Development of a Web-Based Health Literacy Promotion Model for Anemia Prevention among Public Health and Allied Health Sciences Students: A PAOR-Based Study

Abstract

Aims: To develop and refine a web-based health literacy promotion model for anemia prevention among public health and allied health sciences students using Planning–Action–Observation–Reflection (PAOR).

Methods: This single-group Phase 2 developmental study integrated a preceding situational assessment, a 12-student focus group and a six-domain framework. Three experts evaluated the prototype, followed by an eight-week try-out with 30 students, including one week of orientation. Participants completed paired 45-item health-literacy assessments. Six exploratory paired Wilcoxon comparisons were unadjusted for multiplicity.

Findings: Expert review yielded 39 item-level judgments: 76.9% Very good, 20.5% Pass and 2.6% Needs improvement. Overall student user-experience ratings were very high (mean 4.68, SD=0.23). All 30 participants had matched assessments, with higher mean scores across six domains and the largest descriptive increase in communication (+1.13); all unadjusted p-values were <.01. Font presentation and AI voice clarity were refined before try-out, and correct-answer quiz feedback afterward. Smartphone optimization remained deferred.

Conclusion: The PAOR process supported systematic prototype development, preliminary acceptability and exploratory within-person health-literacy change. The uncontrolled design does not demonstrate causal effectiveness; controlled evaluation and smartphone usability testing are needed.

Keywords: Anemia; Health Literacy; Health Promotion; Internet-Based Intervention; Artificial Intelligence; Students.

MeSH keyword records

Anemia: https://www.ncbi.nlm.nih.gov/mesh/68000740
Health Literacy: https://www.ncbi.nlm.nih.gov/mesh/68057220
Health Promotion: https://www.ncbi.nlm.nih.gov/mesh/68006293
Internet-Based Intervention: https://www.ncbi.nlm.nih.gov/mesh/2030848
Artificial Intelligence: https://www.ncbi.nlm.nih.gov/mesh/68001185
Students: https://www.ncbi.nlm.nih.gov/mesh/68013334

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Introduction

Anemia remains a major global public health problem and contributes substantially to morbidity and disability [1, 2]. Iron deficiency is an important contributor, although anemia has nutritional, physiological, infectious, and other causes [3]. Progress in reducing anemia remains insufficient in many settings, supporting continued attention to prevention and nutrition-related health promotion. University students are an important but comparatively less targeted population for anemia prevention. Studies have reported anemia among undergraduates, including health sciences students [4-9], with female students particularly vulnerable because of menstrual blood loss, dietary factors, and lifestyle patterns [10, 11]. Studies among university students have examined cognitive abilities and scholastic performance in relation to anemia [12, 13]. One cross-sectional study found no significant association between iron deficiency anemia and cognitive abilities [12]. Another found no association between anemia status and scholastic performance, although hemoglobin levels differed between high and low academic performers [13]. Anemia prevention remains relevant to public health and allied health sciences students, who also require skills to communicate health information in future professional roles.

Studies among university students, including those in health-related disciplines, have reported varying levels of anemia-related knowledge, attitudes, and preventive practices [14-19]. Some identified knowledge or dietary-practice gaps, whereas others reported generally adequate knowledge and awareness [14, 17, 18]. Anemia prevention, however, requires more than factual knowledge: students must identify reliable information, interpret and communicate it, appraise competing claims, make informed decisions, and apply information to self-care. Health literacy (HL) has been defined in terms of the knowledge and competencies needed to access, understand, appraise, and use health information and services [20]. Drawing particularly on the six-domain Thai health literacy framework and related health literacy pathway and media-literacy concepts [21-23], this study operationalized health literacy as access to health information and services, knowledge and understanding, communication, self-management, media literacy, and decision-making.

Digital learning environments can support these competencies because university students routinely encounter health information through websites, social media, and online search. A systematic review found that university digital-health-literacy research remains predominantly descriptive and identified a literacy-to-intervention gap [24]. Another review found a limited higher-education intervention evidence base and emphasized interactive components and clearer theory-informed design [25]. Web-based health education should therefore engage students in finding, understanding, appraising, communicating, and applying information rather than merely presenting content.

Generative artificial intelligence (AI) adds both opportunity and risk. It provides conversational access to health information, yet generated content may be inaccurate or misleading. Evidence indicates that generative AI can increase the volume, speed, and perceived credibility of health misinformation [26]. Educational use should therefore include explicit questioning, verification, and critical appraisal. In this intervention, AI was used as a learning scaffold rather than a diagnostic or medical decision-making tool.

