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The Effect of Problem Oriented Project Based Learning (POPBL) Model Assisted by Artificial Intelligence (AI) on Creative Thinking Skills and Collaboration Skills of MA Students

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ABSTRACT
Creative thinking skills and collaboration skills are essential skills for 21st-century education. To develop these skills, innovative learning methods and strategies are required. The POPBL assisted by AI model is one such innovative learning model that can be implemented because it effectively facilitates students in developing 21st-century skills. The effectiveness of the POPBL model is expected to increase with the integration of Artificial Intelligence. This study aims to investigate the impact of the POPBL Assisted by AI model on creative thinking skills and collaboration skills. A quasi-experimental design with a non-randomized control group pretest-posttest design was used in this study. This study involved three groups: POPBL assisted by AI model, POPBL, and lecture method accompanied by assignments. The results of the analysis of students' creative thinking skills showed the POPBL assisted by AI model outperformed the POPBL and the lecture method accompanied by assignments. The results of the analysis using ANCOVA showed that the POPBL assisted by AI model had a significant effect on students' creative thinking skills with a significance value of p = 0.002 and students' collaboration skills also had a significant effect with a significance value of p = 0.000.

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1. INTRODUCTION

The industrial revolution 4.0 is an era of technological development. Technological developments in the 4.0 era cover various industrial sectors, one of which is in the field of education (Teo et al., 2021). This development requires students to adapt by having some of the skills needed. 21st century education focuses on developing skills through students' active role in the real world. Students are expected to develop critical thinking, creativity, collaboration, and communication skills (González-pérez & Ramírez-montoya, 2022). The Partnership for 21st century skills (P21) identifies critical thinking skills, creative thinking skills, communication skills, and collaboration skills as skills needed in the 21st century (Supena et al., 2021).

Future oriented education coined the idea of "4Cs" as "Learning and Innovation Skills" that require a better learning environment (Thornhill-Miller et al., 2023). It is important for students to not only acquire new knowledge when learning, but also develop skills such as problem solving, social collaboration, and creativity to apply the newly learned knowledge to the real world. Such knowledge and skills will help adapt to modern society as well as improve students' competitiveness (Shadiev & Wang, 2022).

Developing creative thinking skills is essential in the modern era so that students can overcome complex problems in everyday (Kardoyo et al., 2020). One focus of improving education in Indonesia is to improve student learning creativity (Machali et al., 2021). Creative thinking skills are skills to find gaps, paradoxes, opportunities, challenges, problems, and new meaningful relationships by generating various possibilities from different points of view, unusual or original possibilities, and details to expand or enrich existing possibilities (Treffinger et al., 2002). Creativity is characterized by the ability to create or embody, invest with new forms, produce imaginative skills to make or present something new (Greenstein, 2012). Creative thinking is included in the cognitive domain level C6 (create), which is the ability to create new things so that students can be trained in developing their ideas

(Anderson et al., 2001). Indicators of creative thinking skills according to Treffinger et al. (2002), namely 1) fluency, 2) flexibility, 3) originality, 4) elaboration, and 5) metaphorical thinking.

Creative thinking skills are a person's ability to generate or create new ideas from existing problems around (Piawa, 2010). Creativity is an individual mental process that gives birth to new ideas, processes, methods or effective products that are imaginative, flexible, and discontinuous, which are useful in various fields for solving a problem (Safi, 2019). The characteristics of a creative personality are being able to think convergently and divergently, high curiosity, self-confidence, independence, conceptual flexibility, producing unique ideas/originality, prioritizing complexity over simplicity, and having many interests and skills in various fields (multiple skills) (Cho, 2017).

Developing creative thinking skills is very important in education because with creative thinking skills students will be able to make the right decisions in a problem (Tayuda & Siswanto, 2020). Through creative thinking skills, students are able to view the world from various perspectives so as to generate new solutions to solve problems in real life (Sumarni et al., 2019). Empowering students' creative thinking skills can be done by providing contextual problems so that students can find or create new ideas based on their existing knowledge (Sari et al., 2021).Creative thinking skills in learning are closely related to the process of effective collaboration between individuals (Thornhill-Miller et al., 2023).

