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The Influence of Collaborative Mind Mapping Integrated with Inquiry-Based Learning on Students' Collaboration Skills and Learning Outcomes in Biology Subject

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Abstract: This quasi-experimental study employed a pretest–posttest control group design to examine the effect of Collaborative Mind Mapping in Inquiry-Based Learning on students' collaboration skills and learning outcomes in biology Grade XI at SMA Negeri 3 Enrekang. The population comprised 105 Grade XI FA students. Two class (XI FA 1 and XI FA 2; n = 70) were selected using cluster random sampling, with one class assigned as the experimental group and the other as the control group. Data were collected using a collaboration skills observation sheet developed based on the indicators and rubrics proposed by Greenstein (2012) and the administration of pretest and posttest learning outcome questions. Descriptive analysis showed that the experimental group's mean collaboration score increased from 40.36 to 78.93, higher than the control group (39.23 to 68.04). Similarly, learning outcomes improved from 58.51 to 86.49 in the experimental group, compared to 58.40 to 75.20 in the control group. The ANCOVA analysis results obtained a significance value for collaboration skills of 0.000 < 0.05, and a significance value for learning outcomes of 0.002 < 0.05. It can be concluded Collaborative Mind Mapping in inquiry-based learning significantly improves students' collaboration skills and learning outcomes in biology Grade XI.

Keywords: Collaborative mind mapping; Collaboration skill; Learning outcomes

Introduction

Biology education in the 21st century has undergone a major transformation with the use of technology, interdisciplinary approaches, and more interactive learning methods, requiring effective and relevant teaching and learning strategies to meet the needs of the current generation (Juanda et al., 2021). Students are required to master 21st-century skills. Skills such as critical thinking, creativity, communication, and collaboration are important aspects for facing the challenges of the current era so that they are able to compete globally (Panggabean et al., 2021; Nuraini, 2017). One of the important 21st-century skills to develop is collaboration (Ekizer & Yildirim, 2023; Evans, 2020). Collaborative skills are the ability of students to effectively and responsibly make the necessary commitments to achieve common goals (Scoular et al., 2020; Hidayati, 2019). Collaboration involves good communication, listening skills, and mutual respect for differences of opinion (Gusta et al., 2020). Collaboration requires students to learn to interact with one another while sharing and processing information. This creates positive interdependence and shared responsibility, which encourages greater awareness of the learning process. Collaboration is also a means of active learning when students face complex tasks. Students are expected to share ideas, support each other, and discuss individual views in order to achieve the desired goals (Marmoah et al., 2022).

Collaboration skills are essential for students to possess in every learning process to enhance knowledge, social interaction, self-confidence, and motivation (Hardinata et al., 2023). Poor collaboration skills can

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hinder students' problem-solving processes (Putri et al., 2023). Collaboration has distinct advantages over individual problem solving because it allows for effective division of labor, combining information from various sources of knowledge, perspectives, and experiences, and improving the quality of solutions and creativity stimulated by ideas from other group members. In addition, collaboration has been shown to improve students' social competencies, such as the ability to resolve conflicts and find solutions to problems that do not meet their needs (Child & Shaw, 2016). Students' collaboration skills in science learning are low and therefore still need to be empowered. Previous studies in three leading high schools in East Java have revealed that students' higher-order thinking skills are good, but their collaboration skills are still low (Latif & Kusdaryani, 2023; Ilma et al., 2021). Initial observations conducted at SMA Negeri 3 Enrekang show that students' collaboration skills are still low. The low level of collaboration skills among students at the school is characterized by their poor skills in carrying out group learning and their lack of respect for differences of opinion. Students have closed minds and do not accommodate one another. Students are unwilling to share roles and responsibilities in working on educational projects together (Nahar, 2022; Le et al., 2018).