Despite evidence on anemia prevalence, associated factors, knowledge, and practices among university students [4-19], less attention has been given to systematic development of comprehensive anemia-prevention health literacy interventions. Broader university health literacy research also provides limited detail on how theory, user needs, educational activities, expert input, and user experience are translated into components and refined before effectiveness testing [24, 25].

The present study used a Planning-Action-Observation-Reflection (PAOR) framework [27]. Planning integrated a preceding situational assessment, student focus-group needs, and the six-domain health literacy framework; Action produced Prototype V1; Observation generated formative evidence through sequential expert and student evaluation; and Reflection integrated that evidence into Retain, Modify, Add, or Remove decisions to produce Prototype V2.

This study aimed to develop and refine a web-based health literacy promotion model for anemia prevention among public health and allied health sciences students. Objectives were to (1) translate empirical needs and six health literacy domains into intervention components; (2) examine preliminary appropriateness, comprehensibility, usability, acceptability, and perceived usefulness; and (3) integrate evaluation and process-related evidence through structured reflection to produce a refined prototype.

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Materials & Methods

Study Design

This single-group, uncontrolled Phase 2 developmental study formed part of a broader research program. Phase 1 was a preceding situational assessment. Phase 2 comprised PAOR-based prototype development, formative evaluation and an eight-week student try-out, including one week of orientation, with exploratory pre–post health-literacy assessment. It was not designed to establish intervention effectiveness.

Development followed PAOR [27] (Supplementary Figure S1). Planning integrated Phase 1 findings, focus-group needs and the six-domain health literacy framework; Action produced Prototype V1; Observation comprised expert and student evaluation; and Reflection linked component-level evidence to Retain, Modify, Add or Remove decisions for Prototype V2.

Study Setting and Participants

The study was conducted at Kanchanabhishek Institute of Medical and Public Health Technology, Faculty of Public Health and Allied Health Sciences, Praboromarajchanok Institute, Thailand. The investigator confirmed that all 30 try-out participants belonged to the first-year cohort. Differing self-reported year-of-study labels may reflect interrupted and resumed study; individual questionnaire records were not recoded on this basis.

Twelve first-year students were purposively recruited for a Planning focus group from Phase 1 complete blood count (CBC) strata: normal, anemia-risk and anemia-case (four per stratum). Three experts represented hematologic disease, information technology and educational technology. For the try-out, researchers directly invited eligible first-year students with available Phase 1 CBC results; 30 participated (10 per stratum), none from the focus group. Non-consent or inability to complete scheduled activities were exclusion criteria. The number declining was not recorded, preventing calculation of a recruitment response rate. Study-defined sampling strata used hemoglobin (Hb) and mean corpuscular volume (MCV): normal, Hb ≥12 g/dL and MCV ≥80 fL; anemia-risk, Hb <12 g/dL with MCV ≥80 fL or Hb ≥12 g/dL with MCV <80 fL; anemia-case, Hb <12 g/dL and MCV <80 fL. These indicators were informed by Thai Society of Hematology guidance [28], but the three-group scheme was study-defined, not diagnostic. The guidance provides age- and sex-specific Hb values; 12 g/dL is not a universal diagnostic cutoff.

Planning: Identification of Needs and Design Requirements

Planning combined the six-domain framework, student needs and Phase 1 data. Complete situational-assessment data were available for 280 first-year students from seven colleges (302 targeted), recruited through college-based quotas and voluntary participation. At the prototype college, 226 students had complete CBC records for sampling. Focus groups used six open-ended questions covering anemia experience and information sources, desired content and preferred web learning activities. A researcher facilitated discussion, took notes and audio-recorded with consent. Transcripts were checked, repeatedly read, segmented into meaning units, coded, grouped into categories and synthesized into themes, which were checked against original data. Focus-group duration and independent second-coder review were not documented. Findings were mapped to health literacy domains; domains not prominent in discussion were retained when supported by Phase 1 evidence or theory.

Students associated anemia with pallor and fatigue but had difficulty interpreting technical blood-result information. Family and social media were common information sources; systematic searching and credibility appraisal were limited. Desired content covered causes, symptoms, prevention, diet, iron-supplement information, self-care, health-service use and follow-up blood testing. Students preferred concise, multimodal, interactive, self-paced learning with simple navigation.

