Australian Journal of Teacher Education

Volume 50 | Issue 2 Article 2

2025

Raising Information Literacy of Biology Pre-service Teachers: Study on Three Problem Solving Methods

Muhammad Saefi
Universitas Islam Negeri Maulana Malik Ibrahim Malang, Indonesia

Hadi Suwono
Universitas Negeri Malang, Indonesia

Rifka Fachrunnisa
Universitas Negeri Malang, Indonesia

Widi Cahya Adi
Universitas Islam Negeri Walisongo Semarang, Indonesia

Herawati Susilo
Universitas Negeri Malang, Indonesia

Ahmad Kamal Sudrajat
Universitas Negeri Yogyakarta, Indonesia

Recommended Citation

Saefi, M., Suwono, H., Fachrunnisa, R., Adi, W. C., Susilo, H., & Sudrajat, A. K. (2025). Raising Information Literacy of Biology Pre-service Teachers: Study on Three Problem Solving Methods. *Australian Journal of Teacher Education, 50*(2). https://doi.org/10.14221/1835-517X.6442

Raising Information Literacy of Biology Pre-Service Teachers: Study on Three Problem Solving Methods

Muhammad Saefi
Biology Study Program, Faculty of Science and Technology, Universitas Islam Negeri Maulana Malik Ibrahim Malang, Indonesia
Hadi Suwono
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia
Center of Research and Innovation on STEM Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia
Rifka Fachrunnisa
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia
Widi Cahya Adi
Biology Education Study Program, Faculty of Science and Technology, Universitas Islam Negeri Walisongo Semarang, Indonesia
Herawati Susilo
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia
Ahmad Kamal Sudrajat
Department of Biology Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Indonesia

Abstract: Integrating information literacy teaching methods with subject-content curricula to develop prospective biology teacher students' abilities is still problematic. This quasi-experimental research, with a nonrandomized pretest-posttest control group design, intends to compare the influences of challenge-based learning (CBL), problem-based learning (PBL), and problem-solving through classroom discussion (PCD) – as the control- in improving information literacy. This study involved 183 students from three classes of freshmen and three sophomores in the biology education program. The results showed that CBL significantly improved students' information literacy compared to PBL and PCD across five indicators: 1) identifying the required information, 2) attaining the required information effectively and efficiently, 3) critically evaluating information and its sources, 4) effectively using the information to achieve goals, and 5) considering the ethical and legal aspects of information use. This work has revealed that CBL needs to be developed intensively in higher education to prompt students' information literacy.

Keywords: information literacy; problem-based learning; prospective biology teacher.

Introduction

Information literacy is the capacity to search, find, access, evaluate, and use information legally and ethically (Saunders et al., 2017). Information literacy is the prime goal of education to prepare individuals for lifelong learning (Atikuzzaman & Ahmed, 2023; Feng & Ha, 2016; Rieh et al., 2022; Solmaz, 2017). The global generation needs information literacy as the basic foundation for decision-making and problem-solving in everyday life (Guerola-Navarro et al., 2023; Kopp et al., 2012). Information literacy through the discovery, reading, and interpretation of scientific literature is important for biology students at universities with plans for further postgraduate study, teaching/becoming teachers, or filling professional positions in various industries (Porter, 2005). Information literacy is needed to become a professional with good leadership qualities (Klebansky & Fraser, 2013; Machin-Mastromatteo & Lau, 2015; Virkus & Mandre, 2015).

Teaching information literacy schooling is generally still limited through the librarians, for example through library-based research programs (Fernández-Ramos, 2019; Lwoga, 2013; Rath, 2022), library orientation (Jabeen et al., 2014), training using web-scale discovery tools (Dulle & Alphonce, 2016). Information literacy is also developed through credit-bearing research methods classes administered by library instructors (Scott, 2017). Another researcher developed the IDEA framework (Interview, Design, Embedding, Assessment), a systematic, library-specific approach for integrating information literacy instruction and resources into academic courses (Mullins, 2014).

Nevertheless, the outcomes of information literacy improvement programs conducted by librarians still do not guarantee high levels of information literacy performance (Harrison & Deans, 2021). Many studies show that students lack the necessary skills to find and use information effectively (Ilogho & Nkiko, 2014; Lewis & Mallaiah, 2014; Tachie-Donkor & Ezema, 2023). Students do not pay enough attention to the validity and credibility of information used in academic activities (Klemenčič & Chirikov, 2015; Kriscautzky & Ferreiro, 2014). The impact of students' low information literacy is that it is difficult to understand the meaning of the information contained in articles for academic purposes (Lim et al., 2022), resulting in a tendency to produce academic papers by copying (Malliari et al., 2014). In science education, failure to grasp information literacy skills leads to frustration during mastering the scientific process skill (Klucevsek, 2017).

In the information age, teachers are the front line in preparing students to become an information-literate global generation (Laretive, 2019). Students who plan to become teachers must be able to teach information literacy skills to their students effectively (Wu et al., 2022). Teachers with information literacy have demonstrated significant positive impacts on the instructional processes of information (Hammons, 2020). Preservice teachers need information literacy not only from a micro perspective to achieve their undergraduate academic degree and their lives but also from a macro perspective to prepare and understand the importance of their future profession as teachers who play an important role in preparing an information-literate society (Karamustafaoğlu et al., 2013; Tarango et al., 2017). Several research studies on the impact of information literacy on prospective teacher students have shown poor results. The results of information literacy research conducted Karamustafaoğlu et al. (2013) and Fry & Seely (2011) and information literacy self-efficacy by Adaher & Serin (2012) show that the ability of preservice teachers is still classified at the intermediate level, even two-thirds of students have not been able to identify relevant journal articles. The study results show that developing information literacy for preservice teachers is still necessary.

Information literacy education can be implemented by integrating information literacy skills into subject-specific courses (Chang, 2012). Teaching using logical, progressive,

content-oriented approach to information literacy instructions in biology science courses provide valuable experiences for students in the process and the production of scientific tasks. Gross et al. (2016) explored the possibilities of teaching information literacy skills to mathematics major students who enrolled in written courses and completed their undergraduate studies. Hulseberg & Versluis (2017) enhanced the information literacy of undergraduate students who were integrated into the geography research methods course research activities. They utilize an integrated platform where instructors offer feedback on students' work, and librarians facilitate activities related to information literacy, including keyword searches, citing referenced sources, and others. This reinforces the importance of instructions that encourage active information search (Loo et al., 2016) and problem-solving (Argelagós et al., 2022; Shultz & Li, 2016) to help students improve information literacy. In any case, teaching methods that can effectively increase the information literacy of prospective teachers still need to be examined. This study aims to compare the influence of collaborative problem-solving teaching methods and information seeking on improving the information literacy of students aspiring to become biology teachers.

Literature Review

Information Literacy

Information literacy is the capacity to search, find, access, evaluate, and use information legally and ethically (Saunders et al., 2017). Information literacy is an intellectual framework for understanding, finding, evaluating and using information (Podgornik et al., 2017). Information literacy education aims to develop students' ability to find, evaluate, use, and create information effectively (Association of College & Research Libraries, 2000). Information literacy is not only a skill to find and access information but also involves high-level thinking competencies on evaluating, interpreting, and using information (Lau, 2006; Liu, 2023). In scientific disciplines, information literacy includes reading, understanding and analyzing a phenomenon appropriately, making judgments and communicating the results by obtaining perspectives and outlooks based on scientific information (Miller et al., 2023). Students will utilize important information, rather than simply memorizing facts, to build a strong foundation for argumentation through active inquiry and reasoning in solving problems. Information literacy is fundamental for developing problem-solving abilities (Willer & Eisenberg, 2014).

Information literacy in the first and second years is interesting to study, especially in the context of prospective teachers. They are transitioning from high school to higher education, where they must utilize information independently (Valenza et al., 2022; Zhang, 2021). Information literacy skills are very important for prospective teachers, considering their role in the future as learning facilitators who must be able to identify, evaluate, and use information sources effectively (Shannon et al., 2019).

Existing research focuses on information literacy in the first year (Hebert, 2018; Lupton, 2008; Öncül, 2021; Yager et al., 2013). Some studies compare information literacy between generations, but most compare years 1 and 4 (Wickramasinghe & Seneviratne, 2021). In other words, information literacy is widely explored between juniors and seniors. There has been no comprehensive study comparing years with thinner ranges or peers. This study provides insight into whether there is a significant increase in just one year of study in college.

