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Enhancing Students' Health Literacy Through PBL-CMM: An Innovative Approach in High School Biology Education

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ABSTRACT

The enhancement of students' health literacy represents a pivotal element in preparing them to confront contemporary health challenges. Accordingly, this study evaluates the impact of a combined problem-based learning and collaborative mind mapping (pbl-cmm) framework on improving students' capacities for health literacy. Conducted with 110 senior high school students in Parepare, Indonesia, this quasi-experimental study employed a pretest–posttest non-equivalent control group design focused on the excretory and reproductive system topics in biology. Three groups were compared: PBL-CMM, PBL only, and conventional learning. Health literacy was measured through the Biology-Related Health Test (BRHT) and the Health Literacy Questionnaire (HLQ), which were developed based on four literacy dimensions: access, understand, appraise, and apply. The ANCOVA results revealed that students in the PBL-CMM group achieved significantly higher health literacy scores (corrected mean = 77.70) than those in the PBL (65.09) and conventional groups (56.20), p < .05. Similarly, the BRHT scores showed consistent patterns (PBL-CMM = 78.17; PBL = 70.26; Conventional = 65.95). The findings suggest that the PBL-CMM model is effective in fostering comprehensive health literacy through collaborative, problem-centered learning strategies. Future research is recommended to apply this model across diverse educational contexts, larger student populations, and different subject areas to examine its broader applicability and long-term impact on students' critical thinking and decision-making in health-related issues.

Keyword: Biology Education, Collaborative Mind Mapping, Health Literacy, Problem-based Learning

INTRODUCTION

Biology plays a central role in fostering students' scientific and health competencies that are essential for sustainable living in the 21st-century education context (Faradila et al., 2023). As a discipline that directly explores human body systems, disease prevention, and environmental health, biology serves as an appropriate subject for developing students' health literacy. The construct of health literacy encompasses an individual's intellectual and social proficiency in accessing, understanding, evaluating, and employing health information to support rational

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decision-making in self-management, preventive practices, and health advancement (Sørensen et al., 2012). This competence is vital for enabling students to think critically and reflectively about biological and health information encountered in everyday life (Ismayati et al., 2023; Pelikan et al., 2018). Strengthening health literacy through biology education aligns with the goals of 21st-century learning, which emphasize the integration of scientific knowledge, critical thinking, and responsible decision-making in addressing global health challenges (United Nations Educational, 2003).

The results of the first literacy survey in Indonesia in 2013-2014 identified that 64% of 1,029 respondents showed inadequate health literacy levels. Among them, 72% were in the 15-18 age group (Nurjanah et al., 2017). This age group corresponds directly to senior high school students, the primary target population of this study. Such findings highlight a critical need to strengthen health literacy through formal education, particularly in biology learning contexts that address health-related topics and decision-making.According to a 2021 survey by the Ministry of Communication and Informatics on the intensity of internet use to access healthcare information, 71% of 10,000 respondents from 34 provinces in Indonesia had never accessed the internet to seek health information (Hartono et al., 2021). According to The Legatum Prosperity Index 2023, Indonesia ranks 87th out of 167 countries. The global health literacy deficit during the COVID-19 pandemic highlights the need for the development of individual health literacy (Okan et al., 2021; Syah et al., 2020). The results of a Systematic Literature Review (SLR) also indicate that research on health literacy in education has been relatively underexplored by researchers over the past two years (Salim et al., 2024).

Despite the recognized importance of health literacy in promoting informed health behaviors, research on health literacy within the educational context, particularly in biology learning remains relatively limited in Indonesia (Salim et al., 2024). Previous studies have primarily focused on measuring general literacy levels or assessing health literacy in clinical and public health domains, leaving a gap in understanding how it can be effectively cultivated through classroom instruction (Inten & Permatasari, 2019). This lack of empirical evidence underscores the need for pedagogical innovation in biology education that explicitly integrates health literacy development. In this regard, Problem-Based Learning (PBL) has been identified as one of the most effective instructional models in health education, as it actively engages students in analyzing real-world problems, constructing knowledge, and making evidence-based decisions related to health issues (Suwono et al., 2017). Therefore, integrating PBL into biology learning offers a promising pathway to enhance students' multidimensional health literacy competencies (Durham et al., 2020).

