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ReCODE integrated collaborative mind mapping to improve students' creative thinking skill

Kalimatul Maghfiroh, Susriyati Mahanal*, Sitoresmi Prabaningtyas

Universitas Negeri Malang, Indonesia

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Abstract: This study aims to determine the effect of reading, connecting, observing, discussing, and evaluating (ReCODE) model integrated with collaborative mind mapping (CMM) on creative thinking skills of high school students in biology learning. This quasi-experimental study used a pretest-posttest nonequivalent control group design. There were 10 description questions used in assessing students' creative thinking skills. Data were collected from 106 students of class XI at senior high school in Sidoarjo, Indonesia. The data were analyzed using ANCOVA at 5% significance level followed by LSD test. The results showed that the ReCODE-CMM learning model had an effect on students' creative thinking skills. The conclusion of this study is that the ReCODE-CMM model is able to improve each indicator of creative thinking skills because the components of this indicator have been integrated into the syntax of the learning model which involves the process of reading, linking concepts and facts in the problem, and organizing information collaboratively to create a solution to a problem.

Keywords: : Collaborative mind mapping, creative thinking skill, ReCODE

Abstrak: Penelitian ini bertujuan untuk mengetahui pengaruh model pembelajaran *reading, connecting, observing, discussing, dan evaluating* (ReCODE) terintegrasi *collaborative mind mapping* (CMM) terhadap keterampilan berpikir kreatif siswa SMA pada pembelajaran biologi. Penelitian kuasi eskperimen ini menggunakan desain *pretest-posttest nonequivalent control group*. terdapat 10 pertanyaan uraian yang digunakan dalam menilai keterampilan berpikir kreatif siswa. Data dikumpulkan dari 106 siswa kelas XI SMA di Sidoarjo, Indonesia. analisis data penelitian menggunakan ANCOVA pada tingkat signifikansi 5% diikuti dengan uji LSD. Hasil menunjukkan bahwa model pembelajaran ReCODE-CMM berpengaruh terhadap keterampilan berpikir kreatif siswa. Kesimpulan penelitian ini yakni model ReCODE-CMM mampu meningkatkan setiap indikator keterampilan berpikir kreatif karena komponen indikator ini telah diintegrasikan ke dalam sintaks model pembelajaran yang melibatkan proses membaca, mengkaitkan konsep dan fakta dalam permasalahan, dan mengorganisir informasi secara kolaboratif untuk menciptakan solusi dari suatu masalah.

Kata kunci: Collaborative mind mapping, keterampilan berpikir kreatif, ReCODE

*Corresponding author: susriyati.mahanal.fmipa@um.ac.id

INTRODUCTION

Students of the 21st century need to master some knowledge and skills to face world of work competition and global challenges (Afandi et al., 2019, Nasir et al., 2024). In line with this, education must be oriented not only toward academic achievement but also toward equipping students with relevant competencies for the future. 21st century skills are complex and need to be taught in the learning process (Mutohhari et al., 2021). These skills encompass critical thinking, communication, collaboration, and creativity, which must be integrated into various learning activities. One of the 21st century skills needed by students to become quality human resources is creative thinking skills (Ramdani et al., 2021). Creative thinking plays a key role in helping students generate original ideas and adapt to dynamic situations. Quality human resources are able to master everything conceptually

and come up with new innovations (Shahroom & Hussin, 2018). This means they are not only knowledgeable but also capable of applying their knowledge in innovative ways. New innovations can be raised in students through empowering creative thinking (Bai & Song, 2018; Tamba et al., 2020).

Creative thinking skills involve the skills to combine ideas, produce original concepts, and assess the value of current ideas (Bengi, 2015). Creative thinking skills are skills to transform something into a new or different form (Greenstein, 2012). Creative thinking involves activities in finding gaps in a problem, looking for meaningful connections, generating many possibilities (from different points of view or perspectives) original and detailed to expand the possibility of problem solving (Treffinger et al., 2002). Creative thinking skills play a crucial role in enabling students to resolve problems (Hobri et al., 2020) and generate solutions through innovative ideas (Prianto et al., 2016).