Teaching Information Literacy in the Problem-solving Process

Integrating information literacy into subject-content teaching can improve university students' information literacy (Burkhardt, 2007; Dawes, 2017). Dawes (2017) proposed a teaching model concept that integrates information literacy with subject content. It emphasizes teaching students how to find and use relevant information sources, evaluate the credibility and relevance of information, and effectively utilize it in scientific communication.

In recent years, problem-based teaching methods have been commonly applied in university learning processes and have become popular in educational research (Anggraeni et al., 2023). Through problem-solving strategies, students can ask questions, gather information, discuss their findings, and share their conclusions (Chiang, 2017; Syahrin, 2021). In problem-based instruction, students seek information relating to existing problems and consequently put information literacy into practice during learning processes (Shultz & Li, 2016). Three prominent problem-based teaching methods are challenge-based learning (CBL), and problem-solving through classroom discussion (PCD).

PBL is a student-centered teaching method that uses authentic issues to help students demonstrate their ability to identify their information needs and solve problems. PBL is guided by several core principles, including building a broad and adaptable knowledge base, enhancing effective problem-solving abilities, fostering self-directed lifelong learning skills, becoming proficient collaborators, and cultivating intrinsic motivation for learning (Hmelo-Silver, 2004). This process, in turn, can lead to developing their information literacy (Diekema et al., 2011). Information literacy skills, when enhanced, are valuable in motivating students to seek and utilize information from diverse resources necessary for problem-solving. These skills are key to successfully applying PBL in the classroom (Diekema et al., 2011). Students engaged in PBL have opprotunity to actively access information relating to database searches actively, leading to better information literacy improvements compared to the outcome of lecture-based learning methods (Dolničar et al., 2017). PBL provides situations where students come into contact with different perspectives on certain issues and problems. University students must motivate themselves to seek information and its sources to become critical of relevant issues and problems, leading to the development of information literacy (Tachie-Donkor & Ezema, 2023).

Hines & Hines (2012) discovered that PBL increases students' engagement with library sources and provides the mechanisms to identify and correct students' lack of knowledge and information literacy skills. PBL encourages students to use skills to get credible information (Ghani et al., 2021) by allowing them to explore and use information independently (Cebert, Patrick, Cragnoloni, Smith, 2011). PBL is considered the appropriate method for learning information literacy (Greenwell, 2013; Santharooban & Premadasa, 2015; Wenger, 2014). PBL provides a way to naturally integrate information literacy into a task by guiding students through research to find solutions for a problem (Shultz & Li, 2016).

Challenge-Based Learning (CBL) is a multidisciplinary approach that encourages students to work collaboratively and use technology to solve real-world problems in the context of their school, family, or local community (Johnson & Adams, 2011). CBL is a learning process developed from problem-based learning (PBL) (Johnson & Adams, 2011), which has many advantages over PBL, especially in relation to life, decision-making process/solution, and integration with technology. CBL is a teaching method designed to improve information literacy (Hess, 2015; Leijon et al., 2022). CBL teaching encourages students to become accustomed to solving relevant and complex problems through collaborative processes and information seeking (Malmqvist et al., 2015). CBL can increase the motivation to seek information, an important predictor of information literacy (Ross et al.,

2016; Swiden, 2013). Strong collaborations during CBL allow students to conduct information exchange activities (Johnson & Adams, 2011). CBL also has the characteristic of directing students to use information and aiding students' understanding of relevant concepts (Bruce & Hughes, 2010). In knowledge acquisition aspect, the study showed that students who studied using CBL and traditional methods obtained equivalent amounts of knowledge, but CBL students demonstrated greater improvements in thinking abilities (Leijon et al., 2022; López-Fernández et al., 2020).

PCD is a problem-solving method through collaborative discussions (Del Favero et al., 2007). Discussions in PCD focus on exploring explicit understanding and negotiating multiple perspectives to determine the right decision (Lindahl & Folkesson, 2015). Discussions allow students to interact verbally and develop high-level thinking skills that enable students to interpret, analyze and manipulate information (Abdulbaki et al., 2018). Discussions develop critical thinking and problem-solving skills (Short et al., 2020). Discussions give students the opportunity to share information (Athanases et al., 2020). Discussions increase the number of student interactions and a reduction in the number of teacher involvements, increased understanding of text and literacy, as well as improving inference abilities, critical thinking, and reasoning abilities (Murphy et al., 2009).

Currently, the scope of the topic discussions has been experiencing progress, for example using socio-scientific issues to bridge school knowledge and everyday knowledge (Åkerblom & Lindahl, 2017). Research has shown that teacher-led classroom discussions, in addition to developing students' content understanding abilities, are also important to improve the quality of students' argumentation skills (Lindahl & Folkesson, 2015). Through PCD, teachers can assess the validity of student scientific materials, as well as be able to assess their argumentative legitimacy in a dialectical context (Nilsen, 2012). Williams & Clement (2015) has shown that dialogical methods can engage students to effectively communicate their scientific ideas in the classroom. Regardless, there are insufficient accounts on the validity of PCD effectiveness in increasing information literacy. Although the three collaborative methods are intended to prompt students' problem-solving through seeking information, they have some distinct dimensions that conceivably impact the effectiveness to help students foster their information literacy. Based on the study presented above, these distinct dimensions have been demonstrated in Table 1.

Dimension	PBL	CBL	PCD
Knowledge	Interdisciplinary	Interdisciplinary	Monodisciplinary
Working practice	Collaborative	Collaborative	Collaborative
Administrator	Expected outcomes	Student designed	Expected outcomes
Driver	Problem Orientation	Authentic Real-world	Conceptual Orientation
Teacher	Professional guide	Coach and co-researcher	Professional guide
Question	Somewhat scripted	Open Ended	Scripted
Orientation	Context-orientated	Action-orientated	Concept-orientated

Table 1: Dimesional Differences among PBL, CBL and PCD

Problem of Research

The previous literature mentioned three collaborative problem-solving teaching methods (PBL, CBL, and PCD as active, collaborative teaching methods, focusing on authentic issues and problems) as having been widely studied and implemented in higher education. Although problem-based teaching methods are perceived to encourage students to use information literacy skills to solve problems, the effectiveness of the three methods is still in need of further reviews and comparisons. This study aims to; (1) explore whether

collaborative problem-solving and problem-based approach has the impact to increase information literacy, (2) explore whether the increase of information literacy in first-year university students differs from that of second-year students, and (3) compare and evaluate the influence of three collaborative problem-solving teaching methods, PBL, CBL, and PCD, in improving information literacy.

Method

This research is a quasi-experimental research with *a nonrandomized pretest-posttest control group design*. The independent variables in this research were CBL, PBL, and PCD. The dependent variable in this research corresponds to the scores obtained by participants of each experimental group in the Informational Literacy Test (ILT).

Research Participants

The participants in this study consisted of 183 university students from three first-year classes and three second-year classes who were enrolled in an undergraduate Biology Education Program in Indonesia. Sampling was done using a *cluster random sampling* technique. General information of the study groups is presented in Table 2.

Sample features	First-year students			Second-year students		
	CBL	PBL	PCD	CBL	PBL	PCD
Quantity of research samples (N)	31	31	31	30	30	30
Quantity and percentage of male participants	6 (19.4%)	5 (16.3%)	7 (22.6%)	5 (16.7%)	7 (23.3%)	7 (23.3%)
Quantity and percentage of female participants	25 (80.6%)	26 (83.7%)	23 (77.4%)	26 (83.3%)	23 (76.7%)	23 (76.7%)
Age range	18-20	18-20	18-20	19-21	19-21	19-21

Table 2: General Information of Research Samples

Procedures

PBL, CBL, and PCD were implemented for 16 weeks on first-year students of General Biology courses. These courses discussed biosystematic topics, anatomical and organisational physiology, growth and development of organisms, ecology, microbiology, and biotechnology, in three major themes, namely biodiversity, health, and biological conservation (http://biologi.um.ac.id/wp-content/uploads/2016/11/RPS-Biologi-Umum-NBIO600.pdf). Problems that are the focus of these three teaching methods are environmental damages, biodiversity damages, tropical diseases, sanitation maintenance efforts, disease prevention, and waste management.

