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Collaborative Mind Mapping-Assisted RICOSRE to Promote Students' Problem-Solving Skills

Liah Badriah
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia ORCID: 0000-0002-6715-5002

Susriyati Mahanal*
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia ORCID: 0000-0001-5764-2184

Betty Lukiati
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia ORCID: 0000-0002-9248-7893

Murni Saptasari
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia ORCID: 0000-0001-7990-1482

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Problem-solving skills are a series of complex thought processes that play an important role in the 21st century learning process. Problem-solving skills must be an important focus because they direct students to problem-solving activities and find alternative solutions that are needed objectively in learning or in everyday life. The purpose of this study was to examine the effect of Collaborative Mind Mapping (CMM)-Assisted RICOSRE on improving students' problem-solving skills. This study uses a nonequivalent pretest-posttest control group design with three classes of the Biology Education Study Program at Siliwangi University in Tasikmalaya, Indonesia. This study recruited 100 students, 40 students were in the experimental group with the RICOSRE-CMM model, 35 students in the positive control group used RICOSRE, and 25 students in the negative control group applied direct instruction. The effectiveness of RICOSRE-CMM model learning towards improving problem-solving abilities was evaluated at two points, namely pre-course and post-course. Essay questions were used to collect research data and assess students' problem-solving skills. A rubric is used to evaluate student responses. The findings of this study indicate that the RICOSRE-CMM learning model significantly affects Siliwangi University students' problem-solving skills in Tasikmalaya. Studying with RICOSRE-CMM can simplify students' complex thinking processes toward frequently encountered problems. Systematically organized visualization can help speed up the process of finding solutions effectively and efficiently.

* Correspondency: susriyati.mahanal.fmipa@um.ac.id

Introduction

Problem-solving skills are a person’s cognitive processing activities that enable them to comprehend and solve problems and to use indirect problem-solving methods. (Shute et al., 2016). These problem-solving skills are considered the key to learning in college. These skills help students identify, make the right decisions carefully, systematically, logically, and consider various points of view, and increase learning, achievement, and social motivation (Asiye & Bilge, 2016; Bishara, 2016). Improving problem-solving skills can result in a more meaningful learning experience. The training of problem-solving skills is deemed crucial for college students because they are an integral part of actualizing thinking for the students to navigate various approaches to solving problems encountered in class, career, work, and real-life (Jonassen, 1997).

According to research, the achievement of problem-solving skills tends to be low due to students' passive activities, inability to identify problems, and lack of interest in reading. Students are unable to acquire problem-solving skills (Muhlisin et al., 2022). Students’ poor problem-solving abilities must be addressed immediately to maximize their academic performance. To address this, immediate innovation in the learning process is required to enhance students’ problem-solving skills. Learning innovations must be oriented towards increasing the intensity of student involvement actively, collaboratively, and able to direct students to focus on addressing problems in a systematic and planned manner so that learning is more meaningful (Baran & Sozbilir, 2018; Ültay, 2017). Implementing learning models that encourage students to apply classroom knowledge to a variety of real-world problem-solving situations is one step that can be taken to improve students’ problem-solving skills. One of the suggested innovative learning models is RICOSRE.

RICOSRE is a learning model that emphasizes using problems as a basis for achieving learning objectives for students to actively solve problems in groups (Mahanal et al., 2019). One of the stages in RICOSRE directs students to conduct reading activities that can stimulate curiosity and direct students to act and think in new ways. Direct students to be able to investigate related patterns, concepts, or principles (Noviyanti et al., 2021). The implementation of group problem-solving activities must be equipped with a technique that facilitates the organization of information, the presentation of problem-solving performance in a concrete and systematic manner, and the development of convergent thinking, i.e. the transition from considering numerous alternative solutions to the most suitable solution.

The ability of students to organize information is an essential element of the learning process. Information organization techniques aid students in reviewing information quickly and precisely, thereby facilitating a higher level of comprehension (Al-Khateeb, 2018). In biology classes, this organizational strategy can be combined with the RICOSRE learning model. Every organized idea or piece of information is expected to aid in problem-solving, thereby providing students with new insights and knowledge. Before during, or after learning, a teacher can ask students to organize information graphically through note-taking techniques, either on paper or using a digital application, in order to facilitate the organization of ideas (Calfee & Miler, 2004). A mind map is typically used to organize information. In accordance with current technological advancements, mind maps can be created using a digital platform that connects users within a group, thereby supporting a highly effective offline or online collaboration process. Group discussion and collaboration in making mind maps are part of Collaborative Mind Mapping (CMM).