Although PBL has been widely recognized for its potential to promote critical thinking and problem-solving, its implementation often encounters challenges. Students who are accustomed to teacher-centered instruction may struggle with independent inquiry, reduced motivation, and difficulty in organizing complex information during the learning process (Wulandari & Surjono, 2013). These limitations can be effectively addressed through the integration of Collaborative Mind Mapping (CMM), a digital and interactive tool that supports synchronous collaboration, visualization of ideas, and collective knowledge construction (Cendros Araujo & Gadanidis, 2020). The collaborative features of CMM foster peer interaction and shared responsibility, while its visual mapping structure helps students organize, connect, and internalize biological concepts more systematically. By combining PBL's problem-centered approach with CMM's collaborative visualization, students are expected to achieve deeper engagement and enhanced understanding of health-related biological concepts . The objective of this study is to examine the effectiveness of the integrated Problem-Based Learning and Collaborative Mind Mapping (PBL-CMM) model in improving students' health literacy in high school biology education. Specifically, the study hypothesizes that students taught using the PBL-CMM model will demonstrate significantly higher levels of health literacy compared to those taught using PBL alone and conventional learning methods.

METHODS

Research Design

This research employed a quantitative approach using a quasi-experiment design. The independent variables are the PBL-CMM method, PBL, and conventional teaching method, while the dependent variable is students' health literacy. The design used is a pretest-posttest non-equivalent control group design as shown in Table 1. A non-equivalent control group design was selected because the study was conducted in an authentic school setting where random assignment of students to different classes was not feasible due to administrative and scheduling constraints. Each participating class was pre-established by the school and maintained its original composition to ensure minimal disruption to regular teaching schedules. Therefore, the assignment of classes to the PBL-CMM, PBL, and conventional groups was based on school readiness and coordination with the respective biology teachers. This design choice aligns with the principles of quasi-experimental research, which aims to maintain ecological validity while allowing controlled comparison across naturally formed groups.

Table 1. Research Design

Pre-test	Treatment	Post-test
O_1	X_1	O_2
O_3	X_2	O_4
O_5	X_3	O_6

Notes:

O_1, O_3, and O_5	= Pretest on students' health literacy
O_2, O_4, and O_6	= Posttest on students' health literacy
X_1	= Experimental group (PBL-CMM)
X_2	= Postive control group (PBL)
X_3	= Negative control group (Conventional teaching)

Research Population and Sample

The study population comprised all Grade XI Science Program students from a senior high school in Parepare, South Sulawesi, Indonesia. The research encompassed three participating classes, each assigned distinct instructional conditions: the experimental class employed the integrated PBL-CMM model, the positive control class adopted the PBL framework, and the negative control class utilized traditional learning methods. The total sample consisted of 110 students from three pre-existing Grade XI science classes at a public senior high school in Parepare, South Sulawesi, Indonesia (Table 2). The PBL-CMM experimental group included 36 students, the PBL comparison group consisted of 37 students, and the conventional control group comprised 37 students. The allocation of classes to each treatment condition was determined in coordination with the school administration to maintain regular class schedules. Before the intervention, all groups were administered a pretest to assess baseline equivalence in health literacy levels.

Tabel 2. Demographic Characteristics of Participants

Variable	Category	(n)	(%)
Total Participants		**110**	**100.0**
Gender	Male	46	41.8
	Female	64	58.2
Age (years)	16	28	25.5
	17	66	60.0
	18	16	14.5
Class Group	PBL–CMM Experimental Group	36	32.7
	PBL Comparison Group	37	33.6
	Conventional Control Group	37	33.6
Prior Academic Achievement *(GPA equivalent)*	High (≥85)	34	30.9
	Medium (70–84)	61	55.5
	Low (<70)	15	13.6

Research Procedures

The stages of the PBL-CMM method were carried out in this research. Students were given worksheets on the excretory system and the reproductive system materials that had been adjusted to stages of the PBL-CMM method at the beginning of the lesson, as shown in Table 3. The intervention was conducted over six weeks, consisting of twelve class meetings (two sessions per week), with each session lasting approximately 90 minutes. During this period, all groups PBL-CMM, PBL, and conventional, were taught the same biology topics, namely the excretory and reproductive systems, using the respective instructional models. The duration and frequency of instruction were kept consistent across all groups to ensure comparability of treatment exposure.