PBL, CBL, and PCD were also implemented for 16 weeks on second-year students of Plant Physiology courses. The topics of these courses were plant cells, transpiration, transportation and translocation of nutrients and minerals that occur in plant bodies; metabolism that occurs in plants: carbohydrates, fats, and nitrogen; the response of plants to the environment; growth and development, dormancy, aging and death, movements, photoperiodism, and vernalization (http://biologi.um.ac.id/wp-content/uploads/2016/03/RPS-Fisiologi-Tumbuhan.pdf). The focal issues of all three teaching methods on second-year college students were the acceleration of plant growth through nutrient engineering and growth hormones. Stages of the instructional processes in all three teaching methods are

presented as follows.

PBL was conducted in five stages of teaching that refers to (Arends, 2012) i.e., student orientation on problems, the organization of students in learning, investigation guidance, development and presentation of products, and analysation and evaluation of activities that had been implemented. In the early stages of problem-based learning, the lecturer communicates learning objectives clearly i.e., solving problems presented through an investigative process with the support of arguments obtained from the process of searching, evaluating, and selecting information from reliable sources. Information used in the troubleshooting stage was obtained from internet sources. Lecturers presented the issues and involved students in problem identification activities relating to the aforementioned issues. After acquainting themselves to the nature of each problem, students proceeded to the next step i.e., organizing a cooperative problem-solving activity. The investigation team was of various gender groups and various levels of abilities. Students discuss investigative plans, share investigative tasks, and time/schedule organisation. Students then conduct investigations, the core activities of problem-based learning, cooperatively based on plans that had been prepared. Although each situation required slightly different investigative techniques, they were mostly concerning the process of data collections and experimentations. After obtaining enough data from an investigation of the phenomenon, they test the hypothesis, provide explanations and arguments based on gathered information, and formulated solutions. During the problem-solving stage, lecturers continue to support and provide mediums for exchanging ideas freely and encourage deeper investigation into the problems if necessary. The investigation phase was followed by exhibitions and the creation of artefacts. At the end of each PBL sesssion, students analyze and evaluate their thought processes as well as the investigative, intellectual, and information skills they utilized.

CBL was implemented with a strategy that refers to class guides for teachers developed from (*Challenge Based Learning: A Classroom Guide*, 2010). CBL was implemented through *blended learning* which involved face-to-face interactions and interactions/discussions through *Edmodo*. *Web 2.toolsEdmodo* was the preferred online media technology to work with based on a number of considerations, namely, having a recognizable and easy interface, containing features that support learning, and having high accessibility and compatibility resulting in ease of use for students and only requiring the use of personal laptops and smartphones. CBL has multiple learning stages, namely Big Ideas, Challenges, Solutions and Actions, and Assessments and Reflections. The Big Ideas stage consists of orientation activities on the problems by defining big ideas, building important questions, and setting challenges. In setting challenges and formulating action-solutions, students were guided by information obtained from valid and reliable internet sources. As challenge-based learning methods adopt issues from real-world problems, students translated them into local implementation solutions. Solutions and actions are the heart of CBL. One method of performing the action-solutions stage is by counselling local populations on dengue fever prevention by clearing *Aedes aegypti* mosquito spawning sites for its role as dengue virus vectors. At the end of the learning process, students published their action-solutions and reflected on all previous learning activities. Through CBL, students and lecturers were able to communicate with each other and engage in discussions online through discussion forums provided by Edmodo, when students had difficulties during their learning processes.

PCD teaching was performed in learning stages that refers to Del Favero et al. (2007) and Arends (2012) i.e, raising issues, clarifying discussion objectives and preparing students for participation, focusing discussions, discussing, ending discussions, and evaluating discussions. PCD is also used for problem-solving. Unlike PBL and CBL; troubleshooting in PCD is done through discussions and students do not need to discuss it again in the next

learning stage. Initially, lecturers provide problems and explain the purpose of the discussion and invite students to participate. Lecturers confront them with appropriate issues and specific questions and link questions from earlier discussions with prior student knowledge or experience. Well defined questions or problem focus are the keys to start successful discussions. Once students understand the issues from the discussion, they are assigned to seek information related to the problem. This information is then collected and recorded in student books for future discussions. Students conduct discussions to solve problems that were provided by the teacher. To facilitate discussions, teachers manage them by explaining the basic rules, assigning tasks to each participant, and preparing the media (blackboards, flip charts, laptops). During the discussion process, verbal exchanges are organized and recorded. Lecturers monitor student interactions and facilitate discussions in the appropriate direction. At the end of the discussion, teachers assist the students by making summaries and provide additional reviews and explanations when necessary. Teachers then ask the students to evaluate the discussion process and reflect on their thoughts and the meaning of the discussion for them. The operational stages of those three teaching methods for the lost biodiversity's topic are depicted in Figure 1.

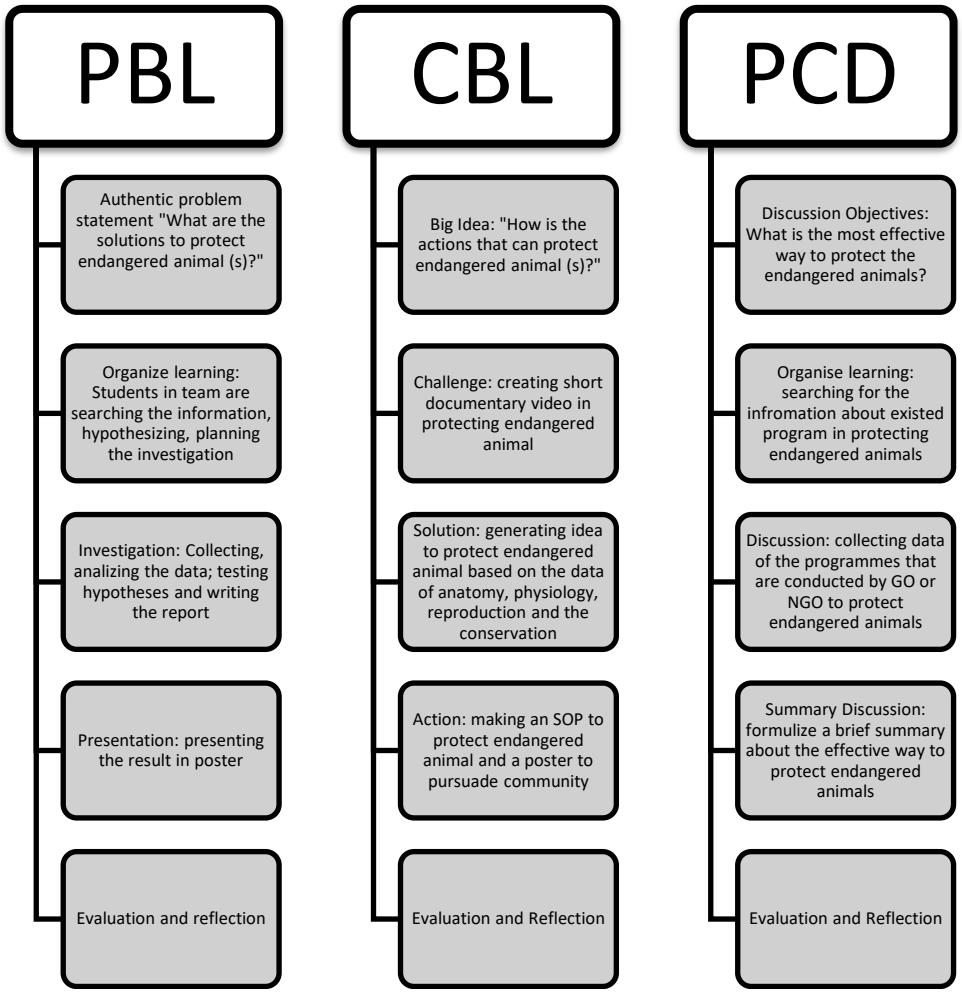

Figure 1: Operational Stages in Three Learning Methods on Lost Bioversity

Instruments

All information literacy data in this research was obtained from the results of information literacy tests (ILT) given prior to a learning process (pretest) and after a learning process (posttest). The information literacy test employed consisted of 28 multiple choice questions referring to five indicators according to Association of College & Research Libraries (2000) and adapted from a b-Tiled instrument developed by O'Neil (2005). The five indicators of information literacy are; 1) Identification of required information (Info Need) (7 questions), 2) Effective and efficient attainment of required information (Access) (8 questions), 3) Critical evaluation of information and its sources (Evaluation) (5 questions), 4) Effective use of information to achieve goals (Info Use) (3 questions), and 5) Consideration of ethical and legal aspects of information use (Ethics) (5 questions). The tests were tailored in accordance to the lecture topics, General Biology, and Plant Physiology. The information literacy tests developed by researchers were reviewed by 3 members of the Malang State University Science Faculty. The adapted instrument was given to three experts to obtain constructive feedback before being tested on potential users. The tests were examined to meet the criteria of validity and reliability. All of the test items have Pearson Correlation value of <0.05 (valid). The reliability value is around 0.82 (high enough). The average index of test difficulty level is 0.51 (moderate). The average item discrimination of 0.24 indicates that ILT effectively differentiates high and low abilities. Samples of ILT items for each indicator are as follows;

Indicator 1: identifying information

2. You were assigned to write a paper on *"The Influence of N, P, K Fertilizer on Rice Plant Growth"*. Which is the most appropriate strategy to find relevant information?

