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Collaborative mind mapping in RICOSRE learning model to improve students' information literacy

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ABSTRACT

This research aimed to determine how the reading, identifying problem, constructing solution, solving problem, reviewing and extending problem solution (RICOSRE) learning model integration with collaborative mind mapping affects students' information literacy in higher education institutions. This quasi-experimental study used a pretest-posttest non-equivalent control group design. There were 40 multiple-choice questions selected to assess student information literacy. All instruments have been validated and are reliable. The data were collected from 100 participants who were college students enrolled in the environmental pollution course of the biology education degree program at Siliwangi University, Indonesia. To analyze the research data, analysis of covariance (ANCOVA) was used at a 5% level of significance, followed by the least significance difference (LSD) test. The ANCOVA results showed that the RICOSRE-CMM learning model impacted students' information literacy. LSD scores were significantly different in terms of students' information literacy. It can be concluded that the RICOSRE-CMM model could enhance each component of information literacy as these components have been integrated into the learning model syntax, which involves a series of information discovery and analysis processes during group work to find a solution to a problem.

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1. INTRODUCTION

In the 21st century education, information literacy is crucial. Information literacy helps students become more self-assured and autonomous so they can carefully achieve their objectives in learning [1]. Literature reviews are essential in scientific investigations and thus highly valued in the academic world when it comes to problem-solving exercises, particularly in biology learning [2]. This set of exercises also aids students in formulating theories related to biology learning, particularly those pertaining to the use of data to address various instances of environmental pollution. Because information literacy skills have a significant impact on learning, students need to acquire these skills [3].

Information literacy is a key factor for lifelong learning [4], [5]. It is useful for obtaining reliable and accurate information to solve various problems. Information literacy includes the integration of skills when information is needed, finding information, using information effectively, and critically evaluating information and its sources [6]. Information literacy has been broadly defined in various literatures. The Association of College and Research Libraries (ACRL) describes information literacy as the ability to recognize when information is required, as well as how to locate, evaluate, and use it responsibly [5]. Information literacy helps students at universities in the process of knowledge reconstruction [7]. Information literacy strengthens students' ability to use various information as a knowledge product. Technological developments provide great opportunities to obtain plentiful information, hence college students need to be equipped with information literacy to minimize errors in information selection. Information literacy is a must in higher education because it supports learning activities, fosters students' critical thinking, and improves their academic performance. Information literacy assists college students in accomplishing various learning tasks that ultimately affect the success of their studies at the university [8] .

The development of information literacy among college students is a fundamental necessity as it can enhance learning goals and has implications for future success. Unfortunately, several studies have reported that students are often unprepared for the complexities of academic research and experience many challenges in finding and evaluating information sources [9]. College students also lack sufficient skills to seek appropriate academic resources. In conclusion, college students' information literacy is still relatively poor, particularly concerning accessing information [10]. In general, college students in Indonesia perform poorly in information literacy, especially in accessing the required information [11].

Teachers need to implement appropriate pedagogical strategies to support the development of information literacy among students in higher education institutions [12]. A holistic view of the information-seeking process suggests that problem-based learning integrated with inquiry activities can improve students' information literacy. Past studies indicate that teacher education programs must incorporate a process-oriented approach to information literacy instruction to effectively meet students' information needs [13], [14]. Previous research indicates that teacher education programs should incorporate a process-oriented approach in teaching information literacy to meet the information needs of college students. Learning that focuses on problem-solving and requires college students to design authentic problem solutions can promote literacy development and create a positive learning atmosphere. This positive learning atmosphere can stimulate students' curiosity, motivating them to organize information [15]. Problem-based learning strategies can assist college students in gathering information and deciding the right course of action to solve the intended problem [16].