Five themes informed Prototype V1: Limited and Uneven Anemia Understanding; Unsystematic Information Seeking and Limited Credibility Appraisal; Need for Practical and Self-Care-Oriented Information; Preference for Concise, Multimodal, and Interactive Learning; and Need for Flexible, Self-Directed, and Simple Web-Based Learning. Themes were integrated with Phase 1 findings and the six-domain framework.

Action: Development of Prototype V1

Prototype V1 was organized into five sequential learning steps that translated the six health literacy domains into web-based activities. Each step emphasized a primary competency while reinforcing related domains; media literacy was treated as cross-cutting.

Step 1, Accessing and screening information, introduced recommended sources, structured searching, and basic source screening.

Step 2, Understanding anemia, provided six concise learning modules with multimedia and short quizzes covering anemia-related knowledge relevant to prevention and self-care.
Step 3, Asking and communicating, used structured question formulation, AI-assisted information seeking, follow-up questioning, and appraisal of AI responses. AI functioned as a pedagogical scaffold, not a diagnostic tool.
Step 4, Making informed decisions, used scenarios requiring students to compare options and justify choices.
Step 5, Applying information through self-management, linked learning with personal planning, preventive practices, and appropriate use of health services.

Observation: Expert and Student Evaluation of Prototype V1

Expert Evaluation

Three purposively selected experts completed a 13-item researcher-developed quality form covering content (6 items), design (4) and utilization (3). Each item was classified as Very good, Pass or Needs improvement, with space for recommendations.
Expert review preceded student use. Font presentation and AI voice clarity were revised before the try-out. Smartphone-responsive problems remained unresolved, so students used iPads or notebook computers.

Student Try-out and User Evaluation

The 30-student try-out lasted eight weeks, including one week of orientation. Participants completed the 45-item health-literacy assessment before and after prototype use, a 29-item user-experience questionnaire with eight open-ended questions, and a separate 12-item satisfaction assessment. The relative administration timing of the user-experience and satisfaction assessments was not documented. Recruitment and CBC-based operational strata are described above.

Process-Related Participant Reflections

Open-ended responses addressed media accessibility and comprehensibility, engagement, learning process and time, perceived application of competencies, and barriers or facilitators. They represented participant-reported reflections rather than researcher-recorded behavioral observations.

Reflection: Integration of Evidence and Prototype Refinement

Reflection compared expert judgments and recommendations with student quantitative, qualitative and process-related evidence at the intervention-component level.
Components were Retained when relevant and supported; Modified when their purpose remained relevant but implementation required improvement; Added when an unmet need was identified; and Removed when redundant, infeasible, unsafe or misaligned.
No fixed quantitative cutoff determined decisions. Accuracy and safety were prioritized, followed by theoretical relevance and recurring concerns. The reflection matrix recorded decisions and implementation status.

Research Instruments and Content Validity

Four distinct instruments were used without combining their scores: a 13-item categorical expert form; a 29-item, five-domain student user-experience questionnaire with eight open-ended questions; a separate 12-item satisfaction measure; and a 45-item anemia-related health-literacy questionnaire. The latter drew conceptually on the Thai six-domain framework [21]: access (6 items), knowledge and understanding (15), communication (6), self-management (6), media literacy (6) and decision-making (6). Five six-item domains measured frequency from 1 (never/not performed) to 5 (every time). Knowledge responses were scored correct (1) or incorrect/unknown (0); items 3, 8 and 15 were keyed No and the others Yes. The knowledge total was multiplied by 5/15 to yield a 0–5 score. Three experts, separate from the prototype panel, reviewed this instrument, with investigator-confirmed item–objective congruence (IOC) values of 0.67–1.00. These values do not establish validity of the other instruments.
In the try-out, Cronbach's alpha for the student user-experience questionnaire was .88 overall (26 complete cases), and .48, .49, .78, .75 and .79 for comprehensibility, usability, acceptability, perceived usefulness and overall satisfaction, respectively. The small sample and short, heterogeneous domains limit precision. Comprehensibility and usability were retained only as exploratory descriptive indicators; their low alphas do not support strong reliability claims. Item-level and qualitative findings should be prioritized pending further psychometric evaluation.

Data Analysis

Expert categorical judgments were summarized as frequencies and proportions, without means or standard deviations because the three-member panel provided ordinal formative judgments.

Student ratings were summarized as means and standard deviations, interpreted as very high (4.21–5.00), high (3.41–4.20), moderate (2.61–3.40), low (1.81–2.60) or very low (1.00–1.80). Four items each had one missing response; available-case item denominators were 29–30, with no imputation. Overall alpha used 26 complete questionnaires. Domain scores remain descriptive because partial-response aggregation was incompletely documented. All 30 matched health-literacy pairs were complete. Exploratory paired Wilcoxon signed-rank tests compared pre–post scores in six domains, without multiplicity adjustment; these comparisons did not test causal effectiveness.