A. Search the article database of agricultural journals
B. Search the article database of agricultural magazines
C. Search for books with agricultural topics in a library
D. Search for encyclopedias containing agricultural topics

(True answer: A)

Indicator 2: Accessing information effectively and efficiently

15. You downloaded a research article from one of many research journal sites. One of the most effective strategies to determine whether the article is compatible with your research is to....

A. Read the Abstract section
B. Read the Discussion section
C. Read the Introduction section
D. Read the Method section dan Research Results section

(True answer: A)

Indicator 3: Evaluating information and sources critically

20. While you are browsing the internet, you found a research article *"Effects of Lantana Camara extract on blood glucose levels of male mice"*. Can you evaluate and determine whether the information in the article is clear and unbiased without having to read it?

A. Yes, one only need to make sure that the article was published by a trusted website
B. No, one needs to read it first to determine if the information is impartial or biased
C. No, one must ensure that the website contains quality research reports
D. Yes, one only needs to see whether the title on the website is clear or biased

(True answer: A)

Indicator 4: Using information effectively to achieve goals.

21. You are assigned to write a paper on biodiversity of seeding plants in Malang, but

information in the form of research journals or reviews on the topic is still very limited. The alternative strategy you can take is ....

A. Take information from variously related research journals for your topic.
B. Use outside information sources related to the topic even if it comes from blogs and Wikipedia.
C. Replace the topic of your paper with other topics due to the lack of resources.
D. Write down any available information despite them being incompatible with your topic.

(True answer:A)

Indicator 5: Taking into account the ethical and legal aspects of using information.

27. You discovered an article that discusses plant genetic engineering in a weekly news magazine. When you are about to do a presentation on the topic of biotechnology, you decide to make a copy of the article and distribute the copy to your classmates. Which of the following concepts are legally allowed to make copies of the work for educational purposes without the need for permission?

A. Copyright
B. Freedom of Information
C. Intelectual Freedom
D. Fair Use

(True answer: D)

Data Analysis

The data analysis used to determine the differences in information literacy improvements from the pretest and posttest of each teaching method is the Paired Sample t-Test equipped with Cohen's d to measure the size effect caused by the teaching methods. The effectiveness of information literacy improvement, including the improvement of five information literacy indicators of the three teaching methods, were analyzed using analysis of covariance (ANCOVA). The pretest score served as a covariate to determine whether the posttest of the three methods differs significantly. Prior to the application of ANCOVA, a Kolmogorov-Smirnov test was conducted to determine the normality of the data including a Levene Test to determine its homogeneity. An Least Significant Difference (LSD) test was used to determine the best teaching method to improve information literacy.

Results

In this study, the information literacy of first and second-year students under three different teaching methods is compared based on the increase from the pretest to the posttest values. The information literacy posttest scores of first-year students under three teaching methods are higher than their pretest scores. The data shows the application of all three teaching methods to increase information literacy of first-year students. Cohen's test results demonstrate the increase of information literacy by the three methods with *size effect*s from largest to smallest (CBL (2.14), PBL (1.04), and PCD (0.76)). Based on the ANCOVA tests, the increase of information literacy from the three different teaching methods are significantly varied ($p < 0.01$). This data analysis reveals that the increase of information literacy through CBL is higher than PBL and PCD.

Information literacy data of second-year students have the same pattern as first-year students. The analysis of pretest and posttest data in all three methods shows an increase in

information literacy, in which CBL has the largest *size effect* of (2.45) compared to PBL at (1.04) and PCD at (0.76). ANCOVA test results show a significant increase in information literacy scores from three different teaching methods at ($p < 0.01$) which revealed CBL as producing a higher increase in information literacy in comparison to PBL and PCD.

The increase of information literacy in first and second-year students were compared to determine whether there is a difference between each teaching method. The paired *t-test* results indicate that the increase in information literacy across the three teaching methods differs significantly between first-year and second-year students. Second-year students have a higher size effect than first-year students (Table 3).

Teaching methods	Student Level	Pretest±SD	Posttest ± SD	*Cohen d*	*F*
CBL	Year 1	45.60±11.50	72.11±6.15	2.14	16.487**
	Year 2	45.70±8.09	79.14±7.23	3.00	
PBL	Year 1	45.72±9.10	57.12±8.84	1.04	24.931**
	Year 2	45.69±7.70	67.24±6.96	2.13	
PCD	Year 1	45.49±6.31	51.71±8.39	0.76	16.352**
	Year 2	45.48±7.14	59.98±8.51	1.53	

** Significance at $p \leq 0.000$

Table 3: ANCOVA Test of Information Literacy by Year

We also analyzed the effectiveness of all three methods in improving each indicator of information literacy. ANCOVA test results of each information literacy indicator show that there are significant differences among the three teaching methods ($p < 0.001$). LSD test results show that CBL is more effective for increasing information literacy than PBL and PCD. Partial Eta squared shows a value above 0.1, this reveals that CBL has a significant influence on all indicators of information literacy (Table 4).

Indicator	Method	Corrected Posttest	*F*	Partial Eta Squared
Info Need	PCD	14.91	15.951**	0.153
	PBL	17.15		
	CBL	18.49		
Access	PCD	16.67	55.642**	0.387
	PBL	18.04		
	CBL	23.51		
Evaluation	PCD	10.30	10.841**	0.110
	PBL	11.74		
	CBL	12.99		
Info Use	PCD	6.15	12.063**	0.121
	PBL	6.52		
	CBL	8.32		
Ethics	PCD	7.82	39.098**	0.308
	PBL	9.21		
	CBL	12.33		

** $p < 0.01$

Table 4: ANCOVA and partial eta squared by teaching methods

Discussion

Problem-based teaching methods can improve the information literacy of first-year and second-year students. This study reinforces the results of previous researches on the relationship between problem-solving and information literacy. For example, research by

Chen et al. (2014) reveals that integrating information literacy into curriculums through integrated instructions with subject content that involves problem-solving inquiry activities, produces information literacy. Shultz & Li (2016) research shows that problem-solving based teaching requires students to possess strong information literacy skills during information seeking processes of problem-solving activities.

In this study, CBL provides the most effective information literacy increase compared to PBL and PCD. CBL's effectiveness had also been reported by Johson and Adam (2011) and Schwenger & Zealand (2016). CBL is an instructional method developed from problem-based learning practices, in which students solve real-world problems collaboratively. One major difference is that it prepares students to face global challenges by applying their ability to develop local solutions and requiring students to take tangible actions (Hwang et al., 2023; Suryawati & Osman, 2018; Vermunt et al., 2023). CBL provides a unique feature; problem-solving challenges covering subjects on global interests that relate to various fields of biology, such as environmental damage, biological agents utilization, global warming, infectious diseases, modern lifestyle-related illnesses, coronary heart diseases, and HIV-AIDS. CBL creates an environment where students can direct themselves to solve real-world problems and think critically during the application of acquired knowledge. Challenges provided by CBL require information from various sources to solve (Leijon et al., 2022; Membrillo-Hernández et al., 2022), instigating the cultivation of information literacy. In CBL, a teachers' primary task shifts from informing to guiding knowledge construction through a number of stages; problem identification, research question development, topic investigation using a variety of key source materials, development of possible solutions, and selection as well as the physical application of appropriate solutions. The identification and implementation of solutions in CBL can display students' ability in information literacy skills honing (Johnson & Adams, 2011). Various works of literature point towards the conclusion that collaborative problem-solving is an appropriate teaching method for increasing information literacy (Mallon & Bernsten, 2015; Santos & Maia, 2023; Sormunen et al., 2013).