An example of active, problem-solving-oriented learning is the reading, identifying the problem, constructing solution, solving problem, reviewing and extending problem solution (RICOSRE) learning model. The RICOSRE learning model prioritizes group performance in systematic and structured problem-solving exercises [17]. Several previous studies reported that implementing RICOSRE in the classroom can support the development of various skills. Compared to traditional learning, RICOSRE can significantly improve the problem-solving skills of high school students in the city of Malang, Indonesia [18]. Furthermore, the RICOSRE learning model is more successful in increasing science literacy than inquiry-based learning strategies [19]. RICOSRE, like other problem-based learning models, can present a conducive learning environment and turn students into independent learners. Each phase of the RICOSRE learning model encourages college students to engage with information needs. Therefore, it is hoped that RICOSRE can develop the information literacy of every individual in tertiary institutions.

However, problem-based teaching alone will not be able to shape the systematic understanding of learning content among college students [20]. Thus, instructors need to add techniques that can help students visualize abstract problems into concrete ones and simplify complex problems by connecting fragmented knowledge in collaboration, so this technique can be used as an effective tool to support the implementation of the RICOSRE learning model. Such learning techniques can be a good complement to the RICOSRE learning model. Collaborative mind mapping is an alternative technique that can be used to help students systematically visualize ideas, brainstorm and work together to solve problems [21]. Collaborative mind mapping also facilitates reflection in the learning process.

The collaborative mind mapping (CMM) technique begins with creating a mind map, either manually or digitally. This technique helps students associate ideas, think creatively, and make possible connections [21]. The use of software offers a more sophisticated way of organizing information in a mind map. CMM is a groupware application that includes a collaborative power to connect visuals synchronously and asynchronously, make shared edits, and save edit history for viewing [22]. Learning in the 21st century often presents the technology, collaboration, and visualization as interconnected components.

The utilization of CMM in the learning process triggers student participation and interest. CMM also helps students sort information, acquire knowledge, and create meaningful learning experiences by generating ideas on topics covered in the classroom [23]. Several related studies report that CMM positively affects group learning dynamics, idea organization, learning achievement, and learning efficiency. College students are satisfied with the use of CMM in the classroom because it can bridge student discussions and help students reconstruct new knowledge [24].

The integration of RICOSRE and CMM aims to encourage student participation in improving information literacy in problem-solving. Linking information and ideas when creating a CMM is a creative task that requires deep thought and excessive focus [24]. Universities must be able to integrate technology-based learning tools to respond to technological developments and create an interactive learning environment. The use of technology in learning, supported by the ease of collaboration, can increase students' motivation to learn and make the learning process more meaningful [25]. Another advantage of CMM is that they can be saved in pdf and jpg format. CMM can be easily shared with the lecturer and other students, making the process of collaboration, assessment and reflection of learning easier.

This combination of RICOSRE and CMM, referred to as RICOSRE-CMM, will be used in the Environmental Pollution course. Students studying biology will learn about different initiatives to address environmental pollution issues in this course on environmental pollution. Common and severe environmental pollution issues in Indonesia include garbage on roads and in rivers, poor air quality in cities, heavy metal pollution in water, high rates of deforestation that result in significant greenhouse gas emissions, soil erosion, soil pollution, air pollution from smoke and haze, loss of biodiversity, and some other issues [26]. The lack of environmental awareness and general information about the natural environment is the main issue causing the significant environmental damage that has taken place in Indonesia. Today's environmental harm is also influenced by human activity [27].

It is anticipated that students possess the ability to examine the ramifications of environmental pollution on living organisms and devise more efficient resolutions to associated issues. The course aims to investigate diverse environmental issues, and it is presumed that these objectives align with the RICOSRE-CMM educational framework. Thus, it is hoped that the instructional approach will support learners in resolving challenges encountered throughout educational endeavors. Collaborative mind mapping facilitates problem-solving by enhancing focus and organizing problems systematically, thereby enabling students to identify solutions with greater ease. Based on the above explanations, this study aimed to identify differences in information literacy between college students supported with the RICOSRE-CMM learning model and college students supported with RICOSRE or conventional learning model.