Table 3. PBL-CMM Activities

Stages	Activities
Orient students to the problem	Student orientation towards problems to foster motivation in learning activities. The problems can be presented by either the students or the teacher.
Organize students for study-CMM	Students are organized into groups to formulate the given problem and then design a learning task in the form of a mind map using the Gitmind application, related to the problem.
Assist independent and group investigation CMM	Formulating hypotheses related to the problem and gathering information from literature. Alternative solutions from group discussions are visualized as a mind map.
Develop and present artifacts-CMM	Developing and presenting solutions to the problem in the form of a collaborative mind

	map.
Analyze and evaluate the problem-CMM	Students analyze the problem-solving process they have done and reflect/evaluate their investigation. Improvements are also applied to the mind map that was previously presented. Students reanalyze the branches of the mind map they have worked on.

Instruments

Assessment is conducted using a Biology-Related Health Test (BRHT) and a Health Literacy Questionnaire (HLQ). The BRHT comprises a written assessment in essay form containing 8 items derived from biological knowledge indicators pertaining to health concepts. meanwhile, the Health Literacy Questionnaire (HLQ) serves as an instrument for evaluating literacy competence and is structured as a multiple-response survey encompassing 12 items. This instrument encompasses a framework consisting of four dimensions of health literacy, namely the abilities to access, comprehend, evaluate, and utilize pertinent health information within three contextual domains: healthcare, disease prevention, and health promotion. The test is developed based on the framework proposed by Sørensen et al., (2012). The validity of the BRHT and HLQ items was tested using the Pearson product-moment correlation test. A total of 8 BRHT items and 12 HLQ items were considered valid, while the Cronbach's alpha reliability test showed that all instrument items were reliable, with a reliability score of 0.635 for BRHT and 0.919 for HLQ. The reliability of the Biology-Related Health Test (BRHT) and the Health Literacy Questionnaire (HLQ) was examined using Cronbach's alpha. The BRHT obtained a reliability coefficient of 0.635, while the HLQ showed a higher reliability of 0.919. An alpha coefficient above 0.60 is considered acceptable for exploratory research or studies involving cognitive test items with diverse constructs. Given that the BRHT consisted of open-ended essay items assessing analytical reasoning rather than homogenous factual recall, a moderate reliability score is deemed acceptable and still indicates internal consistency. In contrast, the HLQ's high reliability reflects strong internal coherence across its items, measuring four dimensions of health literacy. Therefore, both instruments were considered sufficiently reliable for use in this quasi-experimental study.
The indicators within the health literacy scale were generated following four underlying dimensions illustrated in Table 4.

Table 4. Health Literacy Dimensions

No	Dimension	Description
1	*Access*	Obtain/access relevant health information
2	*Understand*	Understanding relevant health information
3	*Appraise*	Processing/assessing relevant health information
4	*Apply*	Applying/using relevant health information

Data Collection and Data Analysis

Inferential statistical techniques were employed to analyze the research data, with ANCOVA applied to assess the impact of the intervention on students' health literacy at the 5% significance level. Subsequent to the ancova, the Least Significant Difference (LSD) test was administered to further delineate group differences..

RESULTS AND DISCUSSION

Results

The assumption testing outcomes summarized in table 4 demonstrated that the p-values associated with normality and homogeneity were above the 0.05 threshold, implying that the data satisfied the criteria for normal distribution and variance uniformity. furthermore, table 5 outlines the analytical results of the one-way ancova pertaining to students' health literacy levels.

Table 5. Results of Homogeneity and Normality Test of Data Distribution

Instrument	Test	N	P	α	Data distribution
Biology-Related Health Test (BRHT)	Pretest	110	0.158	0.05	Normal
	Posttest	110	0.158	0.05	Normal
	Posttest	110	0.521	0.05	Homogeneous
Health Literacy Questionnaire (HLQ)	Pretest	110	0.200	0.05	Normal
	Posttest	100	0.200	0.05	Normal
	Posttest	100	0.710	0.05	Homogeneous

The hypothesis test was conducted to analyze the effect of the PBL-CMM, PBL, and Conventional models on students' health literacy. The health literacy instruments used consisted of two, namely the Biology Related Health Test (BRHT) and the Health Literacy Questionnaire (HLQ). The results of the ANCOVA analysis on BRHT and HLQ show that the learning models obtained a significance value of 0.000, which is smaller than the alpha value of 0.05 (p-value < α). This significant result means that H1 is accepted and it is concluded that there is an effect of the learning models (PBL-CMM, PBL, and Conventional) on the improvement of BRHT. A summary of the ANCOVA analysis of BRHT and HLQ health literacy can be found in Table 6 and Table 7.