Inquiry-based learning is a learning model approach that emphasizes the process of active searching and discovery by students to acquire knowledge, skills, and attitudes through scientific investigation activities. The inquiry model is a learning method that requires students to solve problems through investigative activities that enhance their skills and knowledge independently (Levitt & Grubaugh, 2023; Gholam, 2019; Andrini, 2016). Inquiry-based learning is highly effective in improving students' collaboration skills and learning outcomes (Asmoro & Prayitno, 2021; Korkman & Metin, 2021).

The inquiry-based learning model trains students to develop logical, critical, and systematic thinking skills and includes activities that make students highly curious, express their opinions, and find answers by asking others questions (Hairida et al., 2021). The inquiry learning model also has a number of advantages, including the ability to improve cognitive aspects or learning outcomes, learning motivation, and training independence in obtaining and processing information. In addition, this model emphasizes the active involvement of students in the learning process, thereby encouraging more meaningful and in-depth learning (Leif et al., 2023). Inquiry also helps students develop problem-solving skills, critical thinking, and argumentation skills, which enable them to better relate knowledge to real-world situations and find solutions in the future, which are needed to face the challenges of the 21st century (Sujarwo et al., 2025). Inquiry-based learning still has shortcomings, namely that it sometimes confuses students when organizing the information they find independently. To overcome the shortcomings of inquiry learning, Collaborative Mind Mapping (CMM) can be used. Collaborative Mind Mapping helps students integrate their knowledge collaboratively.

Collaborative Mind Mapping (CMM) is a learning method used to combine ideas from several students into a concept map. This method aims to understand the process of teamwork in creating concept maps, how these concept maps develop over time, and changes in collaboration in the creation of concept maps from several pairs of co-workers (Suharto et al., 2023; Chen et al., 2019). Collaborative mind mapping can develop students' collaboration skills, creativity, learning outcomes, and learning motivation (Polat et al., 2022).

Biology has different characteristics from other fields of science, which examine living things, the environment, and the relationship between the two, thus encouraging active learning where students are actively involved in the scientific process, requiring them to think critically, logically, factually, and master collaboration (Nurajijah & Peniati, 2024; Driessen et al., 2020; Sudarisman, 2015). Biology not only studies the structure, function, and development of organisms, but also the reciprocal relationship between living things and their environment. Biology learning is a complex learning process that cannot be explained with simple concepts, so clear and easy-to-understand methods are needed for students to understand and apply it (Dauer & Dauer, 2016). Biology, especially material on the digestive system, contains many abstract concepts and inter-organ relationships that are difficult to visualize with text alone, requiring mind mapping to simplify them. Thus, collaborative mind mapping is necessary in inquiry-based learning.

Learning outcomes are also an important aspect that must be considered in biology education. Learning outcomes are indicators that show the extent to which students are able to understand, master, and apply the concepts learned after participating in a learning process. Learning outcomes not only cover the cognitive domain, but also the affective and psychomotor domains, which complement each other to form students' overall competence (Aulia et al., 2024). Learning outcomes are closely related to students' ability to understand concepts, analyze problems, and find scientific solutions (Ilma et al., 2020).

Low student learning outcomes can be influenced by low collaboration skills, because the complex biology learning process requires cooperation, information sharing, and discussion to find scientific solutions.

Conversely, if students' collaboration skills improve, their understanding of concepts, motivation, and social interaction will also develop, thereby driving learning outcomes in a better direction (Cahya et al., 2023). Improved learning outcomes can be achieved through learning strategies that involve students actively, collaboratively, and creatively (Ansya, 2023). One strategy that can be used is mind mapping, which can improve student learning outcomes (Kustian, 2021; Annisah et al., 2020). Thus, collaborative mind mapping is needed in inquiry-based learning. Although Collaborative mind mapping has been extensively researched, its integration into Inquiry-Based Learning models, particularly for digestive system material, is still limited.

Based on the above description, this study aims to determine the effect of applying collaborative mind mapping (CMM) in inquiry-based learning on students' collaboration skills and learning outcomes in Grade XI Biology at SMA Negeri 3 Enrekang.