Expert recommendations and student responses underwent structured qualitative content analysis. Refinement feedback used Retain, Modify, Add and Remove categories; process reflections used accessibility/comprehensibility, engagement, learning process/time, emerging skills, and barriers/facilitators. Evidence was integrated at component level. Coder identities, independent coding and disagreement resolution were not documented. Health-literacy assessments were analyzed separately from module quizzes and perceived usefulness or acceptability ratings.

Ethical Considerations

Participation was voluntary and required written informed consent. Confidentiality was maintained, findings were aggregated, and students could withdraw without loss of benefits. AI activities supported educational questioning and appraisal, not diagnosis or individualized treatment. Institutional ethical approval is reported below.

Findings

Findings are presented according to the four PAOR stages: Planning, Action, Observation, and Reflection.

Planning: Student Needs and Intervention Design Requirements

Phase 1 included 280 students and identified anemia-knowledge gaps and variation across health literacy domains. Overall anemia-related knowledge was moderate (mean percentage score=72.64, SD=18.24). Lower correct-response proportions concerned anemia among individuals with alcohol use (54.64%), potential anemia severity (59.29%), hookworm-related iron-deficiency anemia (60.36%), and parasite-related risks from raw or inadequately prepared food or inadequately cleaned fresh vegetables (68.21%); higher proportions concerned fatigue, weakness, and pallor (87.50%) and iron supplementation in prevention (81.79%). Communication had the lowest frequency-based mean (M=3.29, SD=1.05), followed by access (M=3.66, SD=0.86); self-management, media literacy, and decision-making were higher (M=3.73-3.87). These findings supported strengthening foundational knowledge, communication, reliable-information access, and practical application.

Action: Prototype V1

Prototype V1 translated the six health literacy domains into five interconnected learning steps (Supplementary Figure S2). Media literacy reinforced information access, appraisal, decisions and application across steps.

Observation: Expert and Student Evaluation

Expert Evaluation

The three experts provided 39 item-level judgments: 30 Very good (76.9%), eight Pass (20.5%) and one Needs improvement (2.6%) (Table 1). These were 13 items × three experts, not 39 independent experts. All experts rated content and illustration appropriateness, color/background, usefulness for anemia understanding, target-group suitability and self-care application as Very good. The single Needs improvement judgment concerned font size/style and readability. Recommendations also addressed hematology accuracy, content layering, terminology, smartphone display and AI voice output.

Pre-try-out Refinement and Device Adaptation

Font presentation and AI voice clarity were refined before try-out. Smartphone optimization was deferred; subsequent usability findings apply to iPads and notebooks, not smartphones.

Student Quantitative Evaluation

Thirty students completed the formative user evaluation (Table 2). The same Phase 2 try-out group contributed the paired 45-item health-literacy data reported separately in Table 3.

The highest item ratings concerned navigation and improved anemia understanding (both M=4.90, SD=0.31). Quizzes were valued for checking understanding (M=4.87, SD=0.35), whereas

quiz/interactive usability was relatively lower (M=4.41, SD=0.57). AI usability and appropriateness items both averaged 4.40, identifying implementation needs despite favorable overall ratings.

Preliminary Health Literacy Changes During the Phase 2 Try-out

All 30 participants had matched pre–post records: 28 matched by email and two reconciled through administrator verification of system accounts. Mean scores increased across six domains (Table 3), with the largest descriptive change in communication (+1.13). Exploratory paired Wilcoxon tests yielded unadjusted $p < .01$ in every domain. These uncontrolled differences do not establish causation.

Student Qualitative Evaluation

Students valued quizzes, games, matching and end-of-lesson exercises for review and understanding, and scenarios for analysis and application. They generally favored retaining AI-assisted learning but reported restricted interaction, unclear responses, pronunciation, speed or technical instability. Requests included both more concise and more detailed content, additional multimedia, and self-assessment or risk-checking activities. Most opposed removing major components; isolated negative comments concerned AI voice output or passive flashcards.

Process-Related Findings from Student Reflections

Five themes emerged: Accessibility and Comprehensibility of Learning Media; Engagement and Active Participation; Appropriateness of the Learning Process and Time; Emerging Health Literacy Skills; and Barriers and Facilitators. Generally favorable accounts coexisted with requests to clarify terminology, allow flexible sequencing and resolve interface problems. Perceived gains in understanding, questioning, communication, self-care and decisions remained participant-reported process evidence, not objective effectiveness outcomes.