2. RESEARCH METHOD

2.1. Research design

This study employed a quasi-experimental method. Table 1 shows the pretest-posttest non-equivalent control group design used in this study. The independent variable of this study was the learning model, while the dependent variable was information literacy. The current study involved three treatment groups, namely RICOSRE-CMM, RICOSRE, and conventional.

Table.1 Research design

Pretest	Treatment group	Number of students	Posttest
O_1	RICOSRE-CMM	40	O_2
O_3	RICOSRE	35	O_4
O_5	Conventional	25	O_6

2.2. Research subjects

The population of this study consisted of second-year students attending courses on environmental Pollution in the Biology Education program of study, Faculty of Teaching and Education, Siliwangi University, Tasikmalaya, West Java, Indonesia. In addition, this study included 100 preservice biology teachers, including 83 female and 17 male preservice teachers. The participants came from the age group between 19 and 21 years. Participants were randomly selected from three different classes. The research participants consisted of 40 students in RICOSRE-CMM class, 35 students in RICOSRE class, and 25 students in the conventional class.

2.3. Research instrument

The research instrument used to assess participants' information literacy consisted of 40 multiple-choice questions. These questions were developed based on the information literacy framework proposed by the Association of College and Research Libraries as adopted in the research by Podgornik *et al.* [28]. The structure of the multiple-choice test includes five information literacy criteria, which consist of: i) determining the nature and extent of the information needed; ii) accessing needed information effectively and efficiently; iii) evaluating information and its sources critically and incorporating selected information into his or her knowledge base and value system; iv) uses information effectively to accomplish a specific purpose; and v) understands many of the economic, legal, and social issues surrounding the use of information and accesses and uses information ethically and legally.

The information literacy test was reviewed by two experts. The learning instrument expert was invited to do the rational validation, while the expert on environmental science was invited to perform content validity.

The empirical validity and reliability of the instrument were evaluated by a tryout on students who were not part of the study sample. The empirical study was conducted at Siliwangi University, Indonesia. The test validity was conducted using the Pearson product moment analysis. The analysis showed scores between 0.201-0.488 for the test items. The reliability test using Cronbach's Alpha showed a score of 0.799, meaning the test was reliable.

2.4. Research procedure

This study began with participants receiving a pretest before treatment. The aim of conducting the pretest was to obtain initial data on the information literacy of the students from the entire treatment group. At the end of the learning session, a posttest was conducted following the research treatment. In addition, the learning model was implemented in twelve sessions in the environmental pollution class. Environmental Pollution is a course aimed at increasing college students' environmental awareness and higher-order thinking skills as well as improving their ability to explore information and assess problems. The environmental pollution course also provides college students with environmental problem-solving experience.

The learning activities conducted in the RICOSRE-CMM (experimental) class consisted of i) reading; ii) identifying the problems with the CMM; iii) constructing the solution with CMM; iv) solving the problems with CMM; and v) reviewing and extending the solutions with CMM. The learning stages in the RICOSRE experimental class were almost the same as the learning stages in the RICOSRE-CMM. However, RICOSRE-CMM involved the use of CMM in its syntax. The learning process in the RICOSRE classes went through the following phases: i) reading; ii) identifying problems; iii) constructing the solution; iv) solving the problems, and v) reviewing and extending the solutions to problems. Meanwhile, conventional learning consisted of the following phases: i) motivating students to learn; ii) dividing the students into small groups; iii) asking the students to present the results of the group discussions on the topics discussed. In the final phase of the study, the data obtained were analyzed and interpreted to conclude.

2.5. Data analysis

The data from this study were analyzed using ANCOVA followed by the least significance difference (LSD) test. The inferential statistical analysis began with the analysis of the research assumptions in the form of data normality and homogeneity of variance. The one-sample Kolmogorov-Smirnov test was used to determine the normality of the data, while Levene's test was used to analyze the homogeneity of variance. The post-test data were analyzed using ANCOVA, where the pretest scores were used as the covariate. ANCOVA was done to investigate the difference in information literacy between the RICOSRE-CMM, RICOSRE, and conventional students. If the analysis results showed a significant value, ANCOVA was followed by the LSD test to find out the difference in mean scores between all treatment groups.