CMM is paperless groupware that utilizes internet technology as a means of interactive visual representation for synchronous interaction, reciprocal commenting, co-editing in collaborative performance, brainstorming, project management, and many other activities (Arajuo & Gadanidis, 2020). CMM as an instructional design and collaborative strategy that integrates student experience, has been widely implemented in learning (Papushina et al., 2017). CMM facilitates students' construction of knowledge in order to promote student interaction. CMM is also able to pique student interest because it allows students to contribute their knowledge and experience to the generation of material-related ideas and concepts (Stewart & Edwards, 2012). Through CMM, each student in the group can engage in collaborative activities such as editing, revising, saving shared history to be displayed to other students, and conducting synchronous (real-time) and asynchronous discussions without the need for additional applications (Zheng et al., 2020).

CMM is utilized as a navigational tool because it provides coherent problem-solving steps, allowing students to solve problems more structured manner. Structured problem-solving will reduce student difficulties in problem-solving, allowing for more efficient and quicker problem-solving in RISOSRE. Collaborative Mind Mapping as a problem-solving strategy in an environmental pollution course is viewed as a cognitive process in the human brain when discovering and developing a more innovative and diverse new idea (product). This merger produced the Collaborative Mind Mapping-Assisted RICOSRE (RICOSRE-CMM).

The RICOSRE-CMM learning model can enhance students' problem-solving skills because it can stimulate and reconstruct students' thought patterns, allowing them to reorganize the processing of information in order to accelerate problem-solving activities. Students can insert a variety of information in the form of concepts, images, and videos into the CMM that has been designed to address the current problems. CMM has the advantage of facilitating collaboration performance and online discussions with peers or professors in a more flexible, effective, and efficient manner, as well as storing performance results in files that can be easily shared (Arajuo & Gadanidis, 2020). The objective of this study was to determine the effect of RICOSRE-CMM on students'

Research Methods

Research Design

This study is quasi-experimental and employed a nonequivalent pretest-posttest control group design in Siliwangi University, Tasikmalaya, Indonesia between April to June 2021. We chose this design because of the flexibility in comparing the three learning models (RICOSRE-CMM, RICOSRE, and Direct Instruction). We have three classes with the same duration, namely 13 meetings. The students in the three groups all underwent a pre-test. At the end of the courses, a post-test was immediately carried out. Experiment group scores (X1) on pre-test (O1), post-test (O2), positive control group scores (X2) on pre-test (O3), post-test (O4), and negative control group scores (X3) on pre-test (05), post-test (06). This study's independent variables include learning models (RICOSRE-CMM, RICOSRE, and direct instruction). This study's dependent variable is students' problem-solving skills. Table 1 illustrates the research design.

Table 1. Research design

Pretest	Treatment	Posttest
O_1	X_1	O_2
O_3	X_2	O_4
O_5	X_3	O_6

Notes:
O_1, O_3, O_5 = Pretest
O_2, O_4, O_6 = Postest
X_1 = RICOSRE-CMM Learning Model
X_2 = RICOSRE Learning Model
X_3 = Direct instruction Method

Research Sample

In this study, purposive sampling was adopted to select three classes of students at the fourth-semester students level in the 2020-2021 academic year. 100 students (between the ages of 19 and 21) enrolled in the Environmental Pollution class at the Department of Biology Education, Faculty of Teacher Training and Education, Universitas Siliwangi, Tasikmalaya, Indonesia, participated in the study. Prior to sample selection, ANOVA test was conducted in three classes to compare academic level. The ANOVA analysis yielded a significance value of 0.177 > 0.05, indicating no difference in the participants' GPA. Cluster random sampling was used to select the experimental class and the control classes. The RICOSRE-CMM group consisted of 40 students, the RICOSRE group contained 35 students, and the direct instruction group comprised 25 students.