Studies show that high school students' creative thinking skills in biology learning need to be improved. Creative thinking skills in Indonesia are low (Madyani et al., 2020; Zubaidah et al., 2017). The creative thinking skills of grade XI high school students in Sidoarjo have an average aspect of fluency 29.46, originality 28.14, elaboration 48.28, flexibility 36 out of 100 (Mauludiah & Novita, 2021). The results of a preliminary study of creative thinking skills conducted on 90 students of senior high school in Sidoarjo still need to be improved with the acquisition of an average score of 37.22 fluency indicators, 42.78 flexibility, 39.72 originality, 40.56 elaboration, and 40.83 metaphorical thinking out of a total of 100 on human respiration system material. The results of the preliminary study of creative thinking skills on the material of the human excretory system are not much different with the average score of the fluency indicator of 36.67, flexibility of 49.72, originality of 35.83, elaboration of 48.61, and metaphorical thinking of 49.17 out of a total of 100.

The biology learning process in Indonesia primarily emphasizes memorizing concepts (Prayitno et al., 2015). This indicates a learning approach that still centers on rote memorization rather than conceptual understanding. However, biology education should focus on developing students' ability to analyze, create, and apply concepts to real-life situations (Rahmadani et al., 2017). Such competencies are essential for equipping students with higher-order thinking skills that are relevant in modern scientific contexts. Studying biology requires students to build a comprehensive understanding, ranging from microscopic to macroscopic levels (Tamba et al., 2020). Creative thinking skills play a crucial role in biology learning, as they help students grasp concepts effectively and enhance their ability to innovate in daily life (Yustina et al., 2020).

Creative thinking can be fostered by presenting problems that encourage students to develop innovative solutions (Daryanes & Putra, 2022). The learning model chosen by teachers significantly influences how well students' creative thinking abilities are cultivated (Monahan et al., 2019). Implementing problem-based learning models (Muzaimah et al., 2022) and incorporating mind maps into lessons (Mahmud et al., 2013; Papushina et al., 2017) are effective strategies for enhancing creative thinking. Problem-based learning allows students to develop unique problem-solving approaches and interact with their peers in both physical and digital settings, which helps nurture their creative thinking skills (Samaniego et al., 2024).

The ReCODE Learning Model is a problem-based learning model that involves student collaboration in groups so that it can develop students' creative thinking skills (Azis, 2024). The ReCODE model consists of Reading, Connecting, Observing, Discussing, and Evaluating phases (Saenab et al., 2021). The ReCODE model is considered appropriate for fostering curiosity, leading students to actively seek knowledge concepts based on facts and evidence obtained by students (Fahriani et al., 2023). The ReCODE model has the advantage of integrated reading stages in a flipped classroom (Surur et al., 2023). In addition, the ReCODE model has an evaluation stage that is important for empowering creative thinking skills (Akpur, 2020). Creative thinking is thinking that allows students to evaluate their own ideas, their peers' ideas, products, and the final process (O'Sullivan, 2021). The ReCODE learning model has a weakness in that it does not provide opportunities for students to express their ideas in a structured manner during the problem-solving process (Saenab et al., 2021). Therefore, it requires the support of tool to facilitate students in organizing their ideas more systematically and coherently, enhancing the clarity and structure of their thinking within the learning context.

Collaborative mind mapping can serve as an effective tool for structuring idea generation. Integrating mind maps into learning should be further developed to enhance students' creative thinking skill (Yoon & Kang, 2015). This technique engages both the left and right hemispheres of the brain, clarifies thought processes, provides both an overall perspective and detailed insights simultaneously, and helps organize and comprehend information systematically (Spencer et al., 2013). Additionally, it improves creative thinking skills and boosts retention (Feng et al., 2023). Therefore, incorporating collaborative mind maps into the ReCODE model is essential, as they help structure students' ideas during the problem-solving process.