3. RESULTS

3.1. Participants' score on each information literacy standard

Participants' information literacy scores were calculated from their post-test results. There were five standards assessed in the information literacy test given to the participants. Figure 1 compares the information literacy scores of participants from the RICOSRE-CMM, RICOSRE, and conventional groups.

3.2. Results of the normality and homogeneity tests on participants' information literacy data

Before testing the hypothesis, data normality and homogeneity of variance were examined. The normality of the research data was examined using the Kolmogorov-Smirnov test, while the homogeneity of variance was examined using Levene's test $p>0.05$). Table 2 displays the results of the normality and homogeneity tests. Based on Table 2, it is known that the research data were distributed normally and sourced from homogeneous variance. Then, hypothesis testing was conducted to study the effect of the learning models on participants' information literacy. The hypothesis was tested using ANCOVA (at 0.05 significance level), with the pretest scores as the covariate. If the analysis results showed a significant value, ANCOVA was followed by the LSD test to find out the difference in mean scores among the three treatment groups.

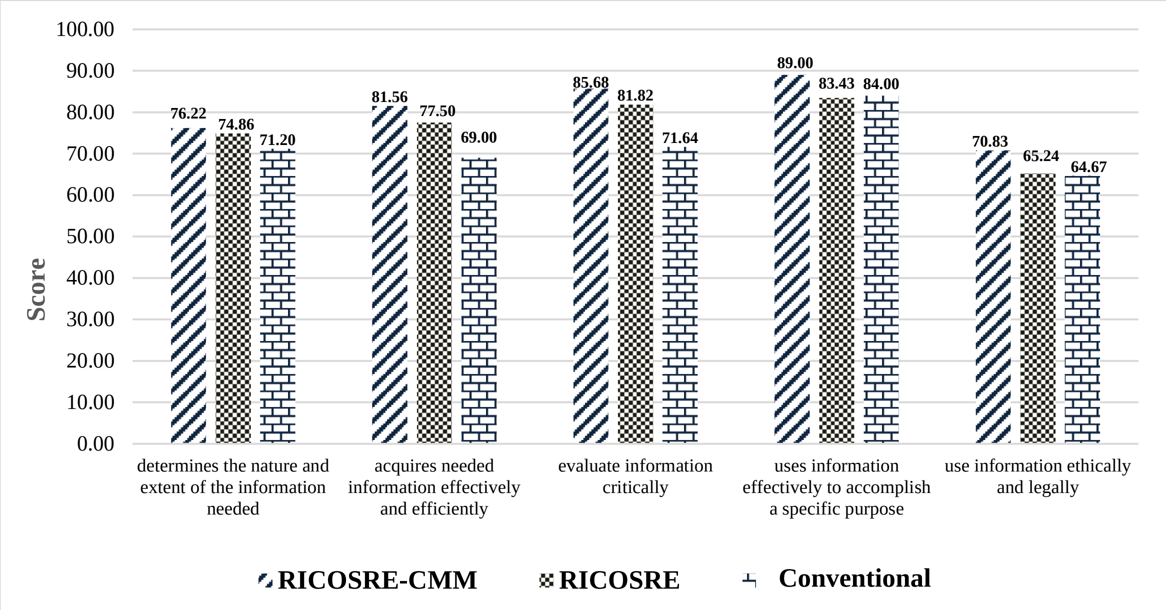

Figure 1. The mean posttest scores on each information literacy standard

Table 2. The results of the normality and homogeneity tests on participants' information literacy data

Group	Normality test		Homogeneity test	
	N	Sig.	Levene's test score	Sig.
Information literacy pretest	100	0.071	0.875	0.05
Information literacy posttest	100	0.078	0.820	0.05

3.3. The effect of the RICOSRE-CMM, RICOSRE, and conventional learning models on college students' information literacy

Table 3 presents the results of the ANCOVA at 5% level of significance on the effect of the learning models on college students' information literacy. The results show significant differences in information literacy between students who attended learning using RICOSRE-CMM, RICOSRE, and conventional learning (F=9.741; p=0.001). This difference is due to differences in learning syntax in each lesson.