Intervention

The experimental group was involved in the RICOSRE-CMM class approach. RICOSRE is a student-centred instructional model that was developed on problem-solving principles. The implementation of a problem-focused model is deemed crucial because it can stimulate the brain to engage in thinking activities, thereby elevating the role of students in the classroom. In addition, the model with the problem-solving type is able to provide a stimulus for students to think critically, acquire new knowledge and important concepts and be able to solve real-world problems (Mahanal et al. 2019).

The five stages of learning in RICOSRE are (1) reading: in groups, students read and interpret keywords in the cases to be studied, for example about "the impact of pesticide residues on soil", (2) identifying the problem: students identify problems, examples of "disturbances to the growth and diversity of useful microorganisms in the soil". Then, students continued by making a mind map, (3) constructing a solution: students formulate goals and solutions based on supporting sources during activities and complete mind mapping for solutions, for example, "organic farm activities", (4) solving the problem: students carry out activities for preparing solutions, choosing solutions, conducting investigations according to work steps, and completing mind mapping, and (5) reviewing and extending the solution: students carry out discussion activities and class presentations on the results of reviewing and extending problems, making conclusions according to cases and solutions (Mahanal et al., 2019). However, some of the weaknesses of problem-oriented models include that most students still have difficulty identifying and solving problems and that it takes a considerable amount of time (Yu et al., 2015). Therefore, additional learning techniques that maximize their application in learning are required.

In addition, CMM is a multi-user application based on internet technology. It enables synchronous interaction, co-editing, and mutual comments by saving the editing history and displaying it to other contributors (Zheng et al., 2020). Some experts explain that CMM can facilitate discussion in building scientific knowledge in groups. CMM can help negotiate and reach consensus on any topic (Marriott & Torres, 2008) and visualize collaborative ideas generated in real-time discussion forums (Hakim et al., 2020). In addition, CMM can lead to a wider individual understanding related to the use of maps as a tool for social thinking in forming such knowledge (Hung et al., 2014; Y.-T. Lin et al., 2016). The learning process that incorporates digital technology can also enhance students' diverse skills and knowledge (Al-Abdullatif & Gameil, 2021; Rosba et al., 2021). Applications that can be used to make CMM include: *Coggle* (Kamrozzaman et al., 2018; Papushina et al., 2017), *iMindMap* (Wan Jusoh & Ahmad, 2016), *GroupMind* (Shih et al., 2009), *Mindmeister, Popplet* and, *Mindomo* (Arajuo & Gadanidis, 2020; Chen et al., 2019) as well as web-based applications such as www.prosseson.com (Zheng et al., 2020). The CMM platform used in this research is *Miro*.

Miro (https://www.miro.com/) is an internet-based CMM instructional tool accessible via the web. The justifications for using Miro are outlined below. First, it facilitates the creation of collaborative thinking maps. Second, the web-based platform connects users directly without requiring software installation on the device. Thirdly, it supports collaboration performance (working group and sharing) with features and straightforward instructions. College students can perform collaborative activities such as editing, reading, commenting, and discussing thinking maps that have been created in real-time without the need for additional applications to conduct online face-to-face meetings. Figure 1 illustrates, for instance, the process of creating a CMM using the Miro platform and a student-created mind map.

