The Effect of Problem Oriented Project Based Learning Model Assisted by Artificial Intelligence in Biology Learning on Science Literacy and Collaboration Skills in Senior High School Students

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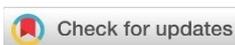
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Abstract

Background: Science literacy and collaboration skills are skills that students must be empowered with in the 21st century. Science literacy refers to understanding science issues and applying them in everyday life, while collaboration skills relate to the ability to work together to achieve goals or solve problems. Students must have these abilities so that empowering them can be done by applying innovative learning methods, strategies or models. POPBL is one of the models that can develop the skills needed by students. The effectiveness of the POPBL model is expected to increase with the integration of Aritifical Intelligence (AI). The role of AI as a tool to facilitate students in learning. This study aims to determine the effect of the AI-assisted POPBL model on science literacy and collaboration skills on circulatory system and respiratory system material. **Methods:** The research method used was quasi-experiment with nonrandomized control group pretest-posttest design. Involving three treatment classes namely POPBL class assisted by AI, POPBL, and regular class (lecture and assignment method). The sample used consisted of three classes selected from a total of four classes in the biology subject. The instruments used were science literacy questions and a collaboration skills questionnaire. Data analysis used the ANCOVA test, before that the prerequisite test was carried out, namely the homogeneity test and normality test. **Results:** The prerequisite tests conducted proved that the data were normally distributed and the data variance was homogeneous. The results of the ANCOVA data analysis value have a significance value of the learning model treatment which is p-value = 0.000. This shows that AI-assisted POPBL has an effect on science literacy and collaboration skills. **Conclusions:** AI-assisted POPBL has an effect on science literacy and collaboration skills.

Keywords: Artificial intelligence; Chatbot; Collaboration skills; Quasy experiment; Science literacy; POPBL

Introduction

Industrial revolution 4.0 as the fourth phase is characterised by the merging of automation and cyber technology (Harahap, 2019). Inventions in the industrial revolution 4.0 era such as Artificial Intelligence (AI), Internet of Things (IoT) to big data. Increasingly sophisticated technology will help make it easier for humans in various fields. The industrial revolution 4.0 allows technological links that are connected to various fields, one of which is the field of education. Parties that take part in education must be able to

keep pace and keep up with technological advances (Effendi & Wahidy, 2019). Technology provides a great opportunity to make learning more interactive, inclusive, relevant, and flexible during the learning process (Shah, 2023).

The rapid development of science and technology requires students to adapt and keep up with the times. Students must prepare themselves to face challenges (Junedi et al., 2020). Teachers as facilitators in learning are expected to direct students to use technology appropriately and responsibly so that it has a positive impact such as fostering new skills (Verawati & Sarjan, 2023). Teachers must present learning that prioritises students to have 21st century skills (Prayogi & Estetika, 2019). Therefore, the role of the teacher as a real facilitator in learning is needed, with the hope of being able to direct students in the appropriate use of technology in order to improve the skills that 21st century education demands.

Along with the rapid and widespread development of technology, scientific attitudes should not be abandoned, so an appropriate ability is needed, namely science literacy. Science literacy is the ability to understand science issues and apply them in everyday life (OECD, 2023). Science literacy sees the importance of thinking and acting skills using scientific thinking in providing solutions. Science literacy requires not only knowledge of science concepts and theories but also knowledge of procedures related to scientific enquiry and the extent to which this knowledge can be proven (OECD, 2019). According to Mayasari & Paidi (2022), individuals who have science literacy will easily adapt to the real world, able to take a role in local, regional and international society. Science literacy is part of the 21st century skills that students must have in order to keep up with the times (Yusmar & Fadilah, 2023).

Science literacy needs to be properly empowered so that students are able to apply it in everyday life and solve problems related to science issues. Problem solving can be done collaboratively, allowing students to exchange ideas and find solutions together. Therefore, in addition to science literacy, collaboration skills must also be properly empowered. Collaboration is defined as the process of working together between individuals or groups who participate with each other in an effort to achieve goals or solve problems (Ofstedal & Dahlberg, 2009). Collaboration is about learning to plan and work together to consider diverse perspectives, participate, listen, and support others (Greenstein, 2012). In addition, to understand and solve science phenomena through the process of investigation, teamwork is needed to solve a problem (Firman et al., 2023).