Collaborative Mind Mapping (CMM) is a website or app that allows multiple users to create mind maps together online. It enables users to collaborate in real time, make joint edits, and leave comments for one another by keeping a record of all changes and displaying them to other users (Zheng et al., 2020). Examples of collaborative mind mapping tools include GitMind, Miro, XMind, and others, which provide interactive features to support online collaboration. In this study, GitMind was used as the collaborative mind mapping tool. CMM can facilitate discussion in building creative thinking skills in groups (Hidayati et al., 2023). Elaboration of ideas can train the elaboration aspect of creative thinking skills (Treffinger et al., 2002). CMM can visualize the ideas generated in the discussion forum in real-time (Lin et al., 2016).

The combination of the ReCODE and CMM learning models, hereafter referred to as ReCODE-CMM, will be implemented in learning biology material on the respiration system and excretory system. Excretory system material is characterized by interrelated concepts and processes, and will be difficult to understand if delivered with conventional models (Panjaitan et al., 2019). Students often struggle to grasp the concept of the excretory system due to its abstract nature (Ristanto et al., 2020). They typically resort to memorizing the organs and processes involved in the human excretory system, without being able to connect the concepts learned to real-life phenomena or the subject matter being explored. (Sunyono, 2018). Human respiration system material is one of the difficult Biology materials because it contains concepts that must be understood and students are required to be able to connect each concept (Nurjanah et al., 2022). Respiratory system material is

material that emphasizes direct experience because it is related to everyday life with abstract concepts (Rafiqa et al., 2022).

Students are expected to develop the ability to connect concepts with factual information to create more efficient solutions to relevant problems. This material focuses on analyzing issues related to the respiratory and excretory systems in daily life, aligning with the framework of the ReCODE-CMM model. Therefore, the instructional approach is designed to assist students in overcoming challenges encountered during the learning process. CMM supports problem-solving by improving students' concentration and structuring problems in an organized manner, which helps in identifying effective solutions more efficiently. Therefore, this study seeks to examine the differences in creative thinking skills among students taught using the ReCODE-CMM model, the ReCODE model, or conventional.

METHOD

This study employs a Quasi-Experimental method. The research design used is the Pretest-Posttest Nonequivalent Control Group Design, characterized by the presence of a control group, although not all groups or classes are capable of fully controlling external variables that may influence the experimental process (Cohen et al., 2018; Creswell, 2012) (Table 1). The independent variable in this study is the learning model, while the dependent variable is creative thinking skills.

Table 1. Research design

Pre-test	Group	Number of Student	Post-test
O1	ReCODE-CMM	35	O2
O3	ReCODE	36	O4
O5	Conventional	35	O6

The population in this study consisted of all 11th-grade high school students specializing in biology at senior high school in Sidoarjo, East Java, Indonesia, during the odd semester of the 2024/2025 academic year. The students were between 16 and 18 years old. Participants were chosen at random. To evaluate students' creative thinking skills, this study employed a research instrument consisting of 10 descriptive questions. The questions were developed with reference to the creative thinking skill indicators proposed by Treffinger et al., which encompass five indicators: fluency, flexibility, originality, elaboration, and metaphorical thinking.

The assessment of creative thinking skills underwent validation by two experts specializing in learning instruments, who served as rational validators, while experts in human physiology assessed the content validity. Additionally, a sample of 90 students who were not members of the primary research group was used to assess the empirical validity and reliability of the instrument. This empirical evaluation was undertaken at a senior high school in Sidoarjo, with the validity study completed using the Pearson product-moment correlation approach. According to the analysis's findings, the test items' validity ratings ranged from 0.201 to 0.488. Reliability testing, conducted using Cronbach’s Alpha, yielded a score of 0.805, indicating that the test was reliable.

The study began with a pretest administered to all students before the intervention, aimed at collecting baseline data on their creative thinking skills across all treatment groups. 16 sessions were employed to apply the learning model, with 8 of those sessions devoted to the respiratory system and another 8 to the excretory system.

