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Research Article

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The role of complexity science problem-based learning with gitmind: Enhancing scientific literacy and collaboration skills of state senior high school

Intan Nurnilam Sari [1,a], Susriyati Mahanal [1,b,*], Sitoresmi Prabaningtyas [1,c]

[1] Department of Biology, Malang State University, Malang, Indonesia
Email: intan.nurnilam.2403419@students.um.ac.id [1,a], susriyati.mahanal.fmipa@um.ac.id [1,b,*], sitoresmi.prabaningtyas.fmipa@um.ac.id [1,c]
* Corresponding author

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ABSTRACT

The 21st-century skills needed by students today are science literacy and collaboration skills. One model that can empower science literacy and collaboration skills is the Complexity Science Problem-Based Learning (CS-PBL) model. The CS-PBL model is supported by the GitMind application, which addresses the limitations of CS-PBL by leveraging technology for collaboration. The purpose of this study was to determine the effect of the CS-PBL model assisted by GitMind on science literacy and collaboration skills of high school students in biology learning. Independent variables in this study were the CS-PBL model assisted by GitMind as an experimental group, the PBL model as a positive control, and conventional learning as a negative control. The dependent variables in this study are science literacy and collaboration skills. The research was conducted at SMAN 6 Malang, East Java, Indonesia. The population of the study was Grade XI students who were in the odd semester of the 2024/2025 school year. The sample taken from the population was grade XI students, consisting of 3 Biology specialization classes. The quasi-experimental research design used a pretest-posttest nonequivalent control group design. Students were given a pretest and a posttest in the experimental group and control group using the same instrument. Data were collected using essay tests to measure science literacy, questionnaires, and observation sheets to measure collaboration skills. Data were analyzed using a one-way ANCOVA test and followed by an LSD test before the ANCOVA test, a prerequisite test was conducted, namely a normality test and a homogeneity test. Novelty/new findings in this research are the integration of the CS-PBL model with GitMind. The results showed that the CS-PBL model assisted by GitMind was more effective in improving students' science literacy and collaboration skills than PBL and conventional learning, with the highest increase of 88.11% for science literacy and 88.53% for collaboration. Suggestions for the implementation of the CS-PBL model assisted by GitMind need to provide a more in-depth explanation of the description of the mind map task to students before learning.

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INTRODUCTION

The era of technology and information in the 21st century brings changes in learning. Skills and abilities in the 21st century can help students adapt to change, integrate ideas or knowledge, and develop habits of thinking systematically (Kozikoğlu, 2019). The 21st-century learning has evolved from Industry 4.0, focused on digital transformation, to Society 5.0, which integrates cyber-physical systems with a human-centered approach (Yusmar & Fadilah, 2023). Complex problems in the era of globalization and technological advancement require individuals to have higher-order thinking-based problem-solving skills (Tomé & Açıkalın, 2019). Scientific understanding enables students to address the complex challenges of the 21st century with effective and applicable solutions (Graesser et al., 2019). Students are prepared to use their skills and knowledge to effectively solve problems around them (Laar et al., 2018). The 21st-century skills in the era of society 5.0 that are important to be empowered by students are science literacy (Yusmar & Fadilah, 2023) and collaboration skills (Supena et al., 2021).

Science literacy is the ability of students to recognize, explain, apply science, and make decisions related to scientific knowledge in various complex life conditions (OECD, 2022). Science literacy involves asking questions about life and seeking answers based on scientific considerations (Merta et al., 2020). Science literacy is very important to be empowered to prepare students to develop the following changes in social life (Mahanal et al., 2021; Zubaidah, 2020). Science literacy can increase a high level of concern for the environment (Rohmaya, 2022). Science literacy is important to be empowered to prepare for decision-making with scientific considerations (Ogunkola, 2018; Rohmaya, 2022). The level of science literacy of high school students in Indonesia is still relatively low, with research showing that only about 35% of students can relate science concepts to everyday life, and only 40% can make science-based decisions (Yusuf et al., 2022). Low science literacy is caused by students' inability to apply knowledge to real life (Merta et al., 2020). Students' difficulty in connecting their knowledge with others' knowledge hinders deeper understanding (Amanda et al., 2021).The achievement of mastery of science literacy can be assisted by students' collaboration skills (Fiore et al., 2018; Sari et al., 2024).