Past interviews study with one of the MAN biology teachers who stated that science literacy has never been empowered. Supported by a preliminary study at one of the MANs of Hulu Sungai Utara Regency on 13 June 2024, the number of subjects was 70 students using science literacy test questions showing that science literacy was in the low category. This indicates that the science literacy of grade XI needs to be properly empowered so that students have 21st century life skills and are able to adapt to the times. This finding agrees with Sutrisna (2021) that the science literacy of Class X high school students in Jambi has a low category, because students are not familiar with questions that demand understanding and analysis. Evaluation questions only require recall of material. In 2022, the PISA results stated that Indonesia's ranking in science literacy had increased by 6 positions from before to 67th out of 81 participating countries, but there was a decrease in score by 13 points (OECD, 2023). This is quite concerning for Indonesia, so it needs continuous efforts to be able to overcome these problems.

Based on preliminary studies with interviews with one of the MAN biology teachers who stated that during the practicum the teacher in several groups to do the practicum, the rest of the students worked independently according to the division of tasks in the group without conducting further discussions to solve problems. Supported by a preliminary study at one of the MANs of Hulu Sungai Utara Regency on 13 June 2024, the number of subjects was 70 students using a collaboration skills questionnaire which showed that collaboration skills were in the moderate category. This indicates that the

collaboration skills of class XI need to be properly empowered so that students have good collaboration skills. Agree with Firman et al. (2023) students' low collaboration skills are due to individualised student interaction patterns that prioritise learning competition.

Through science literacy and collaboration skills, students can build new understanding of real-world science issues. Students together with peers exchange ideas in order to enrich knowledge and understanding. The issues discussed are related to real-world conditions, where students already have prior knowledge. In line with Constructivism learning theory by Jean Piaget which explains the process of assimilation and accommodation to achieve cognitive balance (equilibration). Equilibration occurs when there is an imbalance between the student's cognitive structure and external reality, so to be balanced there is a process of assimilation and accommodation. Assimilation refers to the adjustment of external reality with existing cognitive structures, while accommodation is related to changing the structure of thought to adapt to external reality (Schunk, 2012). Accommodation can be equated with learning so as to produce intellectual growth (Hergenhahn & Olson, 2001).

Students exchange information and help each other in understanding the material so that learning becomes more meaningful. Students work together with peers to help each other solve problems. This is in line with Lev Vygotsky's Sociocultural learning theory which states that individual interaction with the environment can support the learning process. The experience that individuals have into learning can greatly affect learning outcomes. Assistance (scaffolding) from more capable peers can make students at a potential level than when working independently this is related to the zone of proximal development (ZPD) (Schunk, 2012). Collaboration skills can be obtained through social interaction in the learning environment, so that students can learn more effectively by discussing and sharing experiences.

Empowering science literacy and collaboration skills can be done in biology learning. Biology learning prioritises the thinking process in conducting investigations to produce a conclusion. The approaches in learning biology are inquiry approach and contextual approach. Inquiry is related to building knowledge based on evidence obtained from investigations (Bevins & Price, 2016). The contextual approach is related to life that is close to students so that they can make more meaning of learning (Bustami et al., 2018). Students are expected to construct knowledge based on experience and interaction in the environment, this is in line with Constructivism learning theory. Students interact with peers or their environment to help in gaining new knowledge, this is in line with Sociocultural learning theory. Through the above learning approaches and theories, students are given authentic learning experiences so that students are trained in solving daily life problems through scientific work so that in learning biology there is a Problem Oriented Project Based Learning model (Rongbutsri, 2017).

Problem Oriented Project Based Learning (POPBL) is a combination of Problem Based Learning and Project Based Learning (Rongbutsri, 2017). Students are encouraged to formulate their own problems before starting investigations and building knowledge (Strobel & van Barneveld, 2009). Problem Oriented Project Based Learning (POPBL) is a project-based learning model that is orientated to solve problems. POPBL model ensures individuals to achieve learning objectives with project work orientated to contextual problems. The topic chosen for the project should be related to student learning (Rongbutsri, 2017).

