Combining Problem-Based Learning and Collaborative Mind Mapping: A Strategy for Empowering Students' Collaboration Skills

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Collaboration skills are becoming increasingly important for students to effectively solve complex problems in the 21st-century learning era. The purpose of this study is to examine the effect of Problem-Based Learning (PBL) combined with Collaborative Mind Mapping (CMM) on enhancing students' collaboration skills in biology learning. This study employs a non-equivalent control group pretest-posttest design, with a population consisting of all eleventh-grade students at SMAN 4 Parepare, located in South Sulawesi, Indonesia. The study involves 109 students, with 37 students in the experimental group using the PBL-CMM model, 36 students in the positive control group using PBL, and 36 students in the negative control group applying direct instruction. A random sampling procedure was conducted to select the three participant groups. Pretest and posttest data were collected using peer and self-assessment questionnaires. The questionnaires utilized a five-point Likert scale: strongly disagree, disagree, neutral/somewhat agree, agree, and strongly agree. The research data were analyzed using One-Way ANCOVA and LSD tests. The findings of this study indicate that the PBL-CMM learning model significantly influences students' problem-solving skills at SMAN 4 Parepare. The use of PBL-CMM can help students learn how to collaborate to address problems and simplify their complex thinking processes regarding frequently encountered issues. A well-structured visual approach can accelerate the process of finding effective and efficient solutions.

Keywords: Collaboration, Problem Based Learning, Collaborative Mind Mapping, Students

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1. Introduction

The 21st century has brought fundamental changes in various aspects of life. Everyone is required to possess good thinking skills and strong social attitudes. Students must be able to communicate effectively, think critically, creatively, and be competitive in the era of globalization, in order to become a skilled and adaptive generation [1]. Technological advancements demand collaboration as an essential requirement for thriving in a better life in the era of globalization [2]. One way to develop collaboration skills is through learning.

Collaboration can be developed through experiences within schools, between schools, and outside of schools [3]. Collaboration skills involve a learning process that balances differing opinions and knowledge, participates in discussions by offering suggestions, listening, and supporting one another [4]. Participation in cooperation through collaboration skills helps students understand the importance of social and personal aspects [5]. Collaboration gives students the opportunity to consider different perspectives, listen, and support the opinions of other students. The collaboration process builds social intelligence, enhances interpersonal interaction, and makes the learning process more productive [6]

A study on collaboration within student groups in several countries and regions in Indonesia is still categorized as low. The results of the preliminary study indicate that students' collaboration skills show an average collaboration rate of 60.01%, categorized as medium. The low level of students' collaboration skills is mainly due to their tendency to rely on their peers to solve problems. This results in less than optimal grades [7]. Another reason is that students are accustomed to learning through book-centered instruction, with teachers still dominating as the primary source of knowledge [8]. Another issue found is that students refuse to work in groups [9] and students experience group conflicts [10].

The solution to these problems is to implement the Problem-Based Learning (PBL) model combined with Collaborative Mind Mapping (CMM). The PBL model is an instructional approach that focuses on collaboratively solving problems. PBL encourages learners to be independent, prepares them for lifelong learning, and requires students to engage in active and in-depth learning [11], [12]. However, the PBL model also has weaknesses, as students who are accustomed to receiving information from teachers may struggle when learning independently. Another weakness is that a lack of understanding of the problems being solved can lead to students being less motivated to learn [13]. Several weaknesses identified in the PBL model can be addressed by using Collaborative Mind Mapping (CMM).