Collaboration skills are a process of learning students to plan to work together, take into account different points of view, and actively participate in discussion activities (Greenstein, 2012). Collaboration skills are important to develop so that students are more active and not burdened while learning (Fiore et al., 2018). Collaboration skills have an important role for students in achieving understanding and solutions to problems and feel lighter when learning (Labonté & Smith, 2022). Collaboration also plays a role in improving social skills, developing competitiveness, and retaining knowledge (Ramdani et al., 2019). In fact, 48-49% of students in Indonesia with low collaboration skills (Matindike & Ramdhany, 2024). The cause of low collaboration skills is because students only depend on friends who are dominant in class (Priandini et al., 2022). The development of students' collaboration skills is hampered because the learning process is not facilitated by learning models to develop collaboration skills, in addition many students have difficulty connecting their knowledge with that of other group members, so interactions become less meaningful and discussions tend not to coalesce (Song et al., 2018). Therefore, innovative learning models are needed for one of the solutions to the problem. One solution is to apply the Complexity Science-Problem Based Learning (CS-PBL) learning model.

The CS-PBL learning model has the basic principle of studying life systems or real-world problems as a learning context by utilizing collaboration to get solutions (Amanda et al., 2022). The CS-PBL model is assisted by the GitMind application as a solution to overcome the weaknesses of CS-PBL which has not utilized technology as a means of collaboration. The use of GitMind can help students build different cognitive knowledge using how to share and explain their ideas through collaborative mind mapping (Zheng et al., 2020). The use of technology in creating mind maps increased the effectiveness of student collaboration by 27% compared to the manual method (Mursalim et al., 2023). This shows that the integration of GitMind in the CS-PBL model has the potential to strengthen student interaction and engagement in the collaborative learning process.

Research studies related to empowering science literacy and collaboration skills through innovative learning models based on complex problems and technology are current research topics. Constructivism-based learning models can develop science literacy (Kelp et al., 2023). Learning models equipped with a digital mind map creation process can train students' collaboration skills (Badriah et al., 2024; Rikmasari et al., 2020). Problem-based learning models integrated with technology can develop science literacy and student collaboration skills (Amanda et al, 2022; Sari et al., 2024). Based on the background of the above problems and given the importance of science literacy and student collaboration skills in the 21st century, the need for CS-PBL integration assisted by GitMind needs to be implemented.

RESEARCH METHODS

The study used the quasi-experimental research method, with the aim of determining the effect of the CS-PBL model assisted by GitMind on science literacy and student collaboration skills. The research design used was a pretest-posttest nonequivalent control group design (Cohen et al., 2018). The sample taken from the population was grade XI students consisting of 3 Biology specialization classes of students in SMAN 6 Malang 2024/2025 academic year, who took the biology class interest. The samples were selected with the random sampling technique. Before the research was conducted, the condition of the class showed that learning was still dominated by the lecture method and did not involve many collaborative or problem-based activities. The CS-PBL experimental group assisted by GitMind totaled 35 students, consisting of 22 women and 13 men. The positive control group, taught with PBL, totaled 36 students, consisting of 11 women and 25 men, and the negative control group, taught with direct learning, totaled 36, consisting of 20 women and 16 men. The GitMind-assisted CS-PBL, PBL, and direct learning were the independent variables, while the science literacy and collaboration skills were the dependent variables. The research design is presented in Table 1.

Table 1. Research Design

Pretest	treatment	Posttest
O_1	GitMind-assisted CS-PBL	O_2
O_3	PBL	O_4
O_5	Conventional	O_6

Information: O_1, O_3, O_5 = Pretest score; O_2, O_4, O_6 = Posttest score

Supporting learning instruments, such as interview sheets, Alur Tujuan Pembelajaran (ATP), Teaching Modules, LKS, learning model syntax implementation sheet, and assessment instruments of science literacy and collaboration skills, have been developed to collect the data. Science literacy data is taken from test results, and collaboration skills data is taken from filling out self and peer-assessment questionnaires. The supporting learning instruments were deemed valid and reliable. The science literacy assessment rubric was adapted from OECD (2016), and the collaboration skills rubric was adapted from Greenstein (2012). Pearson's Product-Moment was used to test the validity of the instruments, while Cronbach's Alpha was used to test the reliability. The research phase was 1) conducting pretest in three experimental groups to collect students' initial ability of science literacy and collaboration skills, 2) applying different learning models in three groups: CS-PBL-GitMind in the experimental group, PBL in control positive group, and direct learning in control negative group, 3) conducting posttest in three groups to find out the enhancement of students' science literacy and collaboration skills. The data were tested for normality using One-Sample Kolmogorov-Smirnov, and tested for homogeneity using Levene's test. It was followed by ANCOVA at a significance level of 5% ($p<0.05$), having criteria that if the significance value> 0.05, then the research hypothesis is rejected, while if the sig.<0.05, then the research hypothesis is accepted. The results of hypothesis testing that have been significant, then conducted further LSD (Least Significance Different) test at a real level of 5%.