CBL teaches multidisciplinary knowledge studies by taking cues from solved real-world problems and requiring students to translate them and locally implement these solutions. This is consistent with the objectives of the higher education curriculum: Practices that lead to the discovery of relevant contents in various fields, integration of multiple disciplines into problem-solving activities, and real-life challenges in which students link their acquired knowledge to their own experiences. CBL gives students opportunities to examine challenges in the world around them, thus reinforcing the connection between what they learn in school, and what they will face in the real world (Blevis, 2010).

CBL provides many opportunities for students to put their experiences to practice in the 21st-century world. Students operate in teams to exercise the handling of real-world problems and to improve their willingness to work collaboratively (Sjølie et al., 2022). This improves their ability to think critically and solve problems relevant to real-world situations, a crucial skill in managing classroom learning (Naparan & Alinsug, 2021; Wolff et al., 2021). Prospective teachers are invited to work in teams, discuss, and share ideas to solve challenges. This exercise helps them learn how to collaborate with fellow teachers, students, and the school community in the future (Bush & Grotjohann, 2020; Wullschleger et al., 2023).

Exploitation of technology, the use of the Internet and online media for collaboration and communications are common practices in modern professions. Students can gain access to materials from a wide array of sources including articles, research results, and even experts around the world. The use of technology allows students to actively receive and store information (Holderied, 2011). The use of Web 2.0 tools in CBL blends learning procedures,

improves the interaction between students and teachers, and facilitates group discussions and collaborative learning (Bath & Bourke, 2010; Köse, 2010; Lin, 2017; Marsh, 2012). In CBL, technology is often integral to finding information, developing solutions, or delivering results. This helps aspiring teachers become more proficient in technology, a major need in education today. Case studies undertaken by Nazarenko (2015) show that blended learning instructions can assist students in finding, selecting, discussing, and recording obtained information. Students who learn through blended learning can easily practice their communication skills at their own pace comfortably (Sriarunrasmee et al., 2015). Liou et al. (2015) also explained that blended learning instructions are very flexible and convenient for students, as it allows them to obtain information updates and stay in touch with teachers.

This research also uncovered a disparity between first and second-year students' information literacy, with second-year students displaying the better use of their skills. This relates to the fact that second-year students have more experience in the utilisation of information. The results of this research are in accordance with research conducted by Pickard & Logan (2013), which demonstrated senior students as having better information literacy skills, such as finding and evaluating information, compared to their first-year counterparts (Boger et al., 2016; Christie et al., 2014; Pale et al., 2023). From these results, it can be concluded that information literacy teaching for first-year students is preferably done gradually.

In this study, the literacy test was carried out using multiple-choice questions. However, reliance on a multiple-choice format has some drawbacks. Although multiple-choice is effective for analyzing information, this format is less optimal in measuring deep understanding or more complex knowledge (Oc & Hassen, 2024; Robinson & Jones-Edman, 2021). Students with extensive knowledge tend to be distracted by limited answer options, so they focus more on the validity of the overall subject rather than critically analyzing the information.

Conclusion

This study provides empirical evidence that problem-based teaching methods such as PBL, CBL, and PCD, can increase information literacy. This study also provides additional evidence of CBL as being the most effective method for increasing information literacy according to the Association of College & Research Libraries standards. Integration of information literacy teachings into problem-based teaching processes for first-year students, if applied early, will provide benefits.

Recommendations

Limitations are considered in asserting research conclusions. The information literacy instructions in this study focus only on developing students' capabilities in searching, accessing, evaluating, and using information effectively in the fields of biology. Generalizations derived from the findings of this study should be considered by taking into account sample limitations and research timeframe of only 6 months. Despite the sample limitations of this study, we still recommend faculty officials to apply problem-based teaching methods, especially CBL, to improve students' information literacy. We also concluded that it is essential to conduct further research with larger samples, including students from various other disciplines.

The measurement of information literacy using multiple-choice instruments offers its

advantages. However, this instrument cannot accurately capture the analytical, critical, and practical skills of participants' information literacy. Future research suggests using more comprehensive measurement approaches, such as problem-based assignments, in-depth interviews, or essay tests that can explore information literacy skills more thoroughly.

Acknowledgements

Acknowledgements: The authors would like to thank the Institute for Research and Community Service, Universitas Negeri Malang, for funding the research with contract number: 5.4.493/UN32.20.1/LT/2023

References

Abdulbaki, K., Suhaimi, M., Alsaqqaf, A., & Jawad, W. (2018). The use of the discussion method at university: Enhancement of teaching and learning. *International Journal of Higher Education*, *7*(6), 118–128. https://doi.org/10.5430/ijhe.v7n6p118

Adaher, A., & Serin, O. (2012). Teacher candidates' information literacy and self-efficacy. *The Online Journal of Science and Technology*, *2*(2), 71–78. http://www.tojsat.net/index.php/tojsat/article/view/44/0

Åkerblom, D., & Lindahl, M. (2017). Authenticity and the relevance of discourse and fi gured worlds in secondary students' discussions of socioscientific issues. *Teaching and Teacher Education*, *65*, 205–214. https://doi.org/10.1016/j.tate.2017.03.025

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, *49*, 101334. https://doi.org/10.1016/j.tsc.2023.101334

Arends, R. I. (2012). *Learning to Teach*. McGraw-Hill.

Argelagós, E., Garcia, C., Privado, J., & Wopereis, I. (2022). Fostering information problem solving skills through online task-centred instruction in higher education. *Computers & Education*, *180*, 104433. https://doi.org/10.1016/j.compedu.2022.104433

Association of College & Research Libraries. (2000). *Information Literacy Competency Standards for Higher Education*. Association of College and Research Libraries.

Athanases, S. Z., Sanchez, S. L., & Martin, L. M. (2020). Saturate, situate, synthesize: Fostering preservice teachers' conceptual and practical knowledge for learning to lead class discussion. *Teaching and Teacher Education*, *88*, 102970. https://doi.org/10.1016/j.tate.2019.102970

Atikuzzaman, M., & Ahmed, S. M. Z. (2023). Investigating the impact of demographic and academic variables on assessing students' perceived information literacy self-efficacy. *The Journal of Academic Librarianship*, *49*(4), 102733. https://doi.org/10.1016/j.acalib.2023.102733

Bath, D., & Bourke, J. (2010). *Getting Started with Blended Learning* (Issue April). Griffith Institute for Higher Education.

Blevis, E. (2010). Design challenge based learning (DCBL) and sustainable pedagogical practice. *Interactions.ACM*, *XVII*(3), 64. https://doi.org/10.1145/1744161.1744176

Boger, T. S., Dybvik, H., Eng, A.-L., & Norheim, E. H. (2016). An assessment of library instruction: its influence on search behaviour of first- and third-year students. *Journal of Information Literacy*, *10*(2), 64. https://doi.org/10.11645/10.2.2135

Bruce, C. S., & Hughes, H. E. (2010). Informed Learning: a Pedagogical Construct Attending Simultaneosly to Information Use and Learning. *Library and Information Science Research*, *32*(4), A2–A8. https://doi.org/10.1080/10599231.2011.537504

Burkhardt, J. M. (2007). Assessing Library Skills: A First Step to Information Literacy. *Portal: Libraries and the Academy*, *7*(1), 25–49. https://doi.org/10.1353/pla.2007.0002

Bush, A., & Grotjohann, N. (2020). Collaboration in teacher education: A cross-sectional study on future teachers' attitudes towards collaboration, their intentions to collaborate and their performance of collaboration. *Teaching and Teacher Education*, *88*, 102968. https://doi.org/10.1016/j.tate.2019.102968

Cebert, Patrick, Cragnoloni, Smith, W. (2011). Griffith Graduate Attributes Problem Solving Skills Toolkit Table of contents. *Griffith University*, *D*, 1–36.

Challenge Based Learning: A Classroom Guide. (2010). Apple Inc.