Learning activities carried out in the ReCODE-CMM (experimental) class consisted of i) reading; ii) connecting concepts with CMM; iii) observation; iv) discussion with CMM; and v) evaluation. However, CMM is not incorporated into any phase of the ReCODE model. In contrast, conventional learning involves several stages: students are encouraged to engage in classroom activities, work in small groups, and present the outcomes of their group discussions on relevant topics. Analyzing and interpreting the data to make inferences is the main goal of the last learning phase.

The first step of the inferential statistical analysis was assumption testing, which involved evaluations of variance homogeneity and data normality. Normality was assessed using the one-sample Kolmogorov-Smirnov test, while the homogeneity of variances was determined through Levene's test. Following these tests, ANCOVA was applied to the post-test data, using pretest scores as covariates. The ANCOVA aimed to determine the differences in creative thinking skills among students who were instructed using the ReCODE-CMM model, the ReCODE model, and conventional learning. ANCOVA results indicated a significant difference, the LSD test applied to compare the mean scores across all treatment groups.

RESULTS AND DISCUSSION

Students' creative thinking skills were evaluated based on their posttest results. The assessment measured five key indicators from the creative thinking skills test administered to students. Figure 1 presents a comparison of creative thinking skill scores among students in the ReCODE-CMM, ReCODE, and conventional learning groups.

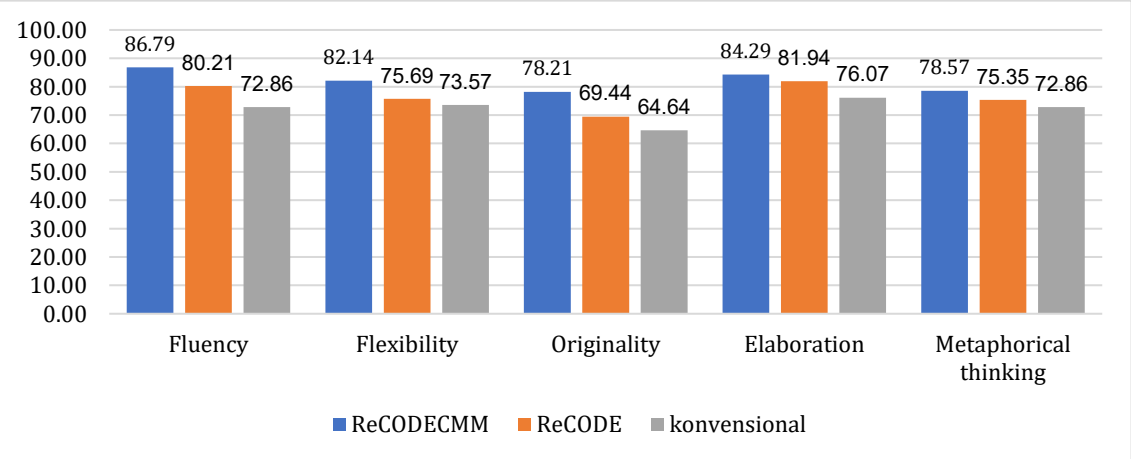

Fig. 1. Average posttest score on each indicator of creative thinking skills

Before proceeding with hypothesis testing, assessments for data normality and variance homogeneity were conducted. Levene's test ($p > 0.05$) confirmed the uniformity of variances, while the Kolmogorov-Smirnov test verified that the data followed a normal distribution. The results of these tests are shown in Table 2, which shows that the data are

normally distributed. The homogenous variance of the data is shown in Table 3. The next step involved hypothesis testing to examine the impact of different learning models on students' creative thinking skills. ANCOVA was used for hypothesis testing, with pretest scores as covariates. If the analysis significant results, the ANCOVA test was followed by the LSD test.