The main principles of POPBL learning are problem-oriented, interdisciplinary project work, student-centred, and collaboration. The POPBL model in the context of Indonesian education has been developed at the Master of Biology Education Study Programme at the State University of Malang. The phases in the POPBL model are 1) orientation and problem formulation, 2) organising students to learn, 3) designing and implementing projects, and 4) presenting results and evaluation (Filmi et al., 2024; Francisco et al., 2024; Suwistika et al., 2024). The POPBL model has been shown to empower students' science literacy and collaboration skills (Filmi et al., 2024; Suwistika

et al., 2024). However, in previous studies, the POPBL model has not been integrated with current technology.

Along with the times, new technologies such as AI have emerged that can help humans to do work faster. AI allows humans to interact as interlocutors, answer questions and engage in open discussions on various topics asked by users (Allen, 2010). The AI can improve the quality of students and the accessibility of learning. This is the right step towards a future of education that is more inclusive, innovative, and in line with the times (Putri et al., 2023). The strength of a chatbot lies in its capacity to manage complex requests with a simple and easily understood end result. Chatbot belongs to the category of weak AI because it is limited to what the user commands (UNESCO, 2023). The AI in the form of Chatbot in PPA/PBL can be used as a virtual mentor (Shah, 2023). Chatbots can provide quick answers to student commands (Rifky, 2024). The responses provided are considered informative and support the understanding of users who have interacted before (Nugroho & Voutama, 2024).

The world of education has not turned a blind eye to technological developments. Technology can be applied in learning by integrating learning models with AI. AI functions as a tool that helps students collect, analyze, and visualize complex data sets (Shah, 2023). The role of AI in learning is to help students obtain the information they need. Previous research using the POPBL model has been able to effectively empower students' science literacy and collaboration skills (Filmi et al., 2024; Suwistika et al., 2024). However, these studies have not integrated Artificial Intelligence (AI) as part of the learning process. In fact, AI has great potential in supporting the process of collecting, analyzing, and visualizing data as well as in obtaining and processing information independently. The novelty of this research lies in the integration of the POPBL model with AI, specifically the use of AI in biology learning. This research not only applies the POPBL model but also utilizes AI as a learning support tool to enhance students' science literacy and collaboration skills. This research offers an innovative technology-based learning approach relevant to 21st century skills. Thus, this study aims to determine the effect of the Problem Oriented Project Based Learning (POPBL) model assisted by Artificial Intelligence (AI) in Biology learning on the science literacy and collaboration skills of grade XI students.

Methods

The research method used was a pseudo-experiment with a nonrandomized control group pre-test post-test research design. The research population was class XI which contained biology subjects, sampling was carried out using the equality test, then the class was randomly selected. This study consisted of three classes, namely an experimental class of 33 students who received AI-assisted POPBL treatment, a positive control class of 33 students who received POPBL treatment, and a negative control class of 38 students who received lecture method treatment accompanied by assignments.The research design is presented in Table 1.

Table 1. Nonrandomized Control Group Pre-test Post-test Design

Class	Testing	Treatment	Testing
Class 1	O_1	X_1	O_2
Class 2	O_3	X_2	O_4
Class 3	O_5	X_3	O_6

Source: adapted from Leedy & Ormrod (2021:233)
Description:
O_1 : Pre-test
X_1 : AI-assisted POPBL
X_2 : POPBL
X_3 : Lecture method with assignments
O_2 : Post-test

This research was conducted at one of the Islamic senior high schools in Amuntai City, Hulu Sungai Utara Regency, South Kalimantan Province from September to October 2024.The biology material discussed in the study was the circulatory system and respiratory system. The instruments used in this study were science literacy test questions and collaboration skills questionnaires developed by the researchers themselves. The instruments of the science literacy test questions and skills have been validated by experts and have been tested for validity and reliability. The validity and reliability tests of science literacy questions and collaboration skills questionnaires were declared valid and reliable.

Science literacy test questions and a collaboration skills questionnaire were given at the beginning and at the end of learning after getting treatment. The implementation of the AI-assisted POPBL model was carried out for 24 lesson hours.

Table 2. Brief Summary of Research Implementation

JP	Activities
2 JP	Preliminary test of science literacy and collaboration skills
4 JP	Orientation and problem formulation and teaching how to make good and correct prompts
4 JP	Organizing students to learn
4 JP	Designing and implementing the project
4 JP	Presenting results and evaluation
2 JP	Final test of science literacy
2 JP	Collaboration skills final test

Based on Table 2, it shows that the class was given questions and questionnaires before being treated and after being treated. The data obtained by researchers in the implementation of the study will be analyzed. Data analysis techniques used in this study include the normality test using the Shapiro Wilk Test, homogeneity test using Levene's Test for Equality of Error Variances, and hypothesis testing using One-Way Analysis of Covariance Test.

