variables, so that even though the relative improvement was large, the class remained in the medium band rather than the high band. Taken together, these three factors — the higher cognitive demand of evaluative problem-solving, the need for far transfer rather than near transfer, and the longer practice time generally required by complex reasoning skills — provide a scientific explanation for why problem-solving developed more slowly than health literacy within the same eight-session intervention.

Relationship between Variables, Scientific Contribution, and Limitations of the Study

Although health literacy and problem-solving were analyzed as two separate learning outcomes, the pattern of results obtained suggests that the two are not entirely independent. Health literacy, particularly the appraise dimension — the ability to judge the validity and relevance of health information — supplied epistemic raw material used by several problem-solving indicators: before students could identify or evaluate a solution for a reproductive-health case, they first had to be able to judge which pieces of information about that case were credible and relevant. Conceptually, this is consistent with the view that health literacy is more than a mere set of comprehension skills; it functions as a determinant of the capacity for informed decision-making and self-management that underlies problem-solving in health contexts (Nutbeam & Lloyd, 2020).

The appraise dimension recorded both the highest posttest score and the highest N-Gain (0.90) among all dimensions in this study, and it is plausible that its strong development provided a foundation supporting the parallel gains observed in the identifying- and evaluating-solutions indicators, since both processes draw on the same underlying skill of weighing evidence before acting on it. Both constructs also developed within the same learning cycle, using the same authentic case materials, the same Discussion Forum, and the same tiered worksheets, so their joint improvement is better understood as two facets of a single problem-based learning experience rather than as two unrelated outcomes running in parallel. This explanation remains a plausible conceptual synthesis rather than a statistically demonstrated causal pathway, because the one-group design used in this study did not include correlation, regression, or mediation analysis directly linking the two variables; formally testing whether improved health literacy statistically predicts or mediates improved problem-solving — for example, through path analysis — is recommended as a direction for future research on the HARVI website.

This study's findings support three specific contributions beyond simply showing that "PBL through HARVI works." First, this study demonstrates the full integr ation of the five-stage PBL syntax — problem orientation, organizing students for learning, individual and group investigation, developing and presenting artifacts, and analyzing and evaluating the process (Arends, 2012) — directly into the architecture of an educational website, rather than merely using digital media as a repository of supplementary material layered on top of a PBL process carried out separately.

This distinguishes HARVI from platforms such as those described by Wiguna et al. (2025), in which digital health-literacy content is delivered without being organized according to the syntax of a complete learning model, and offers a reusable design template in which specific website features (the Discussion Forum, tiered worksheets, reflective questions) are deliberately mapped onto specific PBL stages rather than assembled ad hoc. Second, this study empirically links a fully digital, syntax-integrated PBL environment to adolescent health literacy, specifically in the domain of reproductive health embedded within formal biology instruction — a combination that has been relatively little studied compared with general digital-PBL health-literacy interventions in other subject areas (Salim et al., 2025) or perception-level studies of PBL and health literacy in biology classrooms (Suwono et al., 2023).

Third, the pattern of results — in which each PBL stage corresponds to a specific health-literacy dimension or problem-solving indicator, and in which the appraise dimension plausibly functions as a bridge between the two variables (see above) — provides elements of a conceptual model that biology educators can adapt when designing similar case-based digital media for other socio-scientific topics in which health literacy and problem-solving are joint targets, such as nutrition, infectious disease, or environmental health.

This study used a one-group pretest–posttest pre-experimental design, which did not include a comparison or control group. Consequently, although the statistical results (Tables 10–11 and 14–15) confirm that scores changed significantly between pretest and posttest, these results cannot by themselves rule out three classic threats to internal validity associated with this design. First, a testing effect may have occurred: because the pretest and posttest used structurally similar items, part of the posttest gain could reflect familiarity with the item format rather than genuine competency growth. Second, a maturation effect cannot be ruled out: the pretest and posttest were separated by eight learning sessions, during which the normal cognitive and social development typical of adolescents could itself have contributed to the score increase, independent of the intervention. Third, a history effect may have occurred, because the one-group design cannot control for external events — such as simultaneous exposure to reproductive-health information from other subjects, social media, or public-health campaigns during the intervention period — that could also have affected students' health-literacy or problem-solving scores.

These threats do not negate the observed improvement, particularly given the size and

consistency of the effect across every dimension and indicator measured, but they do mean that this improvement should be attributed to the HARVI-based PBL intervention with due caution, rather than treated as fully isolated causal evidence. The study sample was also limited to a single class in a single school, which limits generalization of the findings to other student populations and contexts. Future research is recommended to use a quasi-experimental design with a non-equivalent control group, or a randomized controlled design where feasible, together with a larger and more heterogeneous sample across multiple classes or schools, in order to more rigorously isolate the causal contribution of the HARVI website from maturation, testing, and history effects.

Conclusion

The implementation of Problem-Based Learning through the HARVI educational website has been proven effective in improving health literacy (N-Gain 0.72, high category) and problem-solving skills (N-Gain 0.651, moderate category) among 11th-grade students at SMA Negeri 1 Sungai Apit on the topic of the Human Reproductive System, with statistically significant differences in both variables ($p < 0.001$). These improvements resulted from the integration of the structured PBL syntax with the interactive features of the HARVI website ranging from authentic reproductive health cases, digital discussion forums, tiered worksheets, to reflective questions that guide students through systematic thinking stages, from problem identification to the application of solutions in real life. Thus, the PBL-based HARVI educational website is worthy of recommendation as an innovative learning medium to improve high school students' health literacy and problem-solving skills.

Acknowledgments
The authors extend their gratitude to all parties who assisted throughout the research process and supported the completion of this manuscript.

Author Contributions
Conceptualization, N.K., D.L., and M.; methodology, N.K. and D.L.; software, N.K.; validation, D.L. and M.; formal analysis, N.K.; investigation, N.K.; resources, N.K.; data curation, N.K.; writing—original draft preparation, N.K.; writing—review and editing, D.L. and M.; visualization, N.K.; supervision, D.L. and M.; project administration, N.K. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

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