Table 2. Results of normality tests

Materials	Group	Sig.	Description
Respiratory System	Pre-test ReCODE-CMM	0.077	Normal
	Post-test ReCODE-CMM	0.200*	Normal
	Pre-test ReCODE	0.126	Normal
	Post-test ReCODE	0.144	Normal
	Pre-test Conventional	0.200*	Normal
	Post-test Conventional	0.188	Normal
Excretory System	Pre-test ReCODE-CMM	0.175	Normal
	Post-test ReCODE-CMM	0.200*	Normal
	Pre-test ReCODE	0.087	Normal
	Post-test ReCODE	0.200*	Normal
	Pre-test Conventional	0.200*	Normal
	Post-test Conventional	0.200*	Normal

Table 3. Results of homogenity tests

Group	Levene's test score	Sig.	Description
Creative thinking pretest	0.320	0.969	Homogen
Creative thinking posttest	0.957	0.388	Homogen

Table 4 displays the ANCOVA results at a 5% significance level, analyzing the impact of three learning models on students' creative thinking skills. The findings indicate a significant variation in creative thinking skills among students who participated in learning using these three models ($F = 16.389$; $p < 0.001$). This difference arises from the distinct phases and instructional sequences within each learning model.

Table 4. ANCOVA result

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1885.688[a]	3	628.563	11.619	<.001
Intercept	22710.032	1	22710.032	419.787	<.001
Pretest	130.387	1	130.387	2.410	.124
Learning Model	1773.224	2	886.612	16.389	<.001
Error	5518.086	102	54.099		
Total	633262.500	106			
Corrected Total	7403.774	105			

Note: R Square=0.255 (Adjusted R Squared = 0.233)

The ANCOVA results in Table 4, with a significance level below 0.001 and $F = 16.389$, demonstrate a statistically significant difference in the creative thinking skills of students

taught using the three distinct learning methods (sig. learning model<0.05). LSD test was conducted to determine the difference. Table 5 presents the LSD test results.

Table 5. LSD test results

Class	Pretest	Posttest	Difference	Average score	LSD notation
ReCODE-CMM	59.21	82.00	22.79	82.04	a
ReCODE	59.86	76.50	16.64	76.51	b
Conventional	59.79	72.00	12.21	71.99	c

Table 5 presents the LSD test results, which identify the most effective learning model for enhancing students' creative thinking skills. The average score for creative thinking in the ReCODE-CMM group (82.04) was higher than that of the ReCODE (76.51) and conventional (71.99) groups.

The variation in students' average scores across the three groups can be linked to differences in classroom activities and task structures. The higher scores in the ReCODE-CMM group indicate that this model is more effective in developing creative thinking skills. This is because the ReCODE-CMM approach includes learning phases that enhance reading skills and enable students to systematically organize concepts through collaborative mind mapping. The CMM activity helps students produce a final product that visualizes concept flow and supports decision-making during discussions. Additionally, CMM fosters collaboration within small groups, allowing students to work together in structuring and solving problems. The main objective of integrating CMM into the ReCODE class is to help students visualize and structure concepts obtained from problem-solving tasks in order to create effective solutions. An example of a mind map developed by students in the ReCODE-CMM group can be seen in Figure 2.