Result

Science literacy

Based on Table 3, the results of the analysis show that there is a difference in the average score between the class taught with the AI-assisted POPBL model, the class taught with the POPBL model, and the class taught with the lecture method accompanied by assignments. The three classes experienced an increase in the average score but the highest increase was obtained by the AI-assisted POPBL model class.

Table 3. Science Literacy Pre and Pots Test Data

Class	Science Literacy			
	Pre-test	Std dev	Post-test	Std Dev
Experiment (POPBL-AI)	69.32	5.69	77.15	5.12
Positive control (POPBL)	68.06	6.64	74.24	6.71
Negative control (Conventional)	65.24	5.75	69.85	4.27

Before the data was analyzed by hypothesis testing, the data was first tested for normality. Normality test was conducted using Shapiro Wilk Test. The results of the normality test show that the significance value of the science literacy variable in each class, namely the experimental class p-value = $0.456 > \alpha = 0.05$, the positive control class p-value = $0.418 > \alpha = 0.05$, and the negative control class p-value = $0.330 > \alpha = 0.05$. This indicates that the science literacy data is normally distributed.

The next pre-requisite test is the homogeneity test using Levene's Test Of Equality of Error Variances. The results of the homogeneity test of science literacy show that the significance value of the science literacy variable p-value = 2.052 > α = 0.05, this states that science literacy data has a homogeneous data variance. Science literacy data can continue hypothesis testing with One Way Analysis of Covariance parametric statistics.

Table 4. ANCOVA Test Analysis Results on Science Literacy Data

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2668,460ᵃ	3	889,487	71,314	0,000	0,681
Intercept	614,381	1	614,381	49,258	0,000	0,330
Awal	1704,585	1	1704,585	136,665	0,000	0,577
Model	336,572	2	168,286	13,492	0,000	0,213
Error	1247,276	100	12,473			
Total	566629,140	104				
Corrected Total	3915,736	103				

Based on Table 4, it is known that the p-value = 0.000 < α = 0.05, which means that H0 is rejected. This shows that there is a significant difference in science literacy between one class and another. It indicates that the AI-assisted POPBL model has an effect on students' science literacy. so it can be interpreted that the AI-assisted POPBL model has an effect on science literacy.

Collaboration skills

Collaboration skills were measured using a questionnaire. The initial and final test data of collaboration skills are presented in Table 5.

Table 5. Collaboration Skills Pre and Post Test Data

Class	Collaboration Skills			
	Pre-test	Std dev	Post-test	Std Dev
Experiment (POPBL-AI)	77.49	5.69	77.15	5.12
Positive control (POPBL)	77.14	6.64	74.24	6.71
Negative control (Conventional)	75.06	5.75	69.85	4.27

Based on Table 5, the results of the analysis show that there is a difference in the average score between the class taught with the AI-assisted POPBL model, the class taught with the POPBL model, and the class taught with the lecture method accompanied by assignments. The three classes experienced an increase in the average score but the highest increase was obtained by the AI-assisted POPBL model class.

Before the data was analyzed by hypothesis testing, the data was first tested for normality. Normality test was conducted using Shapiro Wilk Test. The results of the normality test showed that the significance value of the collaboration skills variable in each class, namely the experimental class p-value = 0.171 > α = 0.05, the positive control class p-value = 0.095 > α = 0.05, and the negative control class p-value = 0.438 > α = 0.05. It shows that the collaboration skills data is normally distributed.

The next pre-requisite test is the homogeneity test using Levene's Test Of Equality of Error Variances. The results of the homogeneity test of collaboration skills show that the significance value of the science literacy variable p-value = 2.448 > α = 0.05, this states that the collaboration skills data has a homogeneous data variance. Collaboration skills data can continue hypothesis testing with One Way Analysis of Covariance

parametric statistics. The results of ANCOVA Test Analysis on collaboration skills are presented in Table 6.