Chang, Y. (2012). Assessing students ' information literacy skills in two secondary schools in Singapore. *Journal of Information Literacy*, *6*(2), 19–35. https://doi.org/10.11645/6.2.1694

Chen, L. C., Chen, Y. H., & Ma, W. I. (2014). Effects of integrated information literacy on science learning and problem-solving among seventh-grade students. *Malaysian Journal of Library and Information Science*, *19*(2), 35–51. https://mjlis.um.edu.my/index.php/MJLIS/article/view/1788

Chiang, T. H. C. (2017). Analysis of learning behavior in a flipped programing classroom adopting problem-solving strategies. *Interactive Learning Environments*, *25*(2), 189–202. https://doi.org/10.1080/10494820.2016.1276084

Christie, H., Lyn, T., Cree, V. E., & Mccune, V. (2014). It All Just Clicked: a Longitudinal Perpective on Transition within University. *Studies in Higher Education*, *41*(3), 478–490. https://doi.org/10.1080/03075079.2014.942271

Dawes, L. (2017). Faculty perceptions of teaching information literacy to first-year students: A phenomenographic study. *Journal of Librarianship and Information Science*, 1–16. https://doi.org/10.1177/0961000617726129

Del Favero, L., Boscolo, P., Vidotto, G., & Vicentini, M. (2007). Classroom discussion and individual problem-solving in the teaching of history: Do different instructional approaches affect interest in different ways? *Learning and Instruction*, *17*(6), 635–657. https://doi.org/10.1016/j.learninstruc.2007.09.012

Diekema, A. R., Holliday, W., & Leary, H. (2011). Re-framing information literacy: Problem-based learning as informed learning. *Library & Information Science Research*, *33*(4), 261–268. https://doi.org/10.1016/j.lisr.2011.02.002

Dolničar, D., Podgornik, B. B., & Bartol, T. (2017). A comparative study of three teaching methods on student information literacy in stand-alone credit-bearing university courses. *Journal of Information Science*, *43*(5), 601–614. https://doi.org/10.1177/0165551516655084

Dulle, F. W., & Alphonce, A. (2016). Addressing online information resources ' access challenges : potentials of resource discovery tools ' application. *Annals of Library and Information Studies*, *63*(December), 266–273.

Feng, L., & Ha, J. (2016). Effects of Teachers ' Information Literacy on Lifelong Learning and School Effectiveness. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(6), 1653–1663. https://doi.org/10.12973/eurasia.2016.1575a

Fernández-Ramos, A. (2019). Online information literacy instruction in Mexican university libraries: The librarians' point of view. *The Journal of Academic Librarianship*, *45*(3), 242–251. https://doi.org/10.1016/j.acalib.2019.03.008

Fry, S., & Seely, S. (2011). Enhancing Preservice Elementary Teachers ' 21st Century Information and Media Literacy Skills. *Action in Teacher Education*, *33*(2), 1–17. https://doi.org/10.1080/01626620.2011.569468

Ghani, A. S. A., Rahim, A. F. A., Yusoff, M. S. B., & Hadie, S. N. H. (2021). Effective Learning Behavior in Problem-Based Learning: a Scoping Review. *Medical Science Educator*, *31*(3), 1199–1211. https://doi.org/10.1007/s40670-021-01292-0

Greenwell, S. (2013). Using the I-LEARN model for information literacy instruction [Univerity of Kentucky]. In *Journal of Information Literacy* (Vol. 10, Issue 1). https://doi.org/10.11645/10.1.2045

Gross, L. K., Chang, S., & Dinneen, M. (2016). Strengthening information literacy in a writing- designated course in the mathematics major. *College & Undergraduate Libraries*, *23*(1), 56–78. https://doi.org/10.1080/10691316.2014.933689

Guerola-Navarro, V., Stratu-Strelet, D., Botella-Carrubi, D., & Gil-Gomez, H. (2023). Media or information literacy as variables for citizen participation in public decision-making? A bibliometric overview. *Sustainable Technology and Entrepreneurship*, *2*(1), 100030. https://doi.org/10.1016/j.stae.2022.100030

Hammons, J. (2020). Teaching the teachers to teach information literacy: A literature review. *The Journal of Academic Librarianship*, *46*(5), 102196. https://doi.org/10.1016/j.acalib.2020.102196

Harrison, S. J. A., & Deans, M. J. O. nie. (2021). The methodology used to deliver information literacy instruction by a select group of academic librarians: a case study. *Asian Association of Open Universities Journal*, *16*(2), 177–192. https://doi.org/10.1108/AAOUJ-01-2021-0006

Hebert, A. (2018). Information literacy skills of first-year library and information science graduate students: An exploratory study. *Evidence Based Library and Information Practice*, *13*(3), 32–52. https://doi.org/10.18438/eblip29404

Hess, A. N. (2015). Motivational Design in Information Literacy Instruction. *Communications in Information Literacy*, *9*(1), 44–59. https://doi.org/10.15760/comminfolit.2015.9.1.175

Hines, S., & Hines, E. (2012). Faculty and Librarian Collaboration on Problem- Based Learning. *Journal of Library Innovation*, *3*(2), 18–32. https://scholarworks.umt.edu/ml_pubs/10

Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, *16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Holderied, A. C. (2011). Instructional design for the active: Employing interactive technologies and active learning exercises to enhance library instruction. *Journal of Information Literacy*, *5*(1), 22–32. https://doi.org/10.11645/5.1.1519

Hulseberg, A., & Versluis, A. (2017). Integrating information literacy into an undergraduate geography research methods course. *College & Undergraduate Libraries*, *24*(1), 14–28. https://doi.org/10.1080/10691316.2017.1251371

Hwang, W.-Y., Hariyanti, U., Chen, N.-S., & Purba, S. W. D. (2023). Developing and validating an authentic contextual learning framework: promoting healthy learning through learning by applying. *Interactive Learning Environments*, *31*(4), 2206–2218. https://doi.org/10.1080/10494820.2021.1876737

Ilogho, J. E., & Nkiko, C. (2014). Information Literacy Search Skills of Students in Five Selected Private Universities in Ogun State , Nigeria : A Survey. *Library Philosophy and Practice (e-Journal)*, *Paper 1040*, 1–22.

Jabeen, M., Yun, L., Rafiq, M., Jabeen, M., & Tahir, M. A. (2014). Information literacy in academic and research libraries of Beijing, China: Practices, methods and problems. *Information Development*, *32*(3), 579–591. https://doi.org/10.1177/0266666914562845

Johnson, L., & Adams, S. (2011). Challenge Based Learning: The Major Findings of the Implementation Project. In *New Media Consortium*. The New Media Consortium.

Karamustafaoğlu, O., Çakır, R., & Kaya, M. (2013). Relationship between Teacher Candidates ' Literacy of Science and Information Technology. *Mevlana International Journal of Education (MIJE)*, *3*(2), 151–156. https://doi.org/10.13054/mije.13.52.3.2

Klebansky, A. and, & Fraser, S. P. (University of T. (2013). A strategic approach to curriculum design for information literacy in teacher education - Implementing an information literacy conceptual framework. *Australian Journal of Teacher Education*, *38*(11), 103–125. https://doi.org/10.14221/ajte.2013v38n11.5

Klemenčič, M., & Chirikov, I. (2015). *How Do We Know How Students Experience Higher Education? On the Use of Student Surveys BT - The European Higher Education Area: Between Critical Reflections and Future Policies* (A. Curaj, L. Matei, R. Pricopie, J. Salmi, & P. Scott (Eds.); pp. 361–379). Springer International Publishing. https://doi.org/10.1007/978-3-319-20877-0_24

Klucevsek, K. M. (2017). *The Intersection of Information and Science Literacy*. *11*(2), 354–365. https://doi.org/10.15760/comminfolit.2017.11.2.7

Kopp, B., Matteucci, M. C., & Tomasetto, C. (2012). E-tutorial support for collaborative online learning: An explorative study on experienced and inexperienced e-tutors. *Computers and Education*, *58*(1), 12–20. https://doi.org/10.1016/j.compedu.2011.08.019

Köse, U. (2010). A blended learning model supported with Web 2.0 technologies. *Procedia - Social and Behavioral Sciences*, *2*(2), 2794–2802. https://doi.org/10.1016/j.sbspro.2010.03.417

Kriscautzky, M., & Ferreiro, E. (2014). The credibility of information on the Internet : criteria stated and criteria used by Mexican studentsI declarados y utilizados por jóvenes estudiantes mexicanos I. *Educ. Pesqui., São Paulo*, *40*(4), 913–934. https://doi.org/10.1590/s1517-97022014121511

Laretive, J. (2019). Information Literacy, Young Learners and the Role of the Teacher Librarian. *Journal of the Australian Library and Information Association*, *68*(3), 225–235. https://doi.org/10.1080/24750158.2019.1649795

Lau, J. (2006). The International Guidelines on Information Literacy. In C. Elliot (Ed.), *Guidelines on Information Literacy for Lifelong Learning*. International Federation of Library Associations and Institutions.