Table 6. Results of One-Way ANCOVA Test on Biology-Related Health Test (BRHT)

Source	***SS***	***df***	***MS***	***F***	***p***
Corrected Model	2831.165[a]	3	943.722	26.326	.000
Intercept	16305.159	1	16305.159	454.841	.000
Pretest	34.979	1	34.979	.976	.326
Model	2808.416	2	1404.208	39.171	.000
Error	3764.048	105	35.848		
Total	564112.208	109			
Corrected Total	6595.212	108			

Table 7. Results of One-Way ANCOVA Test on Health Literacy Questionnaire (HLQ)

Source	*SS*	*df*	*MS*	*F*	*p*
Corrected Model	8584.088[a]	3	2861.363	87.161	.000
Intercept	12046.933	1	12046.933	366.966	.000
NilaiPretest	52.774	1	52.774	1.608	.208
Model	8351.392	2	4175.696	127.197	.000
Error	3446.992	105	32.828		
Total	493155.012	109			
Corrected Total	12031.080	108			

Tables 6 and 7 show that the F value for the model was 39.171 for BRHT and 121.197 for HLQ, with a significance value of 0.000 (P-value indicating that there is a difference in health literacy among students taught with the PBL-CMM learning model, the PBL model, and conventional learning). The corrected means and the results of the LSD test for students' health literacy in each learning model used in the study are presented in Tables 8 and 9.

Table 8. Corrected Mean and LSD Test Results of Biology-Related Health Test (BRHT) for Students in Each Learning Model

Learning Model	**Mean**	**LSD Notation**
PBL-CMM	78.166	a
PBL	70.256	b
Conventional	65.947	c

Table 9. Corrected Mean and LSD Test Results of Health Literacy Questionnaire (HLQ) for Students in Each Learning Model

Learning Model	**Mean**	**LSD Notation**
PBL-CMM	77.703	a
PBL	65.093	b
Convensional	56.203	c

Based on the results summarized in tables 8 and 9, variations exist in the adjusted mean health literacy scores among the learning models. The PBL-CMM model achieved higher corrected mean values (BRHT = 78.166; HLQ = 77.703) than the PBL and conventional models. the LSD analysis supports the conclusion that the PBL-CMM model significantly outperforms both the PBL and conventional approaches, while the PBL model also exhibits a meaningful advantage over conventional instruction.