Table 6. ANCOVA Test Results on Collaboration Skills Data

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1321,180[a]	3	440,393	38,547	0,000	0,536
Intercept	289,757	1	289,757	25,362	0,000	0,202
Awal	608,370	1	608,370	53,249	0,000	0,347
Model	415,720	2	207,860	18,194	0,000	0,267
Error	1142,494	100	11,425			
Total	706541,862	104				
Corrected Total	2463,674	103				

Based on Table 6, it is known that the p-value = 0.000 < α = 0.05, which means that H0 is rejected. This shows that there is a significant difference in collaboration skills between one class and another. It indicates that the AI-assisted POPBL model has an effect on students' collaboration skills.

Discussion

Science Literacy

Science literacy was measured using test questions. Data analysis using ANCOVA showed significant results, indicating that there were differences between the three classes studied. The test results showed differences in average scores between the class taught using the AI-assisted POPBL model, the class taught using the POPBL model, and the conventional class (lecture method). All classes experienced an increase in average scores. The highest increase was obtained by the AI-assisted POPBL model class. Therefore, the AI-assisted POPBL model has an effect on the science literacy of grade XI students on the material of the circulatory and respiratory systems.

Based on the research data, there was an increase from the initial test to the final test. The highest increase was found in classes taught using the AI-assisted POPBL model. The application of the AI-assisted POPBL model has a significant impact on empowering students' science literacy. In line with the research by Suwistika et al. (2024), which states that POPBL can empower science literacy. The novelty in this study is the integration of POPBL with AI. Indications of an increase in science literacy in classes taught using the AI-assisted POPBL model in learning prioritize real problems to be solved by students and assistance from AI. AI presents information in the form of data that is transformed according to the needs of students to find and solve a problem (Lasechko & Lasechko, 2024).

The integration between the POPBL model and technology in the form of AI encourages students to be active in identifying and finding solutions to real-world problems through the use of AI technology. The AI provides fast responses to commands given by students. The presence of AI not only expands students' access to various sources of knowledge, but encourages the development of students' skills and abilities. The learning process becomes more interactive and problem-solving oriented. This integration is a means to train students to think and adapt to technological developments. Through each stage in the AI-assisted POPBL model, students get AI technology support in completing projects as a form of solution to the problems that occur.

The first stage in the AI-assisted POPBL model is problem orientation and formulation. The problem presented was forest fires that occurred in South Kalimantan. Students asked AI to help them formulate the problem. The problem formulation

provided by AI is analyzed and reformulated by students in order to meet the criteria. An understanding of ethics in the use of AI is necessary to ensure that its use is not only effective but responsible (Sangka et al., 2023) .

At this stage students have empowered science literacy because they are able to understand, identify and explain the scientific phenomena presented. The problem-based learning model can improve science literacy by focusing on solving real problems (Supriwardi et al., 2021). During problem formulation, students are expected to be sensitive to emerging science issues, identify questions, and interpret scientific phenomena from a problem scientifically (Wulandari & Sholihin, 2016). Presenting real-life situations in learning can train students to have science literacy (Sumanik et al., 2021). Based on Jean Piaget's Constructivism learning theory, students process their knowledge so that they are able to find connections between new knowledge and existing knowledge to produce deeper knowledge (Schunk, 2012).

The second stage is organizing students to learn. Students with group friends learn concepts related to forest fire problems that will be solved and the material of the respiratory system and circulatory system. Students use knowledge through textbooks, scientific articles, and AI. AI helps in providing real-time feedback to get the information desired by users and can improve student understanding (Rusman & Qadrianti, 2024; Susilowati & Sulasmi, 2020). Students analyze the information obtained and then students make a mind map or summary to determine the extent of student understanding. Mind maps help students understand the material, increase activity, and learning outcomes (Zein, 2015). Therefore, students build new knowledge from the results of information exploration in order to solve problems.

At this stage students design or develop an investigation plan to obtain information through various sources. Students compile a list of questions to conduct field investigations with the help of AI. The list of questions provided by AI is analyzed and selected to be used as questions in the investigation. Investigation activities provide opportunities for students to gain real experience about the phenomena that occur (Putri et al., 2014). This phase is able to empower science literacy because it is able to design investigations. According to Juhji & Mansur (2020) science literacy is needed in mastering biological concepts because students are required to actively read and examine scientific phenomena to answer problems related to phenomena. Students build knowledge and concepts through investigations and new experiences gained. In line with Constructivism theory, students build knowledge by integrating new information into existing mindsets and changing inappropriate mindsets so that cognitive balance occurs which makes students have a deep understanding (Schunk, 2012).