Table 3. The ANCOVA results

Source	Type III sum of squares	df	Mean square	F	Sig.
Learning models	1759.238[a]	3	586.413	8.752	.000
Intercept	8724.114	1	5724.144	130.212	.000
Pretest	454.679	1	454.679	6.786	.011
Model	1305.333	2	6265.667	9.741	.001
Error	6431.950	96	66.999		
Total	600706.250	100			
Total Average	8191.187	99			

Note: R Square=0. 215 (Adjusted R squared=0.190)

The ANCOVA results in Table 4 reveal a statistically significant difference in information literacy between students taught with different learning models, with $F_{calculated}$=9.741 and a significance level of 0.001 (p-value<0.05). Next, to investigate the significance of the difference, LSD test was performed. The LSD test results are shown in Table 4.

Table 4. The results of LSD test on participants' information literacy

Class	Pretest	Posttest	Difference	Score increase	Average score	LSD notation
RICOSRE-CMM	62.00	80.69	18.69	30.14%	80.70	a
RICOSRE	62.14	76.64	14.50	23.33%	76.62	b
Conventional	62.00	71.50	9.50	15.33%	71.51	c

Table 4 shows the results of the LSD test to determine the most effective learning method for increasing students' information literacy. It was found that the mean score of students in the RICOSRE-CMM group (80.70) for information literacy was higher than that achieved by the RICOSRE group (76.62) or by the conventional group (71.51). The RICOSRE-CMM group obtained the highest increase (from the pretest score to the posttest) (30.14%), followed by the RICOSRE group (23.33%), and the conventional group (15.33 %).

Below are some sample information literacy test questions along with student responses from the RICOSRE-CMM and conventional classes. The students of the RICOSRE-CMM class understood that if they wanted to find a plant species, they had to perform valid investigation steps. These steps included using an identification key, matching the species being studied to the herbarium species identified by researchers, matching the species being studied to pictures in a monograph book, or requesting a plant expert directly. In contrast, students in conventional classes were more likely to ask other students about these plants. Therefore, the conventional class students presented difficulties in determining valid steps related to the plant identification problem.

When the lecturer asked students conducted observations to identify species of aquatic plants that commonly cause blooms in aquatic ecosystems, it turns out they are finding a plant species that has never been identified before. To identify these types of plants, the valid investigative steps that students should NOT perform are as follows …

A. Use a determination key
B. Ask other students about the plant
C. Match the plant species with the herbarium specimens that have been identified
D. Match the species being studied to pictures in a monograph book.
E. Ask the identity of the plant to someone who we consider a plant expert and who we think can provide an answer to the question.

(The correct answer is B)

4. DISCUSSION

The difference in the mean scores that students achieved in the conventional class, RICOSRE, and RICOSRE-CMM in each information literacy standard can be attributed to the different phases of the activity or set of tasks completed in the classroom. The students in the RICOSRE-CMM class achieved higher information literacy scores than other students from other treatment groups because the students in the RICOSRE-CMM class went through learning phases that increased their literature awareness and allowed them to search for a complete bibliography. In the RICOSRE-CMM class, the students were supported with the CMM activity that can enhance their information literacy. This CMM activity produced an end product capable of describing the flow of information and finding solutions, which can strengthen decision-making in discussions. The CMM activity was a good example of collaborative activities between students in small groups. The ultimate goal of creating CMMs in the RICOSRE-CMM class was to help students visualize and organize ideas and information gained from problem-solving activities to find effective solutions to problems. An example of a mind map created by students from the RICOSRE-CMM group is shown in Figure 2.