Leijon, M., Gudmundsson, P., Staaf, P., & Christersson, C. (2022). Challenge based learning in higher education– A systematic literature review. *Innovations in Education and https://doi.org/10.1080/14703297.2021.1892503*

Lewis, F., & Mallaiah, T. Y. (2014). Use of Information Resources in Engineering College Libraries of Dakshina Kannada and Udupi Districts : A comparative study. *Annals of Library and Information Studies*, *61*(June), 142–152.

Lim, J., Tigchelaar, M., & Polio, C. (2022). Understanding text-based studies of linguistic development through goals for academic writing. *Language Awareness*, *31*(1), 117–136. https://doi.org/10.1080/09658416.2021.2002880

Lin, Y.-W. (2017). The Effect of Blended Learning in Mathematics Course. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(3), 741–770. https://doi.org/10.12973/eurasia.2017.00641aa

Lindahl, M. G., & Folkesson, A. (2015). Attitudes and Language Use in Group Discussions on Socio-Scientific Issues. *EURASIA Journal of Mathematics, Science & Technology Education*, *12*(2), 283–301. https://doi.org/10.12973/eurasia.2016.1214a

Liou, S.-R., Yu, W.-C., Tsai, H.-M., & Cheng, C.-Y. (2015). Teaching Information Literacy in Nursing Using Blended Learning Pedagogy. *Creative Education*, *06*(13), 1446–1455. https://doi.org/10.4236/ce.2015.613145

Liu, Q. (2023). Information literacy and recent graduates: Motivation, self-efficacy, and perception of credit-based information literacy courses. *The Journal of Academic Librarianship*, *49*(3), 102682. https://doi.org/10.1016/j.acalib.2023.102682

Loo, J. L., Ei, D., Smith, E., Pendse, L., He, J., Sholinbeck, M., Tanasse, G., Nelson, J. K., & Dupuis, E. A. (2016). The Journal of Academic Librarianship Flipped Instruction for Information Literacy : Five Instructional Cases of Academic Librarians. *The Journal OfAcademic Librarianship*, *42*(3), 273–280. https://doi.org/10.1016/j.acalib.2016.03.001

López-Fernández, D., Salgado Sánchez, P., Fernández, J., Tinao, I., & Lapuerta, V. (2020). Challenge-Based Learning in Aerospace Engineering Education: The ESA Concurrent Engineering Challenge at the Technical University of Madrid. *Acta Astronautica*, *171*, 369–377. https://doi.org/10.1016/j.actaastro.2020.03.027

Lupton, M. (2008). Evidence, argument and social responsibility: first-year students' experiences of information literacy when researching an essay. *Higher Education Research & Development*, *27*(4), 399–414. https://doi.org/10.1080/07294360802406858

Lwoga, E. (2013). Faculty perceptions and practices in health sciences information literacy instruction in Tanzania. *Library Philosophy and Practice*, *1017*, 1–19.

Machin-Mastromatteo, J. D., & Lau, J. (2015). The arrival of information literacy. *Information Development*, *31*(2), 190–193. https://doi.org/10.1177/0266666915569147

Malliari, A., Togia, A., Korobili, S., & Nitsos, I. (2014). Information literacy skills of Greek high-school students : results of an empirical survey 1. *Qualitative and Quantitative Methods in Libraries*, *1*, 271–281.

Mallon, M., & Bernsten, S. (2015). Collaborative learning technologies. *Tips and Trends, Winter 2015*. https://doi.org/http://connect.ala.org/node/241215

Malmqvist, J., Rådberg, K., & Lundqvist, U. (2015). Comparative Analysis of Challenge-Based Learning Experiences. *The 11th International CDIO Conference*.

Marsh, D. (2012). *Blended Learning: Creating Learning Opportunities for Language Learners*. 21. https://doi.org/10.1093/elt/ccq043

Membrillo-Hernández, J., Lara-Prieto, V., & Caratozzolo, P. (2022). Implementation of the Challenge-Based Learning Approach at the Tecnologico de Monterrey, Mexico. In E. Vilalta-Perdomo, J. Membrillo-Hernández, R. Michel-Villarreal, G. Lakshmi, & M. Martínez-Acosta (Eds.), *The Emerald Handbook of Challenge Based Learning* (pp. 69–92). Emerald Publishing Limited. https://doi.org/10.1108/978-1-80117-490-920221004

Miller, K., Kaufmann, K. F., & Trnka, R. E. (2023). Measuring outcomes: Information literacy instruction assessment in a cross-institutional study. *The Journal of Academic Librarianship*, *49*(6), 102796. https://doi.org/10.1016/j.acalib.2023.102796

Mullins, K. (2014). The Journal of Academic Librarianship Good IDEA : Instructional Design Model for Integrating Information Literacy. *The Journal of Academic Librarianship*. https://doi.org/10.1016/j.acalib.2014.04.012

Murphy, P. K., Wilkinson, I. A. G., Soter, A. O., Hennessey, M. N., & Alexander, J. F. (2009). Examining the Effects of Classroom Discussion on Students' Comprehension of Text: A Meta-Analysis. *Journal of Educational Psychology*, *101*(3), 740–764. https://doi.org/10.1037/a0015576

Naparan, G. B., & Alinsug, V. G. (2021). Classroom strategies of multigrade teachers. *Social Sciences & Humanities Open*, *3*(1), 100109. https://doi.org/10.1016/j.ssaho.2021.100109

Nazarenko, A. L. (2015). Blended Learning vs Traditional Learning : What Works ? (A Case Study Research). *Procedia - Social and Behavioral Sciences*, *200*(October), 77–82. https://doi.org/10.1016/j.sbspro.2015.08.018

Nilsen, C. (2012). Faculty perceptions of librarian-led information literacy instruction in postsecondary education. *World Library and Information Congress: 78th IFLA General Conference and Assembly*, *June*, 1–25. https://doi.org/10.11645/5.1.1513

O'Neil, P. B. (2005). *Development and validation of the Beile Test of Information Literacy for Education (B-TILED)* [University of Central Florida]. http://proquest.umi.com/pqdweb?did=1016019641&Fmt=7&clientId=18803&RQT=309&VName=PQD

Oc, Y., & Hassen, H. (2024). Comparing The Effectiveness Of Multiple-Answer And Single-Answer Multiple-Choice Questions In Assessing Student Learning. *Marketing Education Review*, *00*(00), 1–14. https://doi.org/10.1080/10528008.2024.2417106

Öncül, G. (2021). Defining the need: digital literacy skills for first-year university students. *Journal of Applied Research in Higher Education*, *13*(4), 925–943. https://doi.org/10.1108/JARHE-06-2020-0179

Pale, M., Ohi, S., & Kee, L. (2023). Towards Pre-Service Teachers' Theory-Praxis Nexus in Early Years English and Literacy Education: A Pilot Study. *Australian Journal of Teacher Education*, *48*(1), 55–73. https://doi.org/10.14221/1835-517X.5880

Pickard, E., & Logan, F. (2013). The Research Process and the Library: First-Generation College Seniors vs. Freshmen. *College & Research Libraries*, *74*(4), 399–415. https://doi.org/10.5860/crl-348

Podgornik, B. B., Dolničar, D., & Glažar, S. A. (2017). Does the information literacy of university students depend on their scientific literacy? *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3869–3891. https://doi.org/10.12973/eurasia.2017.00762a

Porter, J. R. (2005). Information Literacy in Biology Education: An Example from an Advanced Cell Biology Course. *Revista de Neurologia*, *4*, 335–343. https://doi.org/10.1187/cbe.04 https://doi.org/10.1187/cbe.04-12-0060

Rath, L. (2022). Factors that influence librarian definitions of information literacy. *The Journal of Academic Librarianship*, *48*(6), 102597. https://doi.org/10.1016/j.acalib.2022.102597

Rieh, S. Y., Bradley, D. R., Genova, G., Le Roy, R., Maxwell, J., Oehrli, J. A., & Sartorius, E. (2022). Assessing college students' information literacy competencies using a librarian role-playing method. *Library & Information Science Research*, *44*(1), 101143. https://doi.org/10.1016/j.lisr.2022.101143