The third stage is designing and implementing the project. Students together with group friends determine a project theme followed by project implementation. This stage involves the help of AI to get suggestions for alternative project ideas, tools and materials needed, and work steps in order to help students to design projects. During the activity, students are faced with phenomena that have been observed and data from scientific investigations. The data obtained will help in completing the project. This activity can trigger students to read in processing information, formulating conclusions, practicing identifying assumptions, evidence and reasoning related to science (Zulfa et al., 2022). This phase is able to empower science literacy because students are able to explain scientific phenomena, interpret data and evidence scientifically. The problem-based learning model requires students to read to get solutions so that students are trained in solving problems (Widiana et al., 2020). According to Suwistika et al. (2024) students actively collect various relevant information to support project development. In line with Constructivism learning theory, that students construct various knowledge so that they find the connection between new and existing knowledge to produce a solution to the problem (Schunk, 2012).

The last stage is presenting and evaluating the project results. Students present the project results in various forms, then students ask for advice and input from AI regarding

the project results. According to Rifky (2024) AI can be used to assist in evaluating tasks. This is an improvement material that students need to consider. Students present the results while the teacher and other students provide evaluation. This evaluation aims to improve the product for the future. Discussion and presentation activities can make students listen to the opinions of other groups so that there is an exchange of ideas between students (Solikhatun et al., 2015).

At this stage students share knowledge and information so that students are able to understand and apply it. This stage empowers science literacy because students are not only required to understand but also apply in life. According to Suwistika et al. (2024) this activity will improve aspects of science literacy by applying knowledge in everyday life. The underlying theory is Ausubel's meaningful learning where students connect new information with prior knowledge, so that students will more easily understand and apply in everyday life. Students who have good science literacy can apply it in everyday life (Kusuma, 2023).

Based on the explanation above, the AI-assisted POPBL model affects students' science literacy. The influence can be seen from the activities carried out by students in each stage of the AI-assisted POPBL model. This finding is in line with the research of Suwistika et al. (2024) which states that the POPBL model is able to empower students' science literacy.

Collaboration Skill

Collaboration skills were measured using a questionnaire. Data analysis using ANCOVA yielded significance values indicating that there were differences between the three classes studied. The results showed that there were differences in average scores between the class taught using the AI-assisted POPBL model, the class taught using the POPBL model, and the conventional class (lecture method). All classes experienced an increase in average scores, but the highest increase was obtained by the AI-assisted POPBL model class. Therefore, the AI-assisted POPBL model has an effect on the collaboration skills of grade XI students in the subject of the circulatory and respiratory systems.

Based on the data from the initial and final tests in the classroom, there was an increase. The highest increase was in classes taught using the AI-assisted POPBL model. The application of the AI-assisted POPBL model indicates that this model has a significant impact on training students' collaboration skills. Students were divided into several groups to interact and work together to solve problems. This is in line with the research by Filmi et al. (2024), which states that POPBL can improve collaboration skills. The novelty in this study is POPBL integrated with AI to help students solve problems collaboratively.

The integration between the POPBL model and technology in the form of AI encourages students to collaborate actively in finding solutions to real-world problems through the use of AI technology. The AI is able to provide quick responses to commands given by students, thus supporting the effectiveness of the learning process. The presence of AI not only expands access to a wide range of information, but encourages the development of student skills. Through the help of AI technology, students can complete collaborative projects as solutions to problems by following each stage of the AI-assisted POPBL model.

The first stage is problem orientation and formulation. Students together with group friends with the help of AI formulate problems related to forest fires in South Kalimantan. Students analyze the problem formulation provided by AI, then reformulate the problem formulation. The implementation of AI in learning must consider ethical aspects and maintain the essence of education as a process of developing the whole person (Isdayani et al., 2024). Each student contributes ideas to identify and formulate problems with the

help of AI collaboratively. Therefore, AI answers must be analyzed and reformulated collaboratively.

This stage has empowered collaboration skills where students contribute, interact with each other, and try to solve the problem. According to Khofifatul & Wulandari, (2024) collaboration skills can train exchanging ideas and information to find creative solutions and successfully complete tasks that depend on interaction with each other. According to Prasutri et al. (2019) activities to identify problems carried out in groups have a positive impact on students' learning experience. This statement is based on learning theory by Lev Vygotsky which states that learning is building a mental phase to be higher which occurs when interacting with others rather than working independently, so that the Zone of Proximal Development (ZPD) occurs (Schunk, 2012).