Figure 2 is an example of a mind map created collaboratively by students in the RICOSRE-CMM class. Students mapped the problem in the middle of the CMM as the focal point. Next, students made outward ramifications that include the factors causing this problem, the impact of the problem on the environment, and several alternative solutions to the problem. From these branches, the most appropriate solution to solve the environmental problem was then highlighted. Problem-based learning encourages college students to explore different theories, examine empirical data, and use critical thinking skills in evaluating information during the problem-solving process [29]. A series of science activities and the creation of a collaborative mind mapping can strengthen students' information literacy.

The RIOCSRE-CMM, RICOSRE, and conventional learning models can improve information literacy in college students. Implementation of learning generally requires access to information. However, some expert opinions and research indicate that problem-based learning is more effective in promoting information literacy in the classroom [29]. The results of this study showed that the RICOSRE-CMM learning model had a positive effect on college students' information literacy. The RICOSRE-CMM learning stages contributed the greatest to the development of students' information literacy as each standard was trained from the beginning to the end of the lesson.

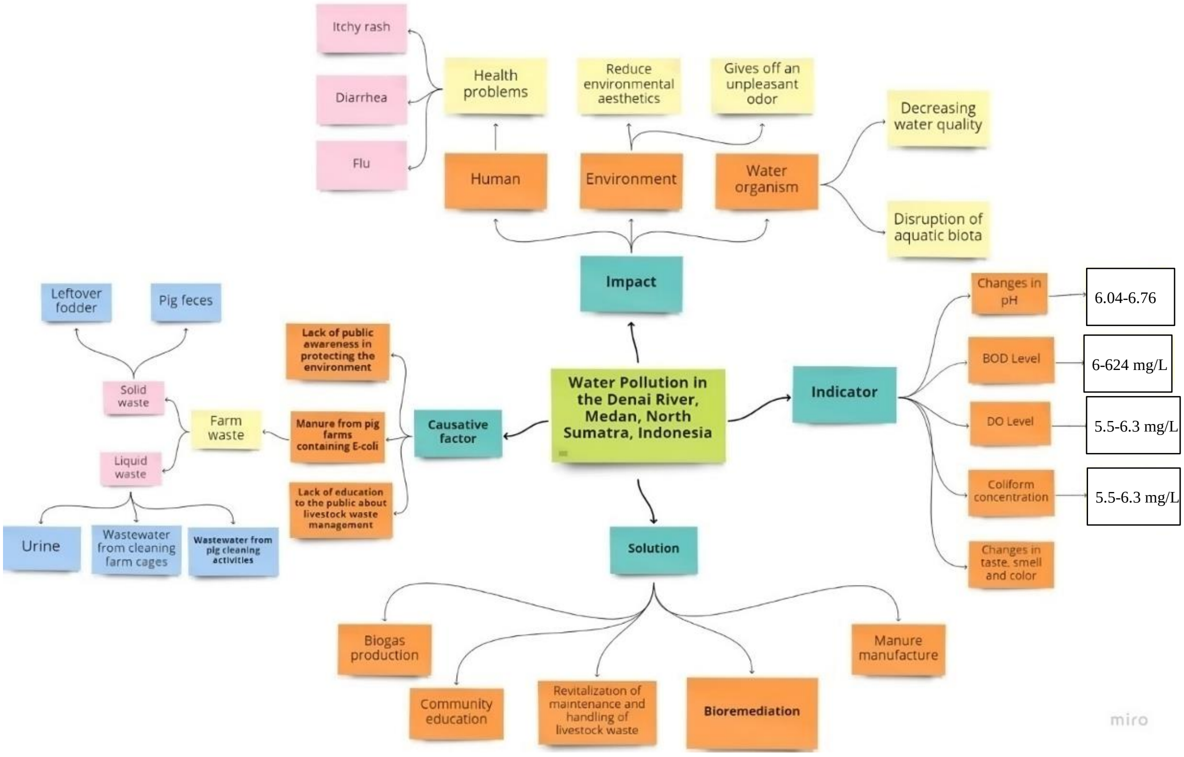

Figure 2. Collaborative mind mapping of environmental pollution

The first syntax of RICOSRE-CMM is reading. At this stage, students were asked to read relevant references to find as much information as possible to build knowledge that would be acquired during the learning process. Reading can train higher thinking skills as it involves active intellectual abilities to derive meaning and purpose from reading sources [17]. Reading leads college students to seek information about the type and amount of information needed (standard 1). The results of this study showed that the RICOSRE-CMM class achieved the highest information literacy score (76.22), followed by the RICOSRE class (74.86) and the conventional class (71.20). Reading is relevant to academic needs. It improves students' ability to find information and increases their information literacy. Reading skills cannot be adequately trained in conventional classes that are geared toward lecturer-centered activities [30].

The second phase in RICOSRE-CMM is identifying the problem using Collaborative Mind Mapping (CMM). In this phase, college students were asked to identify environmental problems based on topics that have been identified and written on student worksheets. Identifying contextual issues can initiate an information search that begins with determining what information is needed. It also trains the ability to access information effectively (standard 2) [31]. In this study, participants in the RICOSRE-CMM class received the highest score (81.56) for the ability to access needed information effectively and efficiently, followed by the RICOSRE class (77.50) and the conventional class (69.00). Higher education students need to develop the ability to access information, as this ability enables them to find the information they need amidst a wealth of information. Mastery of this information literacy standard is characterized by the ability to use information search strategies via search engines and use multiple keywords and specific codes according to computer language [32].