Method

The type of research used was quasi-experimental research with a pretest-posttest control group design. The population in this study was all 105 students in class XI FA at SMA Negeri 3 Enrekang in the 2025/2026 academic year. The sample in this study was class XI FA 1 and XI FA 2, each consisting of 35 students. The sampling technique used was Cluster Random Sampling. This study was conducted in October-November 2025 in the odd semester of the 2025/2026 academic year. The location of the study was at SMA Negeri 3 Enrekang, located on Jalan Poros Makassar-Toraja KM. 275, Kel. Buntu Sugi, Kec. Alla, Kab. Enrekang.

The study began by administering a pretest to students, followed by five learning sessions in two classes, with the experimental class using CMM in inquiry-based learning and the control class using inquiry-based learning. The material taught in both classes was the same, namely the digestive system. During the learning process, observers filled out student collaboration skill sheets. After the learning process, students in the experimental and control classes were given a posttest. The instruments used in this study were collaboration skills observation sheets compiled based on the indicators and rubrics of collaboration skills according to Greenstein (2012) and a learning outcome test in the form of 25 multiple-choice questions. Before use, the instrument was first validated by two expert lecturers.

Research data analysis consists of descriptive analysis and inferential analysis. Descriptive analysis aims to describe the collaboration skills and learning outcomes of students in the experimental and control groups. The data obtained in the form of scores are analyzed and converted into values using the following formula:

$$\text{Score} = \frac{\text{Number of correct scores}}{\text{Maximum scores}} \text{ X } 100 \quad (1)$$

Next, the data was analyzed descriptively to describe the minimum value, maximum value, mean, and standard deviation, as well as the mean of each indicator. Inferential analysis aims to test research hypotheses. Inferential statistical analysis is performed with prerequisite tests consisting of normality and homogeneity tests as well as hypothesis testing using ANCOVA. Inferential analysis is analyzed using SPSS version 26. The normality test aims to determine whether the data is normally distributed or not. The normality test in this study uses the Kolmogorov-Smirnov test. The data is normally distributed if the Sig. value is > 0.05. The homogeneity test aims to determine whether the data in this study is similar (homogeneous) between the control class and the experimental class. The data homogeneity test was performed using Levene's Test of Equality of Error Variances. If the Sig. value was > 0.05, then the variance between groups was homogeneous. Hypothesis testing was performed using the ANCOVA (Analysis of Covariance) test at a level of = 0.05. The ANCOVA test aims to determine whether there is an effect of applying CMM in inquiry learning on students' collaboration skills and learning outcomes in Biology Subject for Grade XI at SMA Negeri 3 Enrekang. The testing criteria are that if Sig. < 0.05, the research hypothesis is accepted, meaning that there is an effect of CMM application in inquiry learning on collaboration skills and student learning outcomes in Biology Subject for Grade XI at SMA Negeri 3 Enrekang. Conversely, if Sig. ≥ 0.05, the research hypothesis is rejected, meaning that there is no effect of CMM application in inquiry-based learning on students' collaboration skills and learning outcomes in Biology Subject for Grade XI at SMA Negeri 3 Enrekang.

Result and Discussion

Result

Descriptive Analysis Results

Description of Students' Collaboration Skills

The descriptive statistics of students' collaboration skills in Grade XI biology material obtained from observations during 5 meetings are presented in Table 1. Based on Table 1, it can be seen that the average collaboration skill score of students in classes that used collaborative mind mapping in inquiry-based learning increased from the first meeting to the fifth meeting.

Similarly, in classes that used the inquiry-based learning model, the average collaboration skill score for each meeting also increased. Although both classes showed improvement, the IBL-CMM class showed a higher increase in value than the IBL class.

More specifically, the average distribution of collaboration skills for each meeting in both classes is presented in Figure 1.