FINDING AND DISCUSSION

The research data obtained was then subjected to descriptive analysis to determine the difference in value, and the improvement of science literacy data and collaboration skills in GitMind-assisted CS-PBL, PBL, and conventional classes. Science literacy data can be seen in Table 2.

Table 2. Summary of Results of Descriptive Analysis of Science Literacy Data

Classes	Average		Difference	Enhancement
	Pretest	Postest		
GitMind-assisted CS-PBL	40,86	76,86	36,00	88,11%
PBL	40,28	70,42	30,14	74,83%
Conventional	40,14	70,00	29,86	74,39%

Based on Table 2, it can be seen that students' science literacy in each class experienced various improvements. The highest increase in students' science literacy occurred in the CS-PBL class assisted by GitMind by 88.11% compared to PBL and conventional classes. Collaboration skills data from the questionnaire results (student self and peer assessment) are presented in Table 3.

Table 3. Summary of Results of Descriptive Analysis of Collaboration Skills Data

Classes	Average		Difference	Enhancement
	Pretest	Postest		
GitMind-assisted CS-PBL	41,34	77,94	36,60	88,53%
PBL	40,91	73,39	32,48	79,37%
Conventional	38,16	64,90	26,74	70,06%

Based on Table 3, it can be seen that the results of the student collaboration skills questionnaire from the results of self and peer assessment show that the biggest increase occurred in the CS-PBL class assisted by GitMind by 88.53% compared to PBL and conventional classes. The CS-PBL+GitMind, PBL, and direct learning were implemented in each group for 12 meetings. Results of ANCOVA analysis on the effect of the learning model on the students' science literacy can be seen in Table 4. Table 4 shows the information on the different learning models (Fcalculated = 5.409 with p-value = 0.006, p-value < (α=0.05)). Therefore, the hypothesis that the learning model affects students' science literacy is accepted. After the hypothesis was proven, the LSD test was performed, as shown in Table 5.

Table 4. Summary of ANCOVA Test Results on the Effect of Treatment on Science Literacy

Tests of Between-Subjects Effects					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	177.750[a]	3	59.250	5.047	.003
Intercept	4056.453	1	4056.453	345.502	.000
XLS	28.135	1	28.135	2.396	.125
kelas	127.004	2	63.502	5.409	.006
Error	1209.297	103	11.741		
Total	860902.000	107			
Corrected Total	1387.047	106			

Table 5. Summary of Further Test Results on the Effect of Treatment on Science Literacy

Classes	Corrected Science Literacy Mean	LSD Notation
GitMind-assisted CS-PBL	90,829	a
PBL	88,802	b
Conventional	87,224	c

The results of further tests in Table 5 show that the CS-PBL model assisted by GitMind produces the largest corrected mean value (90.829) and is significantly different from PBL and conventional classes. Based on these results, it can be concluded that CS-PBL learning assisted by GitMind has a higher potential in improving students' science literacy. The ANCOVA analysis result of the effect learning model on students' collaboration skills can be seen in Table 6.

Table 6. Summary of ANCOVA Test Results on the Effect of Treatment on Collaboration Skills

Tests of Between-Subjects Effects					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1217.358[a]	3	405.786	31.699	.000
Intercept	1031.520	1	1031.520	80.580	.000
XLS	1094.264	1	1094.264	85.481	.000
Kelas	200.230	2	100.115	7.821	.001
Error	1318.530	103	12.801		
Total	647920.000	107			
Corrected Total	2535.888	106			

Table 6 presents information about the difference between the learning models (Fcalculated = 7.821 with p-value = 0.001, p-value < (α=0.05)). Therefore, the hypothesis that the learning model affects students' kolaborasi skills was accepted. After the hypothesis was proven, the LSD test was performed, as shown in Table 7.