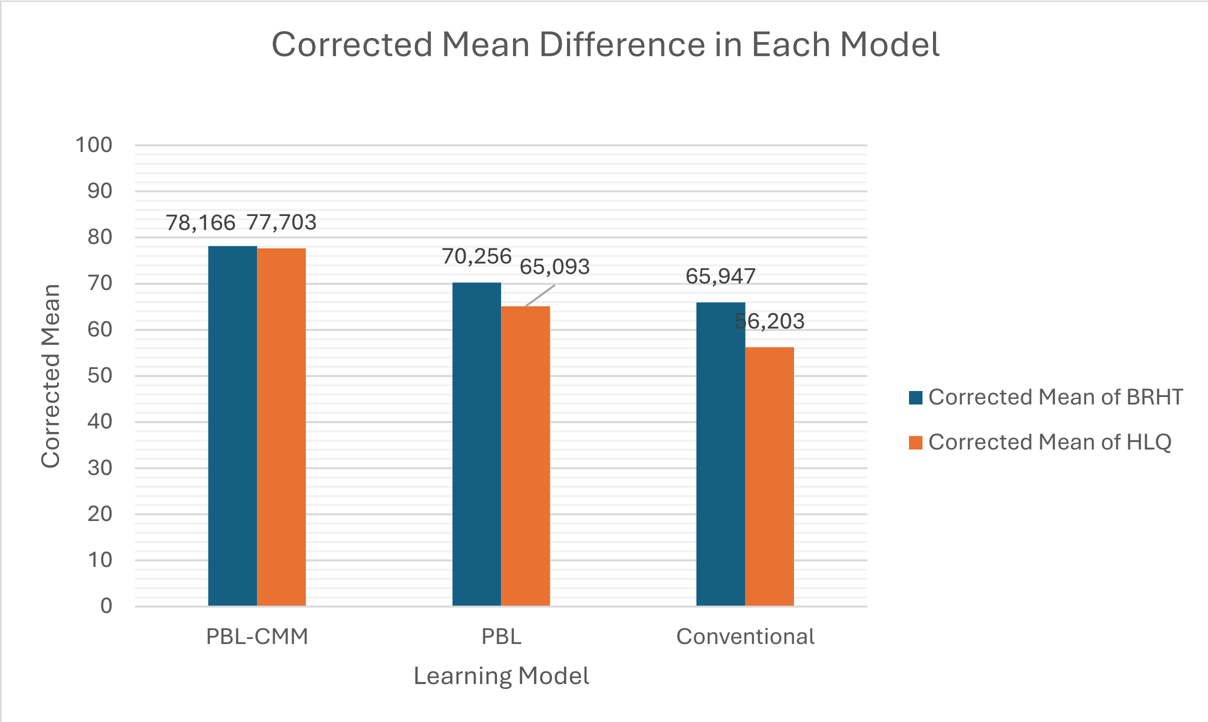

Figure 1. Corrected Mean Difference in Each Model

Discussion

Health literacy can be measured using two types of instruments, namely the cognitive test / Biology Related Health Test (BRHT) and the questionnaire/Health Literacy Questionnaire (HLQ). The ANCOVA results confirmed that students in the PBL-CMM group achieved the highest corrected mean scores for both instruments (BRHT = 78.17; HLQ = 77.70), outperforming the PBL group (BRHT = 70.26; HLQ = 65.09) and the conventional lecture–discussion group (BRHT = 65.95; HLQ = 56.20). These results demonstrate that integrating Collaborative Mind Mapping into Problem-Based Learning significantly enhances students' overall health literacy in high school biology. The conventional learning applied is the method often used by teachers, which is the lecture-discussion method.

Orient students to the problem

The stages of the PBL-CMM model are based on various learning theories that support the creation of meaningful and effective learning experiences. PBL-CMM consists of five learning steps. The first learning step begins with introducing students to real-life problems at the start of the lesson. This step supports students in developing the process of analyzing problems that occur around them. Problem-solving, according to Gestalt theory, helps students develop the knowledge necessary to find innovative solutions (Vitello & Salvi, 2023). This activity starts by orienting students to the problem in order to foster motivation for learning activities (Schunk, 2012). The problem can be presented by either the students or the teacher (Anwar & Jurotun, 2019). The problem provided in the PBL class serves to identify the gaps in students' knowledge. This first activity acts as a guide to achieving the goals and understanding the material more deeply (Barrows, 1996). The problem will help students focus on integrating information from various disciplines. The ability to search for health information from credible sources trains students to understand biological concepts relevant to real-world situations (Bouclaous et al., 2023). This activity of acquiring health information guides students to process the information they obtain (1st Dimension). Students will be able to take actions related to the health of their environment based on the information they have gathered, as having health literacy also means maintaining the health of oneself, family, and community (Freedman et al., 2009; McQueen et al., 2007).

Organize students for study-CMM

The second step, Organize Student for Study, is integrated with CMM. In this stage, students are organized into groups to formulate the given problem and then design a learning task in the form of a mind map using the Gitmind application, related to the problem. Knowledge is manifested as students search for references related to the problem that has been formulated. The process of exploring and organizing knowledge in groups is useful for developing ideas or solutions by reading various references (Bao et al., 2009; Daryanti et al., 2015). The learning objectives pertaining to the excretory and reproductive system materials possess essential value and contextual applicability, enabling students to understand health information as they cover topics related to diseases and health (2nd Dimension). The development of health literacy in students not only effectively enhances their understanding of health information but also helps students become responsive to complex health issues (Budhathoki et al., 2019). In this stage, students also create a mind map collaboratively. The formulated problem is placed at the center of CMM, where group members, as collaborators, can contribute various perspectives that develop during the learning process, leading to the desired outcomes from solving the problem (Wei et al., 2020). The use of PBL with mind mapping stimulates students' critical thinking because it involves the process of analyzing various pieces of information gathered, which are then constructed into knowledge by writing down key points from the material (Hidayati et al., 2020).

Assist independent and group investigation CMM

The third step, Assist independent and group investigation, guides students to formulate hypotheses related to the problem formulation and search for information from various literature studies. The information gathered can be obtained through participation in discussions and involvement in investigative activities, not only from teacher explanations or readings (Blachowicz & Ogle, 2008). This stage also directs students toward the ability to assess health information (3rd Dimension). This dimension is related to the group discussions conducted by students to search, investigate, think, analyze, examine, and utilize the knowledge necessary to develop ideas in finding solutions to health problems (Zannan Alghamdy, 2023; Zhao et al., 2020). In this activity, alternative solutions generated from group discussions are visualized in the form of a mind map. Each group member can systematically view the solution deemed most appropriate as the group’s choice (Widiana & Jampel, 2016). Previous research has revealed that CMM is very flexible, facilitates the simplification of complex information, and is effective in explaining and linking key ideas to solve specific problems (Fung & Liang, 2023; Strickland, 2009).