Table 1. Description of Student Collaboration Skills Scores

Model	Statistic	Meeting number				
		1	2	3	4	5
IBL-CMM	N	35	35	35	35	35
	Mean	40.36	52.68	60	70.36	78.93
	SD	10.32	6.48	6.98	7.93	9.35
	Min	25	37.50	50	56.25	62.50
	Max	56.25	68.75	81.25	87.50	93.75
IBL	N	35	35	35	35	35
	Mean	39.23	48.21	52.68	59.47	68.04
	SD	10.23	6.35	6.99	8.88	11.62
	Min	25	31.25	31.25	37.50	50
	Max	56.25	62.50	62.50	75	87.50

Notes: CMM = Collaborative Mind Mapping, IBL = Inquiry-Based Learning, N = sample size, SD = standard deviation, Min = Minimum Score, Max = Maximum Score

Figure 1. Diagram of the average value of students' collaboration skills

Figure 1 shows a consistent increase in the average collaboration skill scores in the IBL-CMM class and the IBL class from the first to the fifth meeting. However, the average score increase in the IBL-CMM class was higher than that in the IBL class.

Table 2 shows the average score for each indicator of student collaboration skills in the first meeting, which was used as a pretest, and the fifth meeting, which was used as a posttest. In the experimental class that used CMM in inquiry-based learning, there was a higher increase in the average score for each indicator compared to the control class that used inquiry-based learning without CMM.

Table 2. Description of Average Scores for Each Collaboration Skill Indicator

Indicator	Pretest (meeting 1)		Posttest (meeting 5)	
	IBL-CMM	IBL	IBL-CMM	IBL
Works productively	42.86	41.43	85	74.29
Respect	43.57	42.14	78.57	67.14
Compromises	34.29	33.57	72.14	63.57
Responsibility and contributes	40.71	40	80	67.14

Notes: CMM = Collaborative Mind Mapping, IBL = Inquiry-Based Learning

Description of Students' Learning Outcomes

The descriptive statistics of student learning outcomes in Grade XI biology are presented in Table 3. Table 3 shows the average increase in student learning outcomes in the experimental class taught with CMM in discovery-based learning and the control class taught using discovery-based learning without CMM. Although both classes experienced an average increase in learning outcomes, the IBL-CMM class showed a higher increase in scores than the IBL class. More clearly, the distribution of the average pretest and posttest scores in both classes is presented in Figure 2.

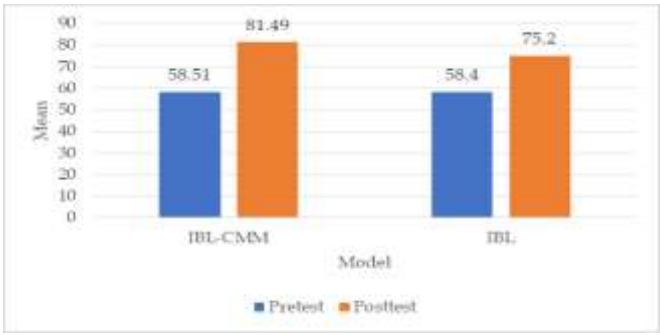

Figure 2. Diagram of average student learning outcomes

Figure 2 shows an increase in the average learning outcomes of students in the IBL-CMM class and the IBL class. However, the increase in the average score in the IBL-CMM class was higher than in the IBL class.

Table 3. Description of Student Learning Outcomes

Statistic	Model IBL-CMM		Model IBL	
	Pretest	Posttest	Pretest	Posttest
N	35	35	35	35
Mean	58.51	81.49	58.40	75.20
SD	11.65	8.95	10.99	8.39
Min	36	64	32	60
Max	76	100	76	92

Notes: CMM = Collaborative Mind Mapping, IBL = Inquiry-Based Learning, N = sample size, SD = standard deviation, Min = Minimum Score, Max = Maximum Score

Inferential Analysis Results

Normality Test

The normality test in this study used the *Kolmogorov-Smirnov* test, which was analyzed using the SPSS version 26 *for Windows* computer program. The data was normally distributed if the Sig. value was > 0.05 and was not normally distributed if the Sig. value was ≤ 0.05.