Reflection and Prototype V2

Expert and student evidence was integrated by component. Favorable overall ratings did not preclude refinement where item-level or qualitative findings identified concerns.

The five-step structure and all principal components were retained. Verified changes comprised font presentation and AI voice clarity before try-out, and correct-answer quiz feedback afterward. Smartphone optimization remained deferred. Content layering, terminology, multimedia and interaction recommendations were recorded for later development unless implementation was verified.

Prototype V2 was therefore an evidence-informed developmental refinement, not a demonstration of effectiveness.

Table 4 separates completed changes, recommendations and deferred work to avoid presenting proposed refinements as implemented.

The separate 12-item satisfaction measure yielded means (SD): content 4.76 (0.37), design 4.68 (0.44), utilization 4.87 (0.29), and overall 4.76 (0.33). These scores were not pooled with the 29-item user-experience results (overall 4.68, SD=0.23); relative assessment timing was undocumented.

Discussion

Principal Findings

This study developed and refined a web-based anemia-prevention health literacy model by linking empirical student needs, a six-domain framework, web-based learning activities, sequential expert and student evaluation, and structured reflection. Its principal contribution is an explicit pathway from needs and competencies to intervention components and evidence-informed refinement.

From Anemia Knowledge to Applied Health Literacy

Phase 1 communication and information-access findings, together with focus-group difficulty appraising sources and interpreting technical information, supported learning beyond factual knowledge. Structured searches, questioning, appraisal, scenarios and self-management translated those needs into activities. Phase 1 was a preceding assessment, not the baseline for the present try-out.

Web-Based and Interactive Learning

Student ratings suggest favorable preliminary user experience under iPad/notebook conditions, while exploratory pre–post HL scores provide a different, outcome-oriented signal from the same Phase 2 try-out. The largest descriptive change was in communication. Neither self-reported usability nor within-person change in an uncontrolled group demonstrates that the prototype caused the observed differences; repeated testing, maturation and other influences cannot be excluded.

AI as a Pedagogical Scaffold

The AI component was designed for question generation, follow-up inquiry, and critical appraisal, not diagnosis. Student comments about pronunciation, clarity, and interaction indicate that an educationally promising function can still present implementation barriers. The risk of misleading AI-generated health content [26] supports retaining verification and appraisal tasks as integral safeguards. AI voice clarity was adjusted before the try-out; further changes should be described as recommendations unless implementation is documented.

Contribution of the PAOR-Based Development Process

PAOR made development traceable: needs informed components, formative evaluation identified concerns, and reflection documented decisions [27]. Observation here comprised evaluation and participant reflections, not direct behavioral observation. The matrix distinguishes completed changes from unresolved work, clarifying what the developmental prototype actually delivered.

Strengths and Limitations

Strengths included a six-domain framework, needs assessment, sequential expert and student input, and matched exploratory assessments. Limitations were purposive single-site recruitment, 30 participants, no control group, an eight-week interval allowing testing or maturation effects, and six unadjusted comparisons. Low alphas (.48 and .49) constrain two user-experience subscales; high ratings and higher post-test scores cannot establish effectiveness.

Usability findings do not generalize to smartphones. Health-literacy assessments captured knowledge and self-reported frequency rather than observed preventive behavior. The uncontrolled design cannot separate prototype-associated change from other influences.

The three-member expert panel and uncertain psychometric stability further limit inference. Future studies should use larger controlled samples, objective behavioral outcomes, sustained follow-up and smartphone-specific testing.

Implications for Health Education and Health Promotion

The prototype offers a documented sequence for developing information access, appraisal, communication, decisions and self-management. Before wider use, unresolved content and interface recommendations require attention, followed by device-specific usability and controlled outcome evaluation. AI-assisted activities require source verification and transparent educational boundaries.

Conclusion

The PAOR process produced a refined web-based anemia-prevention health-literacy prototype informed by needs assessment, expert input, and a 30-student developmental try-out. User ratings indicated favorable preliminary acceptability, and exploratory matched pre–post assessments showed higher mean scores in all six health-literacy domains. These uncontrolled changes do not establish intervention effectiveness. Confirmed refinements included font presentation, AI voice clarity and quiz feedback; smartphone optimization remained deferred. Controlled evaluation and device-specific usability testing are needed.

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