In this phase, the students also developed a mind map together. Collaborative Mind Mapping helped these students organize information and ideas they had gathered from relevant references. CMM also supported the students in generating associations of ideas and encouraged them to think outside the box [33]. Environmental pollution topics such as water pollution, soil pollution, and air pollution discussed in class motivated the students to explore important information. Students who can identify problems demonstrate a higher level of information literacy [29].

The third syntax of RICOSRE-CMM is constructing the solution. When constructing problem solutions, students were encouraged to think creatively. In addition, students were motivated to develop skills to critically evaluate information and use theoretical foundations and scientific laws to construct reasonable alternative solutions. The results of this study confirmed that students in the RICOSRE-CMM class (85.68) were better than the RICOSRE (81.82) and the conventional students (71.64) in evaluating information (standard 3). This finding relates to the use of authentic and actual problems in problem-based learning. Problem-based learning has been shown to provide students with a broad learning experience and improve their ability to evaluate information, which is one of the indicators of information literacy [16], [29]. Evaluating information critically means examining the relevance and usefulness of the information and using the latest technology to access the information [34]. The information assessment phase encourages students to make careful decisions about what information to look for or what information products to create. When constructing alternative solutions, students discussed in groups to visualize problem-solving through collaborative mind mapping. Each group member could systematically see the solution that the group considered the most appropriate. Related studies have previously found that CMM has a high degree of flexibility, simplifies the complexity of information, and can clarify and link key ideas to solve specific problems [35].

The fourth syntax in RICOSRE-CMM is solving the problem. After exploring and developing several alternative solutions, students were trained to determine the most appropriate solution to the problem in this phase. Students were asked to rate the accuracy of the strategies and methods chosen to solve the problem at hand. In this fourth phase, accuracy in evaluating information and determining strategy adequacy is key [17]. Therefore, CMM plays an important part in this stage.

Collaborative Mind Mapping helps students gather important information during problem-solving activities. CMM also helps students remember, regulate, express relationships between information, and add recent information [36], [37]. Collaborative mind mapping can be used to present the results of the discussion more interestingly. Previous studies stated that collaboratively mind mapping can help users think flexibly and systematically. A systematic mindset makes it easier for someone to solve problems. A set of cognitive processes and information literacy skills help find appropriate solutions to complex problems commonly encountered in everyday life [38].