Table 4. Normality Test Result

Variable	Model	Significance value		Description
		Pretest	Posttest	
Collaboration skill	IBL-CMM	0.067	0.076	Normal
	IBL	0.089	0.079	Normal
Learning outcome	IBL-CMM	0.077	0.200	Normal
	IBL	0.196	0.090	Normal

Notes: CMM = Collaborative Mind Mapping, IBL = Inquiry-Based Learning

Table 4 shows the significance values of the pretest and posttest for collaboration skills and learning outcomes. Based on the Kolmogorov-Smirnov test results, the overall significance value is > 0.05, indicating that the overall pretest and posttest data for collaboration skills and learning outcomes are normally distributed.

Homogenity Test

The homogeneity test was used to determine whether the data in this study was similar (homogeneous) between the control class and the experimental class. The data homogeneity test was conducted using Levene's Test of Equality of Error Variances. If the Sig. value was > 0.05, then the variance between groups was homogeneous. If the Sig. value was ≤ 0.05, then the variance between groups was not homogeneous.

Table 5 shows the significance values of collaboration skills and learning outcomes for the experimental class that used CMM in inquiry learning and the control class that used the inquiry learning model. Based on the overall significance values of collaboration skills and learning outcomes obtained from the analysis using SPSS, the significance value was > 0.05, indicating that the students' collaboration skills and learning outcomes were homogeneous.

Table 5. Homogenity Test Result

Variable	Significance value	Description
Collaboration skill	0.174	Homogeneous
Learning outcome	0.638	Homogeneous

Hypothesis testing

Hypothesis testing was conducted using ANCOVA (Analysis of Covariance) at a significance level of 0.05 to determine whether the application of CMM in inquiry-based learning had an effect on students' collaboration skills and learning outcomes in Biology for Grade XI at SMA Negeri 3 Enrekang. The testing criteria are that if Sig. < 0.05, the research hypothesis is accepted, meaning that there is an effect of applying CMM in inquiry-based learning on students' collaboration skills and learning outcomes in Biology Material for Grade XI at SMA Negeri 3 Enrekang. Conversely, if Sig. ≥ 0.05, the research hypothesis is rejected, meaning that there is no effect of CMM application in inquiry learning on collaboration skills and student learning outcomes in Biology Material for Grade XI at SMA Negeri 3 Enrekang.

Table 6 shows the significance value of the model obtained from the ANCOVA analysis of 0.000 < 0.05, so the research hypothesis is accepted. Thus, it can be concluded that there is an effect of applying CMM in inquiry learning on students' collaboration skills in Biology Subject for Grade XI at SMA Negeri 3 Enrekang.

Table 6. Results of the ANCOVA test of Students' Collaboration Skills

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	2189.700[a]	2	1094.850	9.841	.000
Intercept	19946.163	1	19946.163	179.292	.000
Model	2019.819	1	2019.819	18.156	.000
Error	7453.715	67	111.249		
Total	387617.188	70			
Corrected total	9643.415	69			

Table 7. Results of the ANCOVA on Students' Learning Outcomes

Source	Type III sum of squares	Df	Mean square	F	Sig.
Corrected model	1501.327[a]	2	750.664	11.679	.000
Intercept	9010.865	1	9010.865	140.192	.000
Model	683.766	1	683.766	10.638	.002
Error	4306.444	67	64.275		
Total	435440.000	70			
Corrected total	5807.771	69			

Table 7 shows the significance value of the model obtained from the ANCOVA analysis of 0.002 < 0.05, so the research hypothesis is accepted. Thus, it can be concluded that there is an effect of applying CMM in inquiry learning on student learning outcomes in Biology Subject for Grade XI at SMA Negeri 3 Enrekang.

Discussion

The influence of Collaborative Mind Mapping in Inquiry-Based Learning on Students' Collaboration Skills

The descriptive research results show that there was an increase in the average collaboration skill score in each class at each meeting. This shows that collaboration is not a skill that develops instantly, but is formed through a repetitive, structured learning process that requires meaningful social interaction. In the experimental class taught using collaborative mind mapping (CMM) in inquiry-based learning, the average collaboration skill scores of students increased from the first meeting to the last meeting. However, the standard deviation was high because the difference between the maximum and minimum scores of the students was very large. This was due to the fact that the level of student participation in the group was not entirely equal, with students who had good self-confidence and communication skills tending to be more prominent in discussions and mind map preparation, resulting in higher scores, while students who were less active or were still adapting to active group work had lower scores. Meanwhile, in the control class, which was taught using inquiry-based learning without CMM, the average score for student collaboration skills also increased but not as high as in the experimental class. The high standard deviation was caused by the absence of collaborative media such as mind maps, which meant that group discussions tended to be dominated by certain students, while other students were less actively involved, resulting in a wide gap in collaboration skills between students.

Collaborative skills are one of the key competencies in 21st-century learning, which emphasizes students' ability to work together effectively in groups to achieve common goals. Collaboration includes not only physical group work but also communication skills, joint decision-making, problem-solving, and individual responsibility in a group context. Collaborative skills in this study were analyzed based on the indicators proposed by Greenstein (2012), namely working productively, respect, the ability to compromise, and individual responsibility and contribution.

The indicator of working productively in a group is reflected in the active involvement of students in discussions, clear division of roles, and the ability to complete group tasks effectively. Based on the results of the analysis of the observation sheet, the average score for the indicator of working productively in the experimental class that used CMM in inquiry learning was higher than in the control class that used inquiry learning without CMM. This shows that students in the experimental class were better able to use their time efficiently to focus and work effectively on the tasks given compared to students in the control class.

The indicator of respect or mutual respect is demonstrated through the ability to listen to friends' opinions, accept differences of opinion, and not dominate group discussions. Based on the results of the analysis of the observation sheet, the average score for the respect indicator in the experimental class that used CMM in inquiry learning was higher than in the control class that used inquiry learning without CMM. This shows that students in the experimental class were better able to listen to and appreciate the opinions or ideas expressed by their friends during the discussion activity compared to students in the control class.

The compromise indicator can be seen when students are faced with differences of opinion and have to make joint decisions. Based on the results of the analysis of the observation sheet, the average compromise indicator score in the experimental class that used CMM in inquiry learning was higher than that in the control class that used inquiry learning without CMM. This shows that students in the experimental class were more capable of working together flexibly, realizing the importance of cooperation and each other's obligations to achieve common goals compared to students in the control class.

The indicators of responsibility and individual contribution are reflected in students' awareness of their respective roles in the group, completing assigned tasks, and contributing to the final results of the group. Based on the results of the analysis of the observation sheet, the average score for the responsibility and individual contribution indicators in the experimental class that used CMM in inquiry learning was higher than in the control class that used inquiry learning without CMM. This shows that students in the experimental class always contributed to the group by providing suggestions, responses, or ideas, always did their best work, and always followed the instructions well compared to students in the control class.

The hypothesis test results show that there is an effect of the application of collaborative mind mapping (CMM) in inquiry learning on students' collaboration skills. The success of CMM in inquiry-based learning to improve collaboration skills is supported by the stages of CMM in inquiry-based learning, which consist of six main stages, namely presenting questions or problems, formulating hypotheses, designing experiments, conducting experiments, collecting and analyzing data, and drawing conclusions. Each stage makes a different but interrelated contribution to developing students' collaboration skills according to Greenstein's indicators.

In the problem orientation stage, the teacher presents contextual phenomena related to the digestive system material to arouse students' curiosity. At this stage, students begin to collaboratively build an initial mind map containing their initial concepts. The use of CMM encourages students to share their initial knowledge and discuss ideas that arise. This activity contributes to the indicator of working productively in groups. In addition, this process also trains students to respect each other, because every idea presented by students is accommodated and considered together.

In the hypothesis formulation stage, students collaboratively develop tentative assumptions about digestive system problems and organize them in a mind map. Differences of opinion that arise within the group require students to discuss, consider various views, and reach a mutual agreement. CMM serves to organize their hypotheses. This stage directly contributes to the indicator of compromise ability, as students must negotiate ideas and agree on hypotheses with their groupmates.

In the experiment design stage, students determine the tools, materials, procedures, and division of tasks within the group to test or prove the hypotheses that have been formulated. This stage requires joint planning and a clear division of roles among group members. This stage contributes significantly to the indicator of responsibility for individual contributions, because each student has a specific role in the success of the experiment and the accuracy of the information obtained through literature study.

In the experiment stage, students carry out literature studies or practical work according to the agreed design. This stage requires intensive cooperation, coordination between group members, and adherence to the designed procedures. This activity reinforces the indicators of working productively in a group and individual responsibility, because the success of the experiment depends heavily on the contribution of each member.

In the stage of collecting experimental results and analyzing data, students refine and perfect their mind maps based on the information obtained to visually describe the relationships between concepts in the digestive system. Mind mapping serves as an external cognitive tool that reduces students' cognitive load when dealing with complex material on the digestive system. This stage requires in-depth discussion, joint evaluation, and collective revision. These activities reinforce productive work skills and mutual respect because students must consider their friends' arguments before refining the concept structure.

In the conclusion stage, students draw conclusions based on the results of data analysis and the mind map that has been created. Conclusions are formulated together. This stage reinforces all indicators of collaboration skills according to Greenstein, as students must reach a final agreement, reflect on each member's contributions, and appreciate the results of the group's work.

The results of this study are supported by Lianto et al. (2025), Daryanto et al. (2024), and Nurhawa et al. (2023), which show that product-based collaborative learning and intensive discussion can improve the quality of group cooperation, making it more productive, fostering mutual respect, and increasing individual responsibility. In addition, inquiry-based learning that emphasizes hypothesis formulation, experimental design and implementation, and collaborative data analysis has been proven to encourage the development of students' negotiation and compromise skills in reaching mutual agreements (Coila

et al., 2024; Fauziyah et al., 2024; Shani et al., 2023). Other studies that also support these findings include those by Chua et al. (2025), Phimthong et al. (2024), Matuk et al. (2023); Chakim et al. (2021) and Mieg (2019), which confirm that the use of CMM in the inquiry learning stage encourages students to actively participate in sharing and accepting their friends' opinions during discussion activities and organizing ideas into visual forms, thereby strengthening mutual respect, compromise skills, and the responsibility and contribution of each student.

The use of CMM in inquiry learning strengthens collaboration skills because students not only work together to find information but also to organize and represent knowledge. This process requires intensive social interaction, so that each indicator of collaboration according to Greenstein develops simultaneously. The results of the study are also supported by Polat et al. (2022), who show that mind mapping in collaborative learning can increase social interaction and student cooperation (Polat et al., 2022). This is also supported by Tendri et al. (2025), who state that collaborative-based mind mapping can significantly improve collaboration skills.

The Influence of Collaborative Mind Mapping in Inquiry-Based Learning on Student Learning Outcomes

The results of descriptive analysis show that there was an increase in the average learning outcomes of students in both classes. In the experimental class taught using CMM in inquiry-based learning, the standard deviation was high because the range between the minimum and maximum scores of students was wide. This was due to differences in student participation in discussions and mind map preparation. Students who were actively involved in discussions and mind map development demonstrated excellent conceptual understanding, resulting in high learning scores, while students who were less involved demonstrated moderate learning scores. In the control class, which was taught using inquiry learning without CMM, the high standard deviation was due to students' dependence on discussions and teacher explanations. Without the help of CMM, students with good memory tended to obtain high learning outcome scores, while students with poor memory had difficulty understanding the material on the digestive system. As a result, the difference in the range of learning outcome test scores between students was quite large.

Based on the pretest results, students' initial understanding of the sub-material on digestive organ functions, food digestion processes, food substances, differences between human and ruminant digestive systems, and digestive system disorders was still low in both classes. After the application of CMM in inquiry-based learning, there was a more significant increase in learning outcomes in the experimental class compared to the control class. This shows that the understanding of the sub-topics of digestive organ function, food digestion process, food substances, differences between the digestive systems of humans and ruminants, and digestive system disorders in students taught using CMM in inquiry-based learning increased further compared to students in the control class who only used inquiry-based learning without the help of CMM.

The results of the hypothesis test show that there is an effect of using collaborative mind mapping (CMM) on student learning outcomes. The material on the human digestive system covers various abstract and interrelated concepts. The complexity of this material often causes students to have difficulty in understanding the digestive process as a whole. CMM helps students organize the concepts of the digestive system visually, starting from the main organs and their respective functions, the digestive process, food substances, the differences between the human and ruminant digestive systems, and disorders of the digestive system, making it easier for students to understand the material. The collaborative process of creating mind maps allows students to discuss, clarify, and correct misconceptions that arise during learning. In addition, CMM encourages students to actively ask questions and engage in discussion. This activity reinforces the cognitive enhancement process, which contributes to improving student learning outcomes.

The inquiry learning model emphasizes the scientific investigation process through the stages of presenting problems, proposing hypotheses, collecting data, analyzing, and drawing conclusions. In the context of digestive system material, students are involved in identifying problems, such as “how does the process of food digestion in the human body work” or “why can a disorder in one organ affect the digestive system as a whole.” When this inquiry process is combined with CMM, students not only discover concepts independently, but also organize their findings into group mind maps that reinforce the interrelationships between concepts and help students build a deeper understanding.

The results of this study are supported by Rosalia et al. (2024), which show that learning biology on complex material, such as the digestive system, requires learning strategies that are able to integrate concepts so that students not only memorize but also understand the process conceptually. Research by Sari et al. (2023) shows that the use of mind mapping in collaborative learning increases students' cognitive engagement and facilitates understanding of the relationships between complex concepts. Inquiry-based learning improves student learning outcomes because it encourages active

engagement and higher-order thinking processes (Chen, 2021).

The results of this study are also in line with Septiarini et al. (2024), which show that mind map-assisted collaborative learning significantly improves learning outcomes because students find it easier to understand the relationships between concepts. In addition, research by Telaumbanua et al. (2024) states that learning that emphasizes collaborative activities has a significant effect on student learning outcomes. The increase in student learning outcomes in digestive system material shows that CMM is effective for complex biology material. Concept visualization through mind maps helps students understand the cause-and-effect relationships between organs and digestive processes, making learning more meaningful.

According to Aziz et al. (2021), the application of mind mapping can improve students' biology learning outcomes. Mind mapping functions as a cognitive aid that makes it easier for students to organize complex biological concepts. Mind mapping helps students visually link main concepts with subconcepts, so that information is not learned separately but as a meaningful whole. Student learning outcomes improve as students become more actively involved in group discussions, mind map preparation, and collaborative problem solving. The improvement in learning outcomes in this study was also influenced by the student-centered learning process.

Conclusion

Based on the results of this study, the application of Collaborative Mind Mapping (CMM) in Inquiry-Based Learning (IBL) shows positive indications of an increase in collaboration skills and student learning outcomes in Biology grade XI at SMA Negeri 3 Enrekang. This increase is related to two main mechanisms. First, collaborative mind mapping encourages active participation, clearer role sharing, respect, meaning negotiation (compromise), and shared responsibility among group members. Second, the visual representation of interconnected concepts serves as cognitive scaffolding, helping students organize their investigation findings into a coherent conceptual framework. CMM supports deeper conceptual understanding and more structured collaboration during learning activities. Although this study shows positive indications of improved collaboration skills and student learning outcomes, these findings are still limited in that they were only conducted on one biology subject, namely the Digestive System. Given that each biology subject has different conceptual characteristics, levels of abstraction, and complexity, the effectiveness of CMM integration in IBL in other subjects cannot yet be generalized broadly. Based on these limitations, future researchers are advised to apply this strategy to various biology subjects with different conceptual characteristics.

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S., A. M., F.D., and F., guided, supervised the writing of the article, and validated the research instruments used. T.A.M., designed the research plan, analyzed the data, and wrote the article.

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Conflicts of Interest

The authors declare no conflict of interest.

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