The application of CMM in learning is expected to enhance student interest and participation, facilitate collaboration and the brainstorming process, aid in the formation of systematic thinking patterns, and improve students' understanding of the material being studied [14]. Students can interact and collaborate by jointly editing and providing comments on the map without using other online communication tools [15]. New knowledge is also refined and constructed from social interactions, such as group discussions and collaboration among individuals. Students feel satisfied with this tool as it facilitates discussion and the formation of new knowledge [16]. Student participation and achievement through collaborative mind mapping in learning

activities can also be enhanced by expressing opinions through discussions with peers and teachers, as well as by being able to express their imagination [17].
The PBL model combined with CMM is a problem-based learning model optimized by utilizing collaborative mind mapping in its implementation. This combination allows both to stimulate students individually and in groups to learn effectively. The limitations of the PBL model can be supplemented by the use of the Gitmind application, which helps students visualize their knowledge after reading by creating engaging and interactive mind maps. The Gitmind application features text, images, animations, and videos that can clarify materials that are difficult to visualize.
The biology topics used in this study are the excretory system and the reproductive system. These subjects expect students to be able to describe the biological processes occurring within cells, analyze the relationship between the structures of organs in organ systems and their functions, and identify abnormalities or disorders that arise within those organ systems as part of their skill set [18]. Therefore, the aim of this study is to examine the effectiveness of the PBL-CMM learning model on high school students' collaboration skills in biology education. This research contributes to the empowerment of 21st-century skills among students, one of which is collaboration skills.

2. Method

2.1 Research Design

The type of research conducted is a quasi-experimental study. The quasi-experimental design used is the nonequivalent pretest-posttest control group design [19], [20]. The characteristics of this design include a control group, but the group or class cannot fully control various other external variables that may affect the execution of the experiment. The independent variables in this study consist of the PBL-CMM learning model, PBL, and conventional learning. The dependent variable is student collaboration skills. Table 1 presents the design of this research.

Table 1. Quasi-experimental design, nonequivalent pretest-posttest control group design.

Group	Pre Test	Treatment	Post Test
K1	O_1	X1	O_2
K2	O_3	X2	O_4
K3	O_5	X3	O_6

Source: [19], [20]

Description:

K1	= Experimental Group
K2	= Positive Control Class
K3	= Negative Control Class
X1	= Treatment uses PBL-CMM model
X1	= Treatment uses PBL model
X1	= Treatment uses conventional learning
O_1, O_3, O_5	= Pretest
O_2, O_3, o_6	= Posttest

2.2 Research Population and Sample

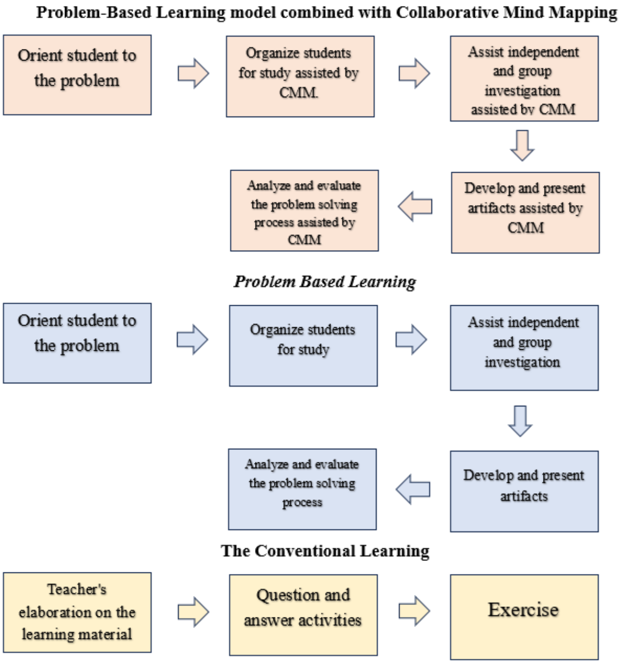
The population in this study consists of all class XI science students at SMA Negeri 4 Parepare, South Sulawesi, Indonesia, which comprises 10 classes. The classes used have undergone equivalence testing, and all class X students at SMA Negeri 4 Parepare have been declared equivalent. Three individual groups were selected using random sampling techniques. The experimental group received instruction through the PBL-CMM model, the positive control group was taught using PBL, and the negative control group used conventional learning models. The total number of students in the three classes used as research samples is 109 students.

2.3 Research Procedures

The experimental group, positive control, and negative control underwent different learning models regarding the material on the excretory system and the reproductive system. Figure 1 illustrates the stages of learning in three different learning activities: PBL combined with CMM, the PBL model, and conventional learning.