Develop and Present Artifacts-CMM

The fourth procedural phase, referred to as develop and present artifacts, entails students’ formulation and presentation of problem-solving outcomes materialized as artifacts. (Yennita & Zukmadini, 2021). The success of students in the fourth stage empowers them to enhance their health literacy skills in the fourth dimension, which is applying relevant health information. Through this syntax, students not only become proficient in presenting solutions or making decisions regarding health issues but also develop the ability to promote and support health (4^{th} dimension) (Osborne et al., 2013; Rababah et al., 2019). The outcome of this stage is a collaborative mind map. In presenting their work, students are expected to demonstrate active participation and effective communication when presenting the results of their discussions, as well as receiving feedback, comments, suggestions, or appreciation from other groups (Prasetyo & Kristin, 2020). CMM is used to present the discussion results in a more engaging way. CMM can help facilitate discussions to build scientific knowledge within the group and support the negotiation process to reach a consensus on the topic (Marriott & Torres, 2008). Prior research has indicated that the collaborative development of mind maps fosters students' cognitive flexibility and systematic reasoning, with the structured mental framework contributing to more effective problem resolution (Badriah et al., 2023; Susilawati et al., 2017).

Analyze and Evaluate the Problem-CMM

The fifth step is to analyze and evaluate the problem. In this final stage, students conduct an analysis of the problem-solving process that has been carried out and reflect/evaluate their investigation (Arends, 2012). This final step aims to prevent misunderstandings of the concepts that students have acquired (Maryati & Monica, 2021). The review process is considered an important part of problem-solving because it can be used to evaluate the accuracy of the strategies used and deepen students' understanding of the material (Foster et al., 2018). In this last stage, students continue their mind map with an in-depth analysis of the information they have gathered and the solutions they have developed (Cendros Araujo & Gadanidis, 2020; Harasim, 2017). This stage focuses on the analysis and evaluation of the information that has been collected and the solutions that have been developed. By reviewing data accuracy, identifying misconceptions, and assessing the effectiveness of proposed solutions, students develop the ability to interpret, judge, and apply scientific information for making informed health decisions (3^{rd} dimension). Students must assess whether the information they used is accurate, relevant, and effective in solving the problem at hand (Hardianto et al., 2024). Processing information means reviewing the data, identifying weaknesses or gaps in the approach used, and considering alternatives or improvements to the solution (Somers et al., 2014; Zheng et al., 2020).

The superiority of PBL-CMM over PBL alone and conventional lecture discussion learning stems from its combination of problem-centered inquiry and technology-mediated collaboration. While PBL engages students in reasoning through problems, it often suffers from reduced motivation and fragmented knowledge construction when conducted without structured visualization tools (Arends, 2012). CMM mitigates these limitations by promoting shared cognitive engagement, visual coherence, and sustained interaction among learners. The integration of CMM therefore transforms traditional PBL into a more interactive, student-driven, and conceptually integrated learning experience, one that aligns with the demands of 21st-century science education, emphasizing digital literacy, collaboration, and critical health reasoning.

CONCLUSION

This study concludes that the PBL-CMM learning model significantly improves students' health literacy, as reflected in both cognitive understanding and the ability to apply health information. The convergence of PBL and Collaborative Mind Mapping (CMM) engenders a participatory and cognitively rich learning atmosphere, which enhances learners' abilities to obtain, interpret, and operationalize knowledge pertaining to health. Compared to PBL alone and conventional learning methods, the PBL-CMM approach offers a more effective framework for developing health literacy in secondary education. Therefore, the PBL-CMM model can be recommended as an innovative pedagogical strategy in biology education to address health-related learning outcomes. However, this study has several limitations. The study sample, restricted to participants from a single urban area and limited to the senior high school level, may constrain the external validity and generalizability of the results across diverse educational contexts. In addition, the duration of the intervention was relatively short, making it difficult to capture the long-term sustainability of students' health literacy improvement. Future research is recommended to replicate this study with larger and more diverse student populations across different regions and educational levels. Longitudinal studies would also be valuable to examine the persistence of health literacy gains over time. Furthermore, integrating qualitative approaches such as classroom observations and student interviews could provide deeper insights into the learning processes and factors influencing the effectiveness of the PBL-CMM model.

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