Table 7. Summary of Follow-up Test Results of the Effect of Treatment on Collaboration Skills

Classes	Corrected Science Literacy Mean	LSD Notation
GitMind-assisted CS-PBL	79,461	a
PBL	77,144	b
Conventional	75,128	c

The results of further tests in Table 7 show that the CS-PBL model assisted by GitMind produces the largest corrected mean value (79.461) and is significantly different from PBL and conventional classes. Based on these results, it can be concluded that CS-PBL learning assisted by GitMind has a higher potential in improving students' collaboration skills. The effectiveness of the CS-PBL model assisted by GitMind is seen by comparing it with other models. The results of the one-way ANCOVA analysis showed that the learning models applied in this study had an effect on students' science literacy and collaboration skills. It shows that there is a significant difference between science literacy and collaboration skills of students when taught using CS-PBL model assisted by GitMind, PBL model, and conventional learning. The GitMind-assisted CS-PBL class had the highest mean compared to the PBL and conventional classes. The GitMind-assisted CS-PBL model has the potential to develop students' science literacy and collaboration skills.

CS-PBL model assisted by GitMind is a problem-based learning that utilizes digital tools to help students work together to solve problems. The CS-PBL learning model facilitates students' mastery of thinking skills and problem-solving skills, which also helps them in acquiring key concepts from the subject matter (Amanda et al., 2022). The CS-PBL learning model makes students actively explore their thinking abilities independently and collaborate with their group (Kamei-Hannan et al., 2023). The 21st-century education focuses on problem-solving, learning to train students' thinking and social skills (Fiore et al., 2018). The education system is expected to produce human resources who are able to think critically, creatively, innovatively, and able to communicate and collaborate to solve problems (Graesser et al., 2019). A learning model based on multidisciplinarity is a very important and practical approach to improve students' ability to solve complex problems in the 21st century (Osman et al., 2020).

The first stage of the GitMind-assisted CS-PBL model is problem orientation. Students must be able to identify, analyze, and find solutions to the problems faced (Hmelo-silver, 2019). Students can access various trusted sources of information to help strengthen understanding in order to solve problems (Hattan & Alexander, 2020). Students are given apperceptions and triggering questions to focus the analysis in order to avoid discussions that are not on the topic of the problem. At this stage students are focused on training ways of thinking and analyzing various components related to the problem (Siagian et al., 2019). This analysis activity can help students to develop science literacy by looking at problems holistically and finding solutions with scientific considerations (OECD, 2022; Sari et al., 2024).

The second stage of the CS-PBL model assisted by GitMind is organizing students to learn. One of the activities of the second stage is reading (Usta et al., 2021). Reading and analyzing material will make students accustomed to analyzing the problems faced and help students develop problem-solving skills in terms of science (Amanda et al., 2023). Collaboratively, students exchange ideas with group members in building solution strategies needed to solve problems related to the survival of living things, so that students better understand the context of the problem (Fiore et al., 2018). Students who work collaboratively will gain a basis for critical thinking when they share ideas and make decisions in solving problems (Supena et al., 2021).

The third stage of the GitMind-assisted CS-PBL learning model identifies the disciplines and concepts needed to solve the problem. Students are directed to make a mind map to connect knowledge and the problem at hand. Making mind maps is done collaboratively facilitated by GitMind. GitMind provides features that can be accessed together, so students are more active in collaborating than making mind maps manually which tends to be only a few students who can contribute (Ho et al., 2023). Learning processes that utilize technology or digital devices can help make it easier for students to collaborate while learning (Maker & Zimmerman, 2020). Making this mind map also provides insight from various other scientific perspectives related to the problem at hand which makes students have more scientific considerations in order to choose the right solution in solving the problem (Maker & Zimmerman, 2020).

The fourth stage of the GitMind-assisted CS-PBL model is to investigate and make clarifications to a team of experts. The goal is to get a quality solution (Hanum & Findyartini, 2020). Students conduct interviews with experts to get the truth about the results of the information they find in order to produce valid solutions (Amanda et al., 2021). This activity is carried out so that students can also improve their collaboration skills with expert sources outside the school environment. Investigative activities can also improve understanding and reduce concept errors in the learning process (Jacobson et al., 2019).