Robinson, K. P., & Jones-Edman, G. (2021). Teaching and assessing students of information literacy in a single session—The case of the University of the West Indies Mona library. *Alexandria*, *31*(1–3), 23–41. https://doi.org/10.1177/09557490211063532

Ross, M., Perkins, H., & Bodey, K. (2016). Academic Motivation and information Literacy Self-effi cacy : The importance of a Simple Desire to Know. *Library and Information Science Research*, *38*(1), 2–9. https://doi.org/10.1016/j.lisr.2016.01.002

Santharooban, S., & Premadasa, P. G. (2015). Development of an information literacy model for problem based learning. *Annals of Library and Information Studies*, *62*(September 2015), 138–144.http://op.niscair.res.in/index.php/ALIS/article/view/8472

Santos, A. de S., & Maia, L. C. G. (2023). Information literacy as social innovation. *Em Questão*, *29*, 126500. https://doi.org/10.19132/1808-5245.29.126500

Saunders, L., Severyn, J., & Caron, J. (2017). Don't they teach that in high school? Examining the high school to college information literacy gap. *Library & Information Science Research*, *39*(4), 276–283. https://doi.org/10.1016/j.lisr.2017.11.006

Scott, R. E. (2017). Communications in Information Literacy Transformative? Integrative? Troublesome? Undergraduate Student Reflections on Information Literacy Threshold Concepts Transformative? Integrative? Troublesome? Undergraduate Honors Student Reflections on Information. *Communications in Information Literacy*, *11*(2), 283–301. https://doi.org/10.15760/comminfolit.2017.11.2.3

Shannon, C., Reilly, J., & Bates, J. (2019). Teachers and information literacy: Understandings and perceptions of the concept. *Journal of Information Literacy*, *13*(2), 41–72. https://doi.org/10.11645/13.2.2642

Short, R. A., Van der Eb, M. Y., & McKay, S. R. (2020). Effect of productive discussion on written argumentation in earth science classrooms. *The Journal of Educational Research*, *113*(1), 46–58. https://doi.org/10.1080/00220671.2020.171231444

Shultz, G. V., & Li, Y. (2016). Student Development of Information Literacy Skills during Problem-Based Organic Chemistry Laboratory Experiments. *Journal of Chemical Education*, *93*(3), 413–422. https://doi.org/10.1021/acs.jchemed.5b00523

Sjølie, E., Espenes, T. C., & Buø, R. (2022). Social interaction and agency in self-organizing student teams during their transition from face-to-face to online learning. *Computers & Education*, *189*, 104580. https://doi.org/10.1016/j.compedu.2022.104580

Solmaz, D. Y. (2017). Relationship between Lifelong Learning Levels and Information Literacy Skills in Teacher Candidates. *Universal Journal of Educational Research*, *5*(6), 939–946. https://doi.org/10.13189/ujer.2017.050605

Sormunen, E., Alamettälä, T., & Heinström, J. (2013). The teacher's role as facilitator of collaborative learning in information literacy assignments. *Worldwide Commonalities and Challenges in Information Literacy Research and Practice*, *NA*(October). https://doi.org/10.1007/978-3-319-03919-0_67

Sriarunrasmee, J., Techataweewan, W., & Mebusaya, R. P. (2015). Blended Learning Supporting Self-Directed Learning and Communication Skills of Srinakharinwirot University's First Year Students. *Procedia - Social and Behavioral Sciences*, *197*(February), 1564–1569. https://doi.org/10.1016/j.sbspro.2015.07.111

Suryawati, E., & Osman, K. (2018). Contextual learning: Innovative approach towards the development of students' scientific attitude and natural science performance. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(1), 61–76. https://doi.org/10.12973/ejmste/79329

Swiden, C. L. (2013). *Effect of Challenge Based Learning on Student Motivation and Achievement* (Issue July). Montana State University.

Syahrin, S. (2021). Literacy Uses and Practices of Schoolchildren Living in a Contemporary Malaysian Context. *Australian Journal of Teacher Education*, *46*(10), 43–61. https://doi.org/10.14221/ajte.2021v46n10.3

Tachie-Donkor, G., & Ezema, I. J. (2023). Effect of information literacy skills on university students' information seeking behaviour and lifelong learning. *Heliyon*, *9*(8), e18427. https://doi.org/10.1016/j.heliyon.2023.e18427

Tarango, J., Evangelista, J. L., Machin-Mastromatteo, J. D., & Cortes-Vera, J. (2017). Inclusion of Information Literacy in the Curriculum Through Learning Communities and Action Research. *Pathways into Information Literacy and Communities of Practice: Teaching Approaches and Case Studies*, 85–114. https://doi.org/10.1016/B978-0-08-100673-3.00004-6

Valenza, J. K., Dalal, H., Mohamad, G., Boyer, B., Berg, C., Charles, L. H., Bushby, R., Dempsey, M., Dalrymple, J., & Dziedzic-Elliott, E. (2022). "First years'' information literacy backpacks: What's already packed or not packed?"." *The Journal of Academic Librarianship*, *48*(4), 102566. https://doi.org/10.1016/j.acalib.2022.102566

Vermunt, J. D., Vrikki, M., Dudley, P., & Warwick, P. (2023). Relations between teacher learning patterns, personal and contextual factors, and learning outcomes in the context of Lesson Study. *Teaching and Teacher Education*, *133*, 104295. https://doi.org/10.1016/j.tate.2023.104295

Virkus, S., & Mandre, S. (2015). *Information Literacy, Leadership and Management BT - Information Literacy: Moving Toward Sustainability* (S. Kurbanoglu, J. Boustany, S. Špiranec, E. Grassian, D. Mizrachi, & L. Roy (Eds.); pp. 80–89). Springer International Publishing. https://doi.org/10.1007/978-3-319-28197-1

Wenger, K. (2014). Problem-Based Learning and Information Literacy: A Natural Partnership. *Pennsylvania Libraries: Research & Practice*, *2*(2), 142–154. https://doi.org/10.5195/palrap.2014.61

Wickramasinghe, V., & Seneviratne, T. M. (2021). Development of information literacy over an undergraduate degree programme - comparison of first- and final-year students. *Journal of Advances in Library and Information Science*, *10*(4), 218–228. https://jalis.in/10-4.htm

Willer, D., & Eisenberg, M. (2014). Mapping Educational Standards to the Big6. In D. M. & R. C. S. Kurbanoğlu, S. Špiranec, E. Grassian (Ed.), *Information Literacy: Lifelong Learning and Digital Citizenship in the 21st Century: Second European Conference* (pp. 81–90). Communications in computer and information science, 492). Heidelberg: Springer. https://doi.org/10.1007/978-3-319-14136-7_9

Williams, G., & Clement, J. (2015). Identifying Multiple Levels of Discussion-Based Teaching Strategies for Constructing Scientific Models. *International Journal of Science Education*, *37*(1), 82–107. https://doi.org/10.1080/09500693.2014.966257

Wolff, C. E., Jarodzka, H., & Boshuizen, H. P. A. (2021). Classroom Management Scripts: a Theoretical Model Contrasting Expert and Novice Teachers' Knowledge and Awareness of Classroom Events. *Educational Psychology Review*, *33*(1), 131–148. https://doi.org/10.1007/s10648-020-09542-0

Wu, D., Zhou, C., Li, Y., & Chen, M. (2022). Factors associated with teachers' competence to develop students' information literacy: A multilevel approach. *Computers & Education*, *176*, 104360. https://doi.org/10.1016/j.compedu.2021.104360

Wullschleger, A., Vörös, A., Rechsteiner, B., Rickenbacher, A., & Maag Merki, K. (2023). Improving teaching, teamwork, and school organization: Collaboration networks in school teams. *Teaching and Teacher Education*, *121*, 103909. https://doi.org/10.1016/j.tate.2022.103909

Yager, Z., Salisbury, F., & Kirkman, L. (2013). Assessment of information literacy skills among first year students. *The International Journal of the First Year in Higher Education*, *4*(1). https://doi.org/10.5204/intjfyhe.v4i1.140

Zhang, X. (2021). Preparing first-year college students' academic transition: What is the value of complementary web-based learning? *Computers & Education*, *172*, 104265. https://doi.org/10.1016/j.compedu.2021.104265