The second stage is organizing students to learn. Students together with group friends learn concepts that are relevant to the problem of forest fires and the material of the respiratory system and the circulatory system. Students read and search for information with the help of textbooks, scientific articles, and AI to support knowledge. AI creates a learning environment that is more responsive to individual needs (Seo et al., 2021)Soe. The results of understanding are put into a mind map or summary, this is done to determine the extent of student understanding. According to Wati et al. (2021). learning with mind maps can improve students' cognitive learning outcomes. Students build new knowledge from the results of collaborative exploration. Students not only learn together but train to build and improve knowledge while interacting with other students.

Interaction with group friends makes students share information to be able to learn related to the material and problems to be solved. Collaboration skills can be possessed by students when given the opportunity to engage and work together in solving problems (Hidayati, 2019). Students interact with each other to share information related to problems and relate material concepts so that this phase can empower collaboration skills (Webster et al., 2022). Through interaction with the environment, children's cognitive structures change, so that the number of experiences continues to grow as well (Hergenhahn & Olson, 2001). This is based on the Sociocultural learning theory by Lev Vygotsky where students build knowledge through experience and interaction with the environment to be able to assist in the learning process (Schunk, 2012).

The third stage is designing and implementing the project. Students collaboratively determine a project theme followed by project implementation. This stage involves AI assistance in the form of suggestions for alternative project ideas, tools and materials needed, and project work steps so that it can help students to design the project to be done. Students share tasks and help each other during the project so that it can be completed on time. When students collaborate, students will gain a basis for critical thinking, share ideas, and make decisions to solve problems (Supena et al., 2021). This is based on Lev Vygotsky's learning theory where there is a process of providing assistance from peers to someone to perform tasks that initially cannot be done alone so that designing and solving problems will become easier to solve together (Schunk, 2012).

The fourth stage is presenting and evaluating the project results. Students present the project results in various forms. Before the presentation, students first ask for advice and input from AI regarding the project results that have been made. AI can support evaluation by providing faster and more accurate feedback (González-Calatayud et al., 2021). The suggestions and feedback from AI are evaluation materials that need to be considered. Students present the project results together with the group while the teacher and other students provide evaluation. Good evaluation skills from teachers can provide specific and useful feedback for students which can increase student confidence (Husni, A dan Randi, 2024). Student involvement in evaluating friends can deepen understanding of the material and improve collaboration skills (Kurniawati & Hadi, 2021).

At this stage students empower collaboration skills, namely reflection. Reflection is done to evaluate and improve the project process and cooperation during learning. The

ultimate goal of collaboration is to practice effective division of labor, improve character, responsibility, and incorporation of information from various sources of knowledge, perspectives, and experiences (Ulhusna et al., 2020). Students learn how to respect the opinions of others, evaluate each project, and help other students when answering questions. These activities can improve social regulation, which will have an impact on improving students' collaborative skills (Shofiyah et al., 2022). This is based on David Ausubel's learning theory of meaningful learning where students obtain new information through the presentation of other group mates, then connect with the knowledge they already have so that students can understand well (Ausubel, 2000).

Based on the explanation above, the POPBL model assisted by AI has an influence on students' collaboration skills. Where each stage in the application of the AI-assisted POPBL model is able to empower students' collaboration skills. This can be seen from the activities carried out by students in each stage of the AI-assisted POPBL model. In line with the research of Filmi et al. (2024) that POPBL can improve collaboration skills. This can be seen in the discussion during problem formulation until students present the results.

Conclusions

The application of Problem Oriented Project Based Learning (POPBL) model assisted by Artificial Intelligence in biology learning has an effect on the science literacy of 11th grade MA students. Students who are taught using the AI-assisted POPBL model have higher science literacy scores compared to students who are taught using the POPBL and the lecture method accompanied by assignments. The application of Problem Oriented Project Based Learning (POPBL) model assisted by Artificial Intelligence in biology learning has an effect on the collaboration skills of grade XI MA students. Students who are taught using the AI-assisted POPBL model have higher collaboration skill scores compared to students who are taught using the POPBL and the lecture method accompanied by assignments.

Declaration statement

The authors reported no potential conflict of interest.

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