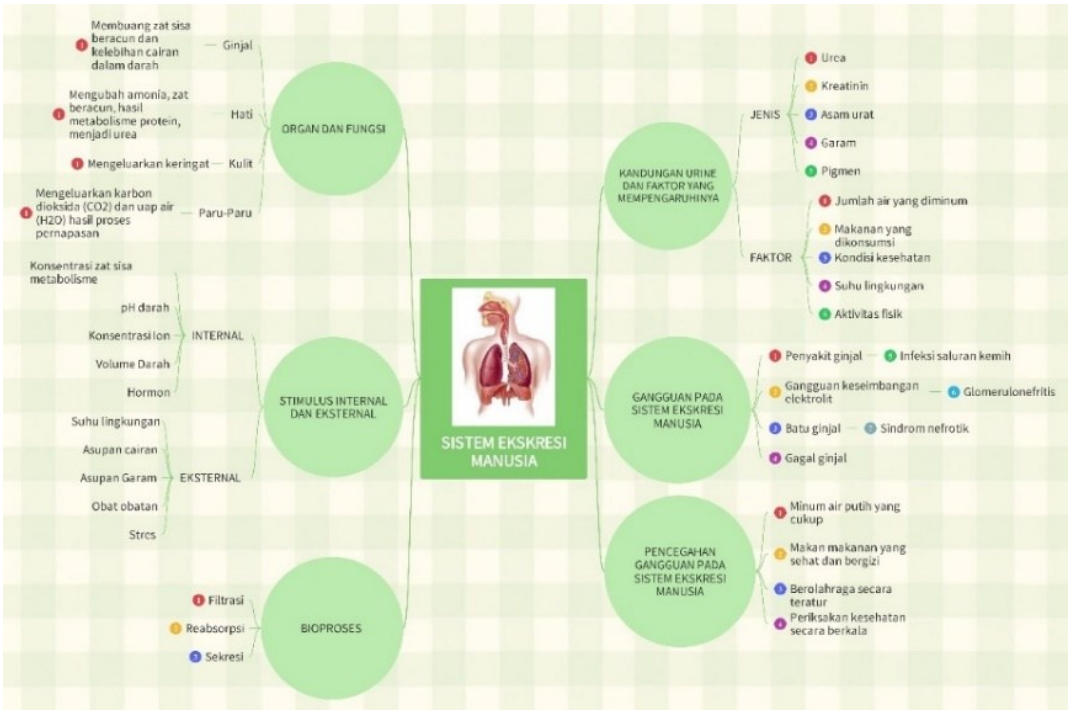

Fig. 2. Collaborative mind mapping on human excretory system material

The initial phase of the ReCODE-CMM model is reading. Students are encouraged to read before attending class (flipped classroom approach) to gather information on the topic to be discussed and note down key concepts they understand or find challenging. Reading serves as a fundamental method for acquiring knowledge (Woolfolk-hoy, 2005). It is a complex cognitive process that involves recalling and reflecting on past experiences (Shihab, 2011). Through regular reading practice, students develop the ability to plan, comprehend, monitor their understanding of the material, and engage in self-assessment (Bahri et al., 2020). Research proves that higher verbal ability correlates with creative thinking skills (Mourgues et al., 2014). Reading comprehension is part of the creative thinking process because reading expresses situations where concepts and ideas are related to each other (Okuda et al., 1991). Reading is important for an individual's elaboration process because it involves mental processes in understanding and interpreting the text contributing to expanding and detailing creative ideas (Altaany et al., 2024).

The second phase of the ReCODE-CMM model is connecting integrated Collaborative Mind Mapping. This phase directs students to connect the reading results with the facts presented by the teacher in the classroom. The facts that are connected to the understanding of the concepts resulting from the reading process play a role in the students' creative thinking process. Creative thinking involves convergent thinking that is closely related to reasoning. At this stage CMM is able to facilitate students to organize concepts in groups (Araujo & Gadanidis, 2020). Every well-defined concept or fact is meant to help pupils solve problems and gain new perspectives and a deeper comprehension (Badriah et al., 2023). Teachers can assist students in organizing information by encouraging them to take notes visually either on paper or digitally before, during, or after the learning process (Miller & Calfee, 2004). Good organization of ideas can empower aspects of flexibility and originality in creative thinking skills (Kenett et al., 2018; Naser & Almutairi, 2015).

The third phase of the ReCODE-CMM model is CMM integrated observation. Students are directed to conduct experiments and then add information found on the mind map. Observation activities are a stage for students to discover and validate concepts through direct experience (Saenab et al., 2021) Creative thinking arises from various stimuli and experiences of an individual (Chakravarty, 2010; Kilgour, 2022). After making observations, students can validate or add keywords to the mind map that has been designed in the second phase so that students can understand and remember the findings that have been obtained. CMM will facilitate students to replace, delete, and add new concepts from the concepts in the previous stage (Suharto et al., 2023). The initial phase of creative ideas is characterized by an increase in alpha power in the brain, which indicates an associative mode of thinking and memory processes (Schwab et al., 2014). This pattern of alpha power is critical for idea retrieval (Rominger et al., 2019). The addition of mind maps at this stage is supported by the opinion of Buran and Filyukov (2015) who stated that remembering keywords on mind maps is easier than remembering readings and students might consider creative ideas by incorporating images and other illustrations.