The fifth stage of the GitMind-assisted CS-PBL model is analyzing and connecting between the information and data collected by creating mind maps to create ideas. After investigating with experts, students analyze by connecting information from experts and from the knowledge they get themselves (Amanda et al., 2023; Sari et al., 2024). The results of the analysis and linking of information are poured in the form of a mind map, which is done collaboratively. At this stage, students are more able to choose the right solution to the problem. The chosen solution is also well considered according to various points of view (Amanda et al., 2022; Sari et al., 2024).

The sixth stage of the GitMind-assisted CS-PBL model is the presentation of ideas to support the development of higher-order thinkin (Kumlin et al., 2020). Students collaboratively present/communicate the solutions applied to solve the problem in order to further develop information based on feedback from other group members. Communication and collaboration are also among the key digital competencies (Tinmaz et al., 2022). All students reviewed the problem-solving solutions related to the survival of living things presented to deepen the concept. Students also assess the accuracy and usefulness of the strategies used to solve the problem (Kaeophanuek et al., 2018).

The seventh stage of the CS-PBL model assisted by GitMind is evaluation. The results of feedback during the discussion will be evaluated so that in the future the solution or problem solving strategy used can be improved to be more efficient in creating problem solutions (Sari et al., 2024). Students also apply previous problem-solving solutions to solve other problems in other situations. Students are trained to develop sensitivity in analyzing a similar problem found in everyday life (Mahanal et al., 2020). In this technological era, every individual is required to not only be able to use digital devices, but also be able to solve various types of problems in the real world (Sari & Alfiyan, 2023).

Problem-based learning models can indeed improve students' collaboration skills (Lara et al., 2023; Nurwahidah et al., 2021). This learning model requires students to work in groups to solve complex and challenging problems (Graesser et al., 2019). This collaborative process encourages students to share ideas, discuss, give and receive feedback, and work together to achieve a common goal (Care et al., 2016). The student learning process using a living system-based model as collaborative learning will train students to find relevant solutions with various scientific considerations (Amanda et al., 2022).

The advantage of the CS-PBL model in improving science literacy is that this model invites students to understand and solve problems with more knowledge about science (Sari et al., 2024). The CS-PBL model is more effective in improving science literacy than conventional PBL because of its focus on understanding complex systems and dynamic interaction patterns. This approach uses realistic problems, utilizes tools such as GitMind to map concepts, and encourages critical and analytical thinking (Amanda et al., 2022). With an interdisciplinary and contextualized approach, students are better able to integrate science concepts and understand their application in real life, making their science literacy more developed (Amanda et al., 2023).

Empowering students' science literacy and collaboration skills is essential, especially in biology learning. The CS-PBL model assisted by GitMind helps visualize complex concepts and supports teamwork, but it faces time constraints since investigation activities often exceed class time, and reliance on digital tools can be a barrier for some students or teachers. The PBL model encourages active learning and problem-solving but may require more preparation time and strong facilitation skills from educators, which are sometimes lacking, leading to suboptimal implementation. Meanwhile, the conventional learning model tends to be teacher-centered and limits student engagement and collaboration, which can reduce students' critical thinking and problem-solving opportunities. These weaknesses highlight the need for careful adaptation and support in applying each model effectively.

The implementation of the CS-PBL model assisted by GitMind generally has constraints on time allocation and internet facilities, for implementation at SMAN 6 Malang has constraints related to time. Investigation activities require more time than the allocated time so that activities are hampered. This obstacle can be overcome by educators by making investigative tasks that are done outside of learning hours so that the time available in class can be optimized and the material learned becomes more meaningful.

CONCLUSION

The application of the CS-PBL model assisted by GitMind affects students' science literacy and students' collaboration skills in high school biology learning. The results showed that the CS-PBL model assisted by GitMind was better in improving students' science literacy compared to the PBL model and conventional learning. The highest increase in students' science literacy occurred in the CS-PBL class assisted by GitMind by 88.11%. The results of the student collaboration skills questionnaire from the results of self and peer assessment showed that the biggest increase occurred in the CS-PBL class assisted by GitMind by 88.53%.

Suggestions for the implementation of the CS-PBL model assisted by GitMind need to provide a more in-depth explanation of the description of the mind map task to students before learning. In addition, it is also necessary to pay attention to the time allocation when implementing learning in the classroom so that it can develop students' science literacy and collaboration skills optimally. Future research is expected to review the availability of internet networks in learning using technology, and can be applied to different materials.

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