Collaboration is defined as the process of working together between individuals or groups who participate with each other in an effort to achieve a goal or solve a problem. Collaboration emphasizes co-creation, where group members share information, ideas, and responsibilities to achieve better solutions. This process involves joint planning, decision-making, and problem-solving together, thus forming one interconnected and mutually supportive cognitive system (Ofstedal & Dahlberg, 2009).

Collaboration is more than just working with others. Collaboration skills are a process in learning that is done together to compensate for differences in views, knowledge, taking part in discussions by giving advice, listening, and supporting each other. Collaboration involves the ability to listen well, respect others, convey ideas clearly to achieve a common goal. In a collaborative classroom, students work and learn together to achieve goals by performing meaningful tasks to generate ideas and products (Greenstein, 2012). Indicators of collaboration skills according to Ofstedal & Dahlberg (2009) are 1) contribution, 2) time management, 3) team support, 4) problem solving, 5) interaction with others, and 6) reflection.

Collaboration skills are important for students because they can help develop students' social and personality relationships, increase motivation and learning outcomes, and train students in collaborative problem solving (Dewi et al., 2020). Collaboration skills are important skills and need to be possessed to encourage one's success both in education and social life (Hayat et al., 2019). Collaboration skills play an important role in improving learning effectiveness (Thahir et al., 2024). Students' collaboration skills can be empowered by providing various tasks that include elements such as the process of setting goals, making plans, generating and selecting strategies, trying solutions, revising plans, and so on (Saenab et al., 2019).

Various contextual problems related to learning can be overcome with students' creative thinking skills. The collaboration process is also important in learning to support students' creative thinking skills because there is interaction in learning. A study conducted at one of the State Madrasah Aliyah in Banjarmasin City on May 16, 2024 with a total sample of 94 people using essay test questions showed that students' creative thinking skills were poor. Elaboration indicators get the lowest results, but indicators of fluency, flexibility, and originality are also still low. This is influenced by the fact that students are rarely trained in creative thinking skills in learning using precise measurements, such as students not yet being able to clearly detail the ideas/concepts presented. This is in line with research conducted by Putri & Alberida (2022) which shows that students' creative thinking skills in one of the schools in West Sumatra are still relatively low. A study was also conducted on students' collaboration skills on May 16, 2024 using a self-assessment questionnaire with a sample size of 94 people showing that students' collaboration skills were classified as sufficient. This is in line with research conducted by Ardelia & Juanengsih (2021) which shows that the level of collaboration skills of students in one of the schools in Banyuwangi Regency in Biology subjects is still relatively low.

The underlying learning theories to develop students' creative thinking skills and collaboration skills are Piaget's constructivism theory and Vygotsky's sociocultural theory. Piaget's constructivism theory states that the process of cognitive development consists of three stages: equilibration, accommodation, and assimilation. When individuals encounter new information that does not match their current understanding, disequilibrium occurs. To re-equilibrate, individuals need to adjust their understanding through assimilation or accommodation. Assimilation is a process in which individuals integrate new information into existing cognitive schemes or structures. Adjustment or change of cognitive schemes in order to accommodate new information that does not fit with previous understanding (Schunk, 2012).

Vygotsky's sociocultural theory suggests that one's interactions with the environment can aid learning. The experiences that a person brings to learning can affect learning outcomes. This relates to the Zone of Proximal Development (ZPD) which defines that the distance between the actual level of development determined by

independent problem solving and the potential level of development determined through problem solving with adult guidance or in collaboration with more capable peers (Schunk, 2012).

Both learning theories emphasize effective learning in an effort to empower creative thinking skills and collaboration skills. In learning, students are given learning experiences by being actively involved to challenge students' thinking so that they are able to build their own knowledge. Learning is designed in a way that teachers provide assistance and guidance to students on elements that are beyond students' capabilities. In addition, through collaboration activities teachers direct students to work with peers in order to achieve the best potential of each individual. Based on Piaget's constructivism and Vygotsky's sociocultural learning theory, problem and project-based learning such as POPBL model can be implemented to develop students' creative thinking skills and collaboration skills. Each stage in the POPBL model can facilitate students in building their own knowledge and working collaboratively in implementing the project.

Some of the previous research conducted in an effort to empower creative thinking and collaboration skills is by implementing innovative project- and problem-based learning (Francisco et al., 2024; Filmi et al., 2024;Suwistika et al., 2024). Project-based learning methods emphasize active, collaborative, and student-centered learning that aims to encourage creativity, innovation, and problem solving (Taliak et al., 2024). One of the project and problem-based learning models is the Problem Oriented Project Based Learning (POPBL) model.

Problem Oriented Project Based Learning (POPBL) model is a project-based learning that is oriented to solve problems. This model is a combination of problem and project-based learning. The POPBL model is used to ensure that students will achieve learning objectives through project work. The topic chosen for the project should relate to the students' current learning (Rongbutsri, 2017). POPBL begins with a problem analysis followed by the design of a project to solve the problem found. The learning outcome of POPBL is not just general knowledge, but also the development of analytical and argumentation skills and presenting solutions to essential questions (Yasin & Rahman, 2011). The POPBL model has been developed in the Master of Biology Education Study Program at State University of Malang with four learning stages including identifying and formulating problems, organizing students to learn, planning and implementing projects, presenting results and evaluating. The main principles of POPBL learning are problem-oriented, work in interdisciplinary projects, student-centered, and group cooperation. Students do project work so that they can manage complex problems related to the real world (Supratman et al., 2021).

The application of innovative learning models can also be supported by technological developments in the present. The field of education can utilize technology to support students' learning and thinking patterns (Kahar et al., 2021). The utilization of technology has opened wide access to information, increased student participation, and presented innovative teaching methods (Candra et al., 2023). One way to utilize technology in learning is to integrate the use of AI into problem-based and project-based learning models. This integration places AI as a tool to help students collect, analyze, and visualize complex data sets during learning. Students can rely on AI systems to handle data while focusing on relevant implications and conclusions (Shah, 2023).

The use of AI in the form of chatbots such as ChatGPT, Bard AI (Gemini), and Co-pilot can support the learning process, helping to find information, summarize, and assist in writing and understanding related to certain materials (Liu et al., 2023; Tiernan et al., 2023). Chatbots also serve as virtual tutors for students and assistants for teachers (Essel et al., 2022). AI chatbots can play the role of an intelligent tutor by presenting subject matter, providing feedback to students, and assisting students and teachers in answering questions and providing guidance in the learning process (Mageira et al., 2022).

AI in the form of Chatbot in the PPA/PBL model can also be used as a virtual mentor. It can be utilized by students to provide guidance, support and resources to students during the problem and project-based learning process. AI facilitates the inquiry process by giving students the opportunity to access extensive information that allows students to explore and investigate topics independently. In addition, in problem- and project-based learning, the role of AI can align learning with real-world problems, facilitate the implementation of PjBL/PBL models for teachers, provide references to various types of projects in learning, and can increase the effectiveness of evaluation and reflection in learning (Shah, 2023).

Various studies on the POPBL model have been conducted by previous researchers such as the research of Suwistika et al. (2024) which examined critical thinking skills and creative thinking skills, research by Francisco et al. (2024) which examined creative thinking skills, and research by Filmi et al., (2024) which examines collaboration skills. However, these studies have not integrated technological assistance in their implementation, especially AI which is widely used today. In addition, this study uses different instruments according to the material taught in the classroom so that this study hopes to support previous research. The implementation of this problem and project-based model has challenges including requiring a relatively long time to implement and some students are less active in groups (Liando & Kadamehang, 2023). In addition, some students experience problems in finding information and understanding the topics taught, making it difficult to find solutions to overcome problems (Adilah & Rosyida, 2024).The POPBL model directs students to create projects in solving contextual problems. This model certainly has challenges because the implementation process requires a long time. In

addition, not all students are able to formulate contextual and complex problems, so they need AI assistance to make it easier to explore problems that need solutions. The use of an AI chatbot in POPBL is expected to increase the effectiveness of the model in improving students' 21st century skills.

Based on this description, this study aims to examine the effect of the AI-assisted POPBL model on students' creative thinking skills and collaboration skills. It is expected that this research will generate valuable insights as a reference learning model, offer solutions to improve the quality of Biology education, improve students' creative thinking skills and collaboration skills so that learning objectives can be achieved properly.

2. RESEARCH METHOD

The research method used was quasi experiment with nonrandomized control group pretest-posttest design (Leedy et al., 2019). The population of this study consisted of all students of class XI specialization in Biology and the sample was randomly selected after an equality test based on students' report card scores. Next, classes that have been declared equivalent are randomly selected to be used as experimental classes, positive control classes, and negative control classes. This research was conducted in one of the Madrasah Aliyah in Banjarmasin City on three groups of students, namely the experimental class, positive control class, and negative control class. Each class was given a different learning model treatment, namely the experimental class using the POPBL model assisted by AI, the positive control class using the POPBL model, and the negative control class using the conventional model with the lecture method. The instruments used in this study to assess students' creative thinking skills were pretest and posttest using essay test questions. Students' collaboration skills were pretest and posttest using a peer assessment questionnaire. The research instrument was developed by the researcher which was then tested for validity and reliability before use.

Data collection procedures were carried out by giving a pretest at the beginning of the learning process to measure students' creative thinking skills and collaboration skills. The three class groups were given the treatment of learning models, namely POPBL assisted by AI, POPBL, and lecture method accompanied by assignments. Furthermore, the posttest was conducted after the treatment to evaluate students' creative thinking skills and collaboration skills at the end of the learning period. The implementation of the AI-assisted POPBL learning model was carried out for 30 JP with details, namely the initial test carried out for 4 JP, the first stage carried out for 3 JP, the second stage carried out for 5 JP, the third stage carried out for 10 JP, the fourth stage carried out for 4 JP, and the final test carried out for 4 JP.

Each creative thinking skills essay test question consists of 5 question items. Respondents were asked to answer the questions according to their respective abilities. Meanwhile, the peer assessment collaboration skills questionnaire consisted of 14 statement items. Respondents were asked to indicate responses on a scale ranging from “strongly agree,” “agree,” “undecided,” “disagree,” and “strongly disagree.” The data analysis technique of this study involved normality test using Shapiro-Wilk, homogeneity test using Levene's Test for Equality of Error Variances, and hypothesis testing using Analysis of Covariance (ANCOVA) test (Howel, 2010). The decision-making criteria are if the significance value > 0.05, then the data is normally distributed. If the significance value is <0.05, then the data is not normally distributed. The homogeneity test aims to determine the uniformity of the data. If the significance value > 0.05, then the data is homogeneously distributed; if the significance value obtained < 0.05, then the data is not homogeneously distributed.

3. RESULT AND DISCUSSION

Normality test was conducted before homogeneity test and prerequisite test. Data normality test was conducted using Shapiro Wilk test. This test was applied separately for the experimental class using the POPBL model assisted by AI, the positive control class using the POPBL model, and the negative control class using the lecture method accompanied by assignments. The homogeneity test is carried out after the data normality test meets the requirements. After the data meets the normality test requirements, then the homogeneity test is carried out with Levene's Test of Equality of Error Variances. The data analyzed came from the pretest and posttest results on the dependent variable, namely creative thinking skills and collaboration skills. After the data met the homogeneity test requirements, the analysis continued with hypothesis testing using ANCOVA. The decision-making criteria are if the p value > 0.05, then H_0 is accepted and the research hypothesis is rejected; if the p value < 0.05, then H_0 is rejected and the research hypothesis is accepted.

Creative Thinking Skills

The data on the results of creative thinking skills obtained were analyzed descriptively. The average scores of the initial and final tests of creative thinking skills are presented in table 1.

Table 1. Average Scores of Preliminary and Final Tests of Creative Thinking Skills

Class	Pretest	Std. Dev.	Posttest	Std. Dev.
Experiment	63,33	6,3	74,86	6,9
Positive Control	62,78	4,0	73,33	5,4
Negative Control	61,03	4,5	69,12	4,9

Explanation:
Std. Dev. = Standard Deviation

The average creative thinking skills in the experimental class (POPBL assisted by AI) experienced an increase in pretest scores of 11,53. The positive control class (POPBL) experienced an increase in value of 10,55. The negative control class (lecture method with assignment) experienced an increase in value of 8.09.

The creative thinking skills data were then tested for normality to determine the distribution of the research data. The normality test results show that the significance value of the creative thinking skills variable in each class, namely