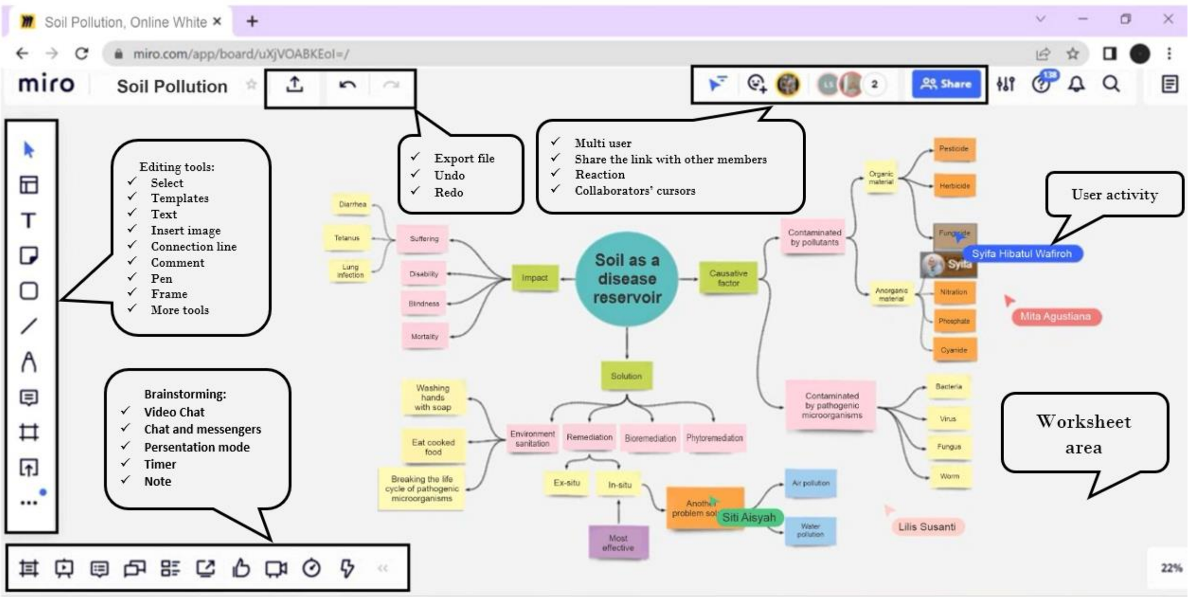

Figure 1. Collaborative Mind Mapping in Miro

Based on previous explanation, Collaborative Mind Mapping-Assisted RICOSRE (RICOSRE-CMM) is a learning model in which implementation is aided by mind map technology and conducted through direct collaboration. The RICOSRE learning model was developed based on the principles of problem-solving activities and aimed to improve students' ability to develop knowledge and collaboration and train their problem-solving skills by identifying appropriate, efficient, and effective steps to solve problems in groups.

The integration of CMM in RICOSRE learning can be seen in every learning syntax. This integration is expected to provide a different learning experience for students (Hidayati et al., 2021) and help visualize ideas and brainstorming activities (Buzan, 2006). Linear and centralized idea construction activities can help students focus on problems so that visual confusion can be avoided in learning (Polat et al., 2022). The use of CMM in learning also initiates digital-based learning that can be done synchronously and asynchronously that can be done collaboratively. This has been proven to increase student motivation and make learning activities more enjoyable (Qi, 2018). The combination of the RICOSRE learning model with CMM, hereinafter abbreviated as RICOSRE-CMM.Table 2 displays the learning steps for the RICOSRE-CMM, RICOSRE, and direct instruction classes.

Table 2. The RICOSRE-CMM, RICOSRE and direct instruction learning stages

Learning Stages		
RICOSRE-CMM	**RICOSRE**	**Direct instruction**
Reading	Reading	Offering encouragement
Identifying the problem with CMM	Identifying the problem	Grouping students
Constructing the solution with CMM	Constructing the solution	Announcing group assignments
Solving the problem with CMM	Solving the problem	Conducting group discussions
Reviewing and extending the solution with CMM	Reviewing and extending the solution	Presenting the results of group discussions

Research Instruments

Problem-solving skills refer to an intellectual activity which is regarded as the highest level of complex thought and perception. Problem-solving involves the utilization of all intellectual abilities possessed by an individual. Every individual who engages in problem-solving activities must simultaneously employ memory, perception, reasoning, conceptualization, and language, as well as emotions, motivations, self-confidence, and situational control (Hoi et al., 2018; Shute et al., 2016). Problem-solving skills in the classroom encourage students to collaborate in developing problem-solving strategies and enhancing problem-solving skills (Muhlisin et al., 2022).

The problem-solving skills test is comprised of twelve essay questions. Environmental science specialists validated the test to determine its rational validity (content and construct validity). The development of this instrument involved three experts. They are invited to provide ratings and suggestions. The result is a CVI value of 0.93. In order to determine the empirical validity and reliability of the test, it was first administered to students not included in the research sample. The results of calculations using the r pearson correlation show a range of 0.242 to 0.463, classified as good to excellent (Kolte, 2015). Meanwhile, Cronbach's alpha value of 0.67 is high and can be used (Guilford, 1956). The validity test demonstrated that the questions were valid and reliable. The essay test contains environmental pollution-related questions that the instructor uses to evaluate the students' problem-solving skills.

The indicators observed in problem-solving skills according to the University of Southern Maine (University of Southern Maine, 2012) include: (1) defining the problem, (2) developing a plan to solve the problem, (3) collecting and analyzing information, and (4) interpreting findings and solving the problem. The test is accompanied by a rubric (Table 3) and was created based on the following indicators: defining the problem, developing a plan to solve the problem, collecting and analyzing information, interpreting the results and solving the problem (University of Southern Maine, 2012). Each indicator corresponds to three questions.

The following are examples of problems that are displayed on the test.
Problem:
When Ani was carrying out a field study around the Lake Gede area, Tasikmalaya City, she identified a partial closure of the waters by hyacinth plants (*Eichhornia crassipes*).
Questions:

- Considering the lake's morphological appearance and the phenomenon discovered by Ani, what problems are affecting the lake?
- Describe one of the most effective initial strategies the local community or government can implement to restore the lake's condition after it has been partially overgrown with aquatic plants.

Table 3. Problem-solving test rubric

Indicator	Descriptors	Score
Defining the problem	Students are able to clearly articulate the problem and identify the root causes.	4
	Students are quite capable of articulating the problem without addressing its root cause.	3
	Students are less able to articulate the problem.	2
	Students cannot articulate the problem.	1
Developing a plan to solve the problem	Students develop clear and concise plans for problem-solving that include alternative strategies and are consistent with the conclusions.	4
	Students develop an excellent plan that is consistent with the conclusion.	3
	Students develop standard plans that do not correspond to the conclusions.	2
	Students do not develop a coherent strategy for problem-solving.	1
Collecting and analyzing information	Students gather data from a variety of sources and analyze it in depth.	4
	Students simply collect information and demonstrate adequate analysis skills.	3
	Students gather data that is insufficient for meaningful analytical activities.	2
	Students do not collect sufficient and pertinent data to solve problems.	1
Interpreting findings and solving the problem	Students provide a logical interpretation of the results, the solution to the problem, and an alternative solution.	4
	Students provide a reasonably logical interpretation of the findings and the solution to the problem, but they do not offer alternative solutions.	3
	Students provide an interpretation of the findings that are not entirely logical and do not derive a logical solution to the problem.	2
	Students do not interpret or conclude their findings.	1

Source: University of Southern Maine (University of Southern Maine, 2012)

Data analysis

Descriptive statistics are used to describe the performance of students' problem-solving skills on the pre-test and post-test. Analysis of covariance (ANCOVA) was utilized to analyze the research data (significance level of 0.05). The covariate is the pretest scores, which were used to control variables over which the researcher had no control. Since the analysis results were significant, the LSD (Least Significance Different) test was then conducted. Prior to the ANCOVA analysis, the research data were subjected to two assumption tests: the One sample Kolmogorov-Smirnov test and the levene's test for equality of variances ($p>0.05$). Table 4 summarizes the normality and homogeneity test results.

Table 4. The normality and homogeneity test results

Dataset	Kolmogorov-Smirnov test	Leven's test

	Test statistic	Sig.	Levene statistic	Sig.
Pretest scores	0.076	0.164	0.133	0.875
Posttest scores	0.068	0.200	0.198	0.820

Findings

To answer the research questions, descriptive statistics are applied (Table 5). The calculation results show that the student's initial problem-solving ability performance is 53.20 of the RICOSRE-CMM class, 50.91 of the RICOSRE class, and 50.10 of the Direct Instruction class. These results indicate that there is no significant difference between the three classes. Meanwhile, the performance of solving abilities after being given an intervention was 59.20 of the RICOSRE-CMM class, 53.58 of the RICOSRE class, and 52.28 of the Direct Instruction class. Thus, the increase in the RICOSRE-CMM l class (11.27%) was greater than the RICOSRE class (5.24%) and Direct Instruction (4.94%)

Table 5. The results of the descriptive statistics

Group	Pretest	Post-test	Difference	Score Increase
RICOSRE-CMM	53.20	59.20	6.00	11.27 %
RICOSRE	50.91	53.58	2.67	5.24 %
Direct instruction	50.10	52.58	2.48	4.94 %

The results of the ANCOVA analysis of the effect of the RICOSRE-CMM, RICOSRE, and direct instruction method on students' problem-solving skills can be seen in Table 6. The results of ANCOVA in Table 5 indicate that F = 7.085, with a significance value of 0.001 ($p<0.05$). These findings suggest that the RICOSRE-CMM, RICOSRE, and direct instruction method have a significant impact on the problem-solving skills of college students.

Table 6. The ANCOVA results

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Learning Models	1088.470[a]	3	362.823	7.375	.000
Intercept	3044.614	1	3044.614	61.886	.000
Pretest	200.844	1	200.844	4.082	.046
Model	697.092	2	348.546	7.085	.001
Error	4722.889	96	49.197		
Total	314687.650	100			
Total Average	5811.359	99			

R Square = 0.187 (Adjusted R squared = 0.162)

In addition, the LSD (Least Significance Different) test was conducted to determine the level of statistical significance of the three treatments. Table 7 displays the LSD test results. The results of the LSD test presented in Table 6 indicate that the mean problem-solving score varies depending on the learning model employed. The corrected mean score of problem-solving skills in the RICOSRE-CMM class (58.63) was significantly higher than the corrected mean score in the RICOSRE class (53.74), as well as the corrected mean score in the direct instruction class (52.91). The RICOSRE corrected mean score for problem-solving skills was not significantly different from the direct instruction class corrected mean score.

Table 7. The results of the LSD test on students' problem-solving skills

Group	Corrected Score	Std. Error	95% Confidence level		LSD Notation
			Lower Bound	Upper Bound	
RICOSRE-CMM	58.63	1.122	56.626	61.080	a
RICOSRE	53.74	1.188	51.379	56.095	b
Direct instruction	52.91	1.412	50.107	55.714	b

Discussion and Conclusion

Implementing the RICOSRE-CMM learning model can improve students' problem-solving skills because each learning stage has the potential to promote student engagement in learning and encourage students to think actively and critically (Mulnix, 2012). The RICOSRE-CMM syntax assists students in visualizing and organizing ideas in a systematic manner. Students are also encouraged to work collaboratively and synergistically to enhance evaluation, decision-making, and problem-solving (Yu et al., 2015). The application of CMM to the first RICOSRE syntax, namely *reading*, helped the students to obtain the information needed to comprehend the course material. At this stage, the students were required to read valid and credible literature sources, such as scientific articles, textbooks, and other relevant references. Reading activities are considered an important part of learning because reading is the initial capital for students in the preparation of mind mapping (Astriani et al., 2020; Rosba et al., 2021). Through reading, students are expected to acquire various information and ideas for use as CMM components. Previous research has demonstrated that reading activities performed during the learning process can facilitate the acquisition of a broader knowledge base to support problem-solving activities (Ulu, 2017). When students are given a reading stimulus for learning, they can build on their prior knowledge and connect it to new information in order to solve problems (Garner, 1984; Wijaya et al., 2014).

The second stage in RICOSRE-CMM is *identifying the problem*. Problem identification is the foundation of the problem-solving procedure (Von Hippel & Von Krogh, 2016). This step can teach students to be more critical of the obtained information and develop problem-focused communication (Suhirman et al., 2020). The troubleshooting process will eventually become the focal point of the CMM section. Systematically executing the problem identification procedure will bring the problem's focal point into sharp focus. Suppose this problem is centred on the central section of the CMM. In that case, other members as collaborators can provide diverse perspectives and the desired outcomes from the problem-solving process that can develop during the learning process (Wei et al., 2020). Using CMM can also make it easier for students to organize, comprehend information effectively, analyze, collaborate in real-time with each group member, and visualize their thinking processes. In conclusion, this syntax facilitates problem-solving activities in a directed and efficient manner in order to achieve the desired learning objectives from the outset (H. Lin & Faste, 2011; Rosba et al., 2021; Zahedi & Heaton, 2016).

The third syntax of RICOSRE-CMM is *constructing the solution*. After identifying the problem, students are instructed to identify a variety of alternative solutions. Students are encouraged to explore and analyze more information and are trained to evaluate causal assumptions when selecting solutions to identified problems during this stage. *Constructing the solution* will determine the steps for selecting the most effective strategy to use to solve the problem (Pólya, 1988). Various information that can be used for the preparation of alternative solutions is placed in the CMM. The purpose of collecting and grouping information is to organize and classify the information obtained by students from various kinds of literature. A crucial component of a problem-solving plan is information ordered by importance so that groups can solve problems in class in a modular fashion, making problem-solving activities more effective and efficient (Morris et al., 1998).