Fig 1. Educational Activities

2.4 Research Instrument



Assessment data were collected using observation assessment sheets, self-assessment questionnaires, and peer assessments. The self-assessment and peer assessment questionnaires consisted of 20 positive and negative statements each. These questionnaires used a five-point Likert scale: strongly disagree, disagree, neutral, agree, and strongly agree. Before being used to collect data, the questionnaires underwent construct and content validity testing by experts.

An empirical test was also conducted to measure the validity and reliability of the instruments. The validity of the questionnaire items was assessed using the Pearson product-moment correlation test. Therefore, a total of 19 instrument items were deemed valid, while only 1 instrument item was considered invalid. The Cronbach's alpha reliability test indicated that all 24 instrument items were reliable, with a very high reliability score of 0.975. The items in the collaboration skills questionnaire were constructed based on six indicators listed in Table 2.

Table 2. Collaboration Skills Indicators

Aspects of Collaboration Skill	Descriptors
Works Productively	The skill to use time effectively in order to focus on completing assigned tasks
Demonstrate respect	Skills to listen to and discuss ideas shared with respect
Compromise	Skills to collaborate in achieving common goals.
Share Responsibility	Skills to take responsibility and contribute to assigned tasks.

Source: [4]

2.5 Data Collection and Data Analysis

The responses given by students on the collaboration skills questionnaire were measured using a five-point Likert scale. One-Way ANCOVA was conducted for hypothesis testing at a significance level of 5%. The research hypothesis is that the PBL model combined with CMM is effective in empowering high school students' collaboration skills in biology learning. ANCOVA was only applied to data that followed a normal distribution. The Kolmogorov-Smirnov One-Sample test was used to assess the normality of the data, while Levene's test was used to check the homogeneity of the data. After the ANCOVA test was completed, the data were further analyzed using the LSD test.

3. Results

The results of the assumption tests in Table 3 show that the p-values for normality and homogeneity are both greater than 0.05, suggesting that the data follow a normal and homogeneous distribution. Table 4 displays the results of the one-way ANCOVA analysis on students' collaboration skills.

Tabel 3. Results of the normality and homogeneity tests

Test		N	P	α	Ket
Pre-Test	Normality	106	0,200	0,05	Normal
Post-Test	Normality	106	0,200	0,05	Normal
Post-Test	Homogeneity	106	0,055	0,05	Homogen

Tabel. 4 Results of the One-Way ANCOVA

Source	Type III sum of squares	Df	Mean Square	F	Sig.
Corrected model	4037.864[a]	3	1345.955	42.333	.000
Intercept	32961.763	1	3296.719	1036.719	.000

Pretest	652.043	1	20.508	20.508	.000
Model	4033.759	2	63.435	63.435	.000
Error	3338.403	105			
Total	576688.250	109			
Corrected Total	7376.266	108			

Table 4 shows an F-value of 63.435 with a significance value of 0.000 (P-value < 0.05). Therefore, it can be concluded that there are differences in the collaboration skills of students taught using the PBL-CMM model, the PBL model, and conventional learning. The adjusted means and the results of the LSD test on students' collaboration skills for each learning model can be seen in Table 5.

Table 5. The LSD test results

Learning Model	Mean	LSD Notation		
PBL-CMM	79.846[a]	a		
PBL	79.926[a]		b	
Conventional	68.829[a]			c

In Table 5, the LSD notation indicates that the adjusted mean scores of collaboration skills for the PBL-CMM model group are significantly different from those of the PBL model and the conventional group. The PBL-CMM model has the highest adjusted mean score (79.846) compared to the PBL model (79.926) and conventional learning (68.829). These results demonstrate that the PBL-CMM model is effective in empowering high school students' collaboration skills in biology learning.

4. Discussion

This study indicates that there are significant differences in students' collaboration skills when applying different learning models (PBL-CMM, PBL, and Conventional). The implementation of the PBL-CMM learning model has a significant impact and is more effective in enhancing collaboration skills. The problem-based learning model can teach students to collaborate with others in solving problems in their surrounding environment related to the learning material [21]. The learning stages of the PBL-CMM model result in significant differences in students' collaboration skills because each indicator of collaboration skills is thoroughly practiced from the beginning to the end of the learning process.

The success of the PBL-CMM model in enhancing collaboration skills is supported by several stages of the PBL-CMM model. The first stage of the PBL model is orienting students to the problem. This initial stage uses authentic and meaningful problems so that students can investigate and discover the answers on their own. [22]. The problem can be posed by either the students or the teacher [23]. Providing questions and selecting one essential question can stimulate students' thinking processes and allow them to learn independently or in small groups so that they can find solutions to the problem [24], [25]. It is important for every student to have collaboration skills in the problem-solving process [26]. The lack of collaboration skills among students can hinder the problem-solving process. This is because differences of opinion are bound to arise among students during the discussion process [27].

The second stage is organizing students for learning integrated with CMM. In this stage, students are divided into groups to formulate the given problem, study the concepts, and then design a learning task by creating a mind map using the Gitmind application related to the problem. This step can support the development of collaboration skills, as students must work together to gather and organize information from various sources [28]. Collaboration skills at this stage not only allow students to learn together in groups but also train students to build, monitor, and refine shared knowledge during the interaction process in collaborative activities [29].

The third stage involves independent and group investigation. This activity will encourage students to use their knowledge to formulate hypotheses and seek relevant information in a student-centered manner through discussions in small groups to obtain solutions to the given problem [30]. The solutions obtained can come from the environment through investigation activities. This is expected to enhance a deeper understanding of the concepts [31]. Additionally, through this third stage, students develop interpersonal competencies through intensive interaction and collaboration with their group peers, preparing themselves to be effective problem solvers and leaders capable of managing teams and projects efficiently [32].

The role of CMM at this stage is that the alternative solutions obtained from group discussions are visualized in the form of a mind map. The collaborative editing of the mind map can be saved and shared with other contributors. This activity supports collaboration skills by facilitating efficient teamwork and clear communication among team members [33]. The use of collaborative mind maps in an investigation can encourage students to be more effective in formulating hypotheses and seeking relevant information. By utilizing collaborative mind maps, students can organize ideas systematically and collaborate to obtain solutions to the given problem [34], [35], [36].

The fourth stage involves developing and presenting the final work. The final work at this stage is the collaborative mind map (CMM). Collaboration skills further develop through PBL as students present their results, explain their solutions, and discuss their reasoning with others. This activity helps students to be flexible by offering their opinions and accepting those of their peers [37].

In this final stage, students continue the mind map with an in-depth analysis of the information they have gathered and the solutions they have developed [38], [39]. This stage focuses on the analysis and evaluation of the information that has been collected as well as the solutions that have been developed. Students must assess whether the information they use is accurate, relevant, and effective in solving the problems they face. Processing information means reviewing the data, identifying weaknesses or shortcomings in the approaches used, and considering alternatives or improvements to the solutions [33], [40]. Through the use of mind maps, students can evaluate the group ideas integrated into the final solution. This discussion encourages active engagement and collaboration as students must communicate and discuss the various branches present in the mind map they have created [41].

The use of the PBL model combined with CMM in biology classes offers many benefits. PBL integrated with CMM encourages students to work together to solve problems. The collaborative mind map allows each team member to contribute visually, facilitating a more structured and synergistic exchange of ideas. CMM helps students organize and connect the ideas and information they gather during the PBL process. This visualization enables students to more easily see the relationships between concepts, deepening their understanding of the topics being discussed.

5. Conclusion

The results of this study indicate a difference in students' collaborative skills taught using the PBL-CMM model, the PBL model, and conventional learning. In this study, the group using the PBL model combined with CMM achieved the highest average score (79.846) in collaborative skills among all intervention groups (PBL and conventional). These findings suggest that the PBL model combined with CMM effectively empowers high school students' collaborative skills in biology learning. A limitation of this study is that the application of the PBL-CMM model only measured students' collaborative skills, thus further research is needed on the PBL-CMM model's potential to empower various other 21st-century skills.

6. Author Contribution

Each author has made significant contributions to current research and article writing

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