The fourth phase of the ReCODE-CMM model is discussion. In this phase, students are directed to discuss the results of the mind map in front of the class. Discussion activities can empower creative thinking skills (Aguilar & Turmo, 2019; Göçmen & Coşkun, 2019). Discussion activities play a role in the process of generating and developing the final idea (Soboleva et al., 2021). Discussion activities help individuals to generate better ideas

because every comment related to the idea is able to lead individuals to a more structured and creative outcome (Link et al., 2016). Intergroup feedback communication is important for identifying flaws in ideas and adding valuable insights to the idea generation process (Ignatyeva et al., 2018). Empirical studies related to learning models with integration of discussion methods can improve creative thinking skills (Moma, 2017).

The fifth phase of the ReCODE-CMM model is evaluation, where students reflect on their learning and document it in a journal. During this process, teachers provide feedback based on students' responses, which helps assess the effectiveness of the learning outcomes (Muthik et al., 2022). Evaluation is a crucial part of learning, as without teacher feedback, students may struggle to gain meaningful knowledge (Arends, 2012). Reflection activities are closely linked to creative thinking skills (Akpur, 2020) and can enhance metaphorical thinking abilities (Mars, 2021). Through self-reflection, students can evaluate their own capabilities, analyze the strengths and weaknesses of their ideas, and develop a greater motivation to generate creative solutions in future tasks (Greco, 2019; Verhaeghen et al., 2017). The combination of the ReCODE learning model and Collaborative Mind Mapping (CMM) in biology education plays a crucial role in improving creative thinking skills. Incorporating collaborative mind maps into both phases of the ReCODE model helps students organize information in a structured and efficient manner. The capability to process and comprehend information is essential for achieving the five indicators of creative thinking (Zubaidah et al., 2017).

The use of collaborative mind maps is an effective approach for developing creative thinking skills. This method trains students to engage in cognitive processes such as representing information, exchanging and linking ideas, and managing information flexibly. Based on this concept, the integration of collaborative mind maps into learning is expected to help students structure their thoughts and encourage them to process information comprehensively, leading to the generation of new and innovative ideas (Buzan, 2012; Feng et al., 2023; Sajadi et al., 2024). According to Fung and Liang (2023), collaborative mind maps assist students in connecting prior knowledge with new material. Additionally, research by Bawaneh (2019) revealed that students who utilized mind maps were more effective in recalling, organizing, and reflecting on their learning experiences.

The results of this study are consistent with earlier research by Fatmawati et al. (2021) and Zubaidah et al. (2017) on biology learning. The use of collaborative mind maps helps students visualize, organize, and better understand ideas during brainstorming sessions or problem-solving activities (Rosba et al., 2021). Students reported that mind maps enable them to generate and organize ideas more quickly. The capacity to generate and arrange ideas is an essential element of creative thinking skills (Treffinger et al., 2002). This is further supported by the notion that incorporating various colors, images, and line patterns in mind maps enhances students' ability to express themselves creatively (Shi et al., 2023; Zipp & Maher, 2013). Additionally, the simple design and ability to save collaborative mind maps as image or PDF files facilitate faster work and improve understanding among students during class discussions (Hidayati et al., 2023).

CONCLUSION

The findings of this study demonstrate that the ReCODE-CMM, ReCODE, and conventional learning models have significant differences in their impact on students'

creative thinking abilities. The study also emphasizes that incorporating CMM into the ReCODE model significantly improves students' ability to methodically link and organize concepts and facts. Additionally, ReCODE-CMM fosters higher-order thinking skills, which are essential for solving problems related to the respiratory and excretory systems. This model equips students with the capability to manage information efficiently and innovatively. However, the study is limited by a small sample size, suggesting the need for further research on a larger scale to explore the broader potential of ReCODE-CMM. Future research may explore the implementation of this approach in different biology topics or evaluate its effectiveness in fostering a range of 21st-century skills.

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