Moreover, during the *solving the problem* stage, a number of skills are fostered, including information gathering, classification, analysis, scientific reasoning, and decision-making precision (He et al., 2018). This syntax of RICOSRE-CMM emphasizes the significance of making accurate decisions to select the most appropriate solution from a collection of alternative solutions. Students' high-level and complex thinking, literacy, and communication skills can be stimulated by this activity, leading to efficient information processing, forming complete ideas, and accurate decision-making.

The final syntax of this model is to *review and extend the solution*. At this stage, students present the outcomes of their group discussions in the CMM in order to receive feedback from the audience through class discussions and to evaluate the audience's suggestions (Rezapour-Nasrabad, 2019). The role of CMM at this stage is to assist with managing the flow of presentations and writing reports that are more systematic and straightforward (Papushina et al., 2017). Each group member will be aware of their contribution, which will encourage them to commit to completing the work. CMM also assists group members in seeing and comprehending the subject's purpose. Important criteria for teamwork in achieving the same vision and mission are conducive activities resulting from using CMM.

The combination of RICOSRE and Collaborative Mind Mapping in the Environmental Pollution course contributes significantly to the enhancement of students' problem-solving skills. Combining the characteristics of the problem-based RICOSRE model with CMM, which has many advantages as described previously, is optimal. Previous researchers have implemented CMM in learning, which aids in the development of higher-order thinking skills (Arajuo & Gadanidis, 2020). The ability to solve problems is one of the higher-order thinking skills.

When students participate in CMM using the Miro web application. Each group utilized collaboration in real-time to produce CMM. Each group member might engage in direct conversation in order to practice collaboration skills. In addition, students could rapidly practice their analytical and decision-making skills by using the video, chat, and commentary features to communicate fluently. A further advantage of this platform is its presentation mode, which enabled the students to present slides in class to receive feedback and reflect on other groups' suggestions and contributions.

Students can also visualize problems using CMM. The method of visualizing and systematizing information for learning can enhance students' academic performance (Vorona-Slivinskaya et al., 2020). CMM facilitates the visualization of the connection between the main theme and problem branches (Hakim et al., 2020). In addition, CMM permits limitless idea exploration prior to problem resolution (Chen et al., 2019; Hung et al., 2014; Y.-T. Lin et al., 2016). This study reveals that the RICOSRE and RICOSRE-CMM models effectively enhance students' problem-solving skills. The learning process in higher education should emphasize the development of problem-solving skills. With these skills, graduates are expected to be able to withstand the challenges of the 21st century and compete in the workplace and social spheres.

Conclusion, Limitation and Future Work

On the basis of the above analysis and discussion, it can be concluded that the RICOSRE learning model supported by Collaborative Mind Mapping (CMM) has an effect on students' problem-solving skills. This research also demonstrates that collaborative mind mapping in the RICOSRE model plays a crucial role in visualizing, accommodating, and compiling ideas and information in a systematic and structured manner so as to accelerate the problem-solving process.

This research reveals that RICOSRE-CMM can increase solving ability higher than RICOSRE and Direct Instruction. However, there is potential for biased results because participants in our study used convenient, convenience-based sampling. All participants were registered from Siliwingi University, Tasikmalaya Indonesia. Thus, the sampling technique used can limit inference and generalize research results. The results of this study were also limited to three classes of sophomore students. Future research may be needed using a larger sample taking into account various student demographic variables. In addition, the findings of this study are also limited to Environmental Pollution lectures and problem-solving skills variables so that in the future, the integration of the RICOSRE-CMM model can be implemented in different subjects, education levels and other 21st century skills.

The application of the use of CMM has become a focus for online learning but is often hampered by the application of learning models. This research develops the RICOSRE learning model to support and provide the application of CMM for problem-solving skills. Consequently, direct instruction learning is incapable of enhancing students' problem-solving skills because students tend to be passive and learning is unidirectional (Shishigu et al., 2018; Sihaloho et al., 2017). Therefore, selecting effective pedagogical practices to influence student performance in learning is essential (Davies et al., 2013).

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