After going through the fourth RICOSRE-CMM syntax, participants developed one of the information literacy standards namely uses information effectively to accomplish a specific purpose (standard 4). The results of the current study showed that the RICOSRE-CMM students (89.00) scored higher than the RICOSRE students (83.43) or the conventional students (84.00) in using the information to achieve specific goals. This finding is consistent with the fact that these students were able to apply new information and previous information to find solutions to the problems at hand. They were also able to effectively communicate the results of their investigations to other students in the classroom discussion forums. When asked about solutions to water pollution in their area, the students could explain the newly gained knowledge about the localization of household waste and phosphate substitution in detergents to solve eutrophication problems in water bodies. Another empirical finding also states that every student must have the ability to use the information to achieve specific goals [38].

The fourth syntax of the RICOSRE-CMM learning model can also strengthen students' skills in understanding the ethical and legal use of information (standard 5). In turn, the RICOSRE-CMM students (70.83), the RICOSRE class (65.24), and the conventional class (64.67) showed a poor understanding of ethics and laws of information use. This can be caused by the student's lack of knowledge of how to cite appropriate information sources. In addition, other research has revealed that knowing how to write appropriate sources of information can avoid fraud in information claims and minimize plagiarism in information writing [25].

The fifth syntax of RICOSRE-CMM is to review and extend the solution. In this phase, the students reviewed the results of the discussions which had been incorporated into their CMM. Students were then asked to communicate their investigation results to the whole class to receive feedback and additional information from other students [39]. This stage also encourages students to validate the accuracy of the problem-solving strategies used in the previous phase. Reviewing the solution also sharpens students' understanding of the material. This phase was then followed by extending the solution, in which students were encouraged to expand their perspectives on alternative efficient solutions to the same problems that will arise in the future [17].

The issue raised in this study is environmental pollution. During the lessons, students were asked to organize important information through a series of problem-solving activities and collaborative mind mapping. The integrated collaborative mind mapping into a problem-solving process helps students find solutions faster because the information received is more directed and structured [24]. CMM in problem-based learning also promotes information literacy in the classroom. In the fifth phase of RICOSRE-CMM, reviewing and extending the solution, students re-evaluate the solution so they can be sure that the information used to solve the problem is accurate [40].

Compared to the RICOSRE and RICOSRE-CMM students, students in conventional classrooms had very little opportunity to develop information literacy. This can happen because students only act as recipients of information through lectures. Traditional learning methods failed to provide college students with the experience of organizing information and solving contextual problems [30]. Even in some university courses, professors are more likely to teach broad academic content but ignore the process by which students achieve learning objectives.

To be successful in studying environmental pollution, students need information literacy to develop scientific methods. Traditional learning cannot provide opportunities for students to engage in scientific work processes, such as recognizing and investigating problems, constructing solutions and solving problems [41]. In conventional classes, students typically learn alone with minimal collaboration. Students often complete tasks independently; group work is found only in presentation tasks. Learning activities like these fail to develop the information literacy of college students. The RICOSRE and RICOSRE-CMM learning models require students to collaborate in examining problems and evaluating and testing problem-solving techniques and strategies. Problem-oriented learning activities that involve active student participation at every stage of the learning process can enhance information literacy and promote engaging and meaningful learning experiences [15].

5. CONCLUSION

This study provides empirical evidence that the RICOSRE-CMM, RICOSRE, and traditional learning models differed significantly with the development of information literacy in college students. Among the three, RICOSRE-CMM learning is most effective in developing students' information literacy in higher education institutions. This research also demonstrates that incorporating collaborative mind mapping into the RICOSRE model effectively develops students' ability to integrate and organize knowledge systematically. RICOSRE-CMM is also able to stimulate students' higher-level thinking skills required to solve various problems related to modern biology. The results of this study explain that RICOSRE-CMM contains a learning process that promotes knowledge of biology through a range of problem-solving activities. The RICOSRE-CMM model prepares students to become literate individuals capable of organizing information effectively. This study has important limitations. The sample size was small and future studies should aim for larger participants. Further research is suggested to examine the potential of the RICOSRE-CMM in a wider research area. In addition, it is possible to integrate the learning model into other biology topics or test its effectiveness on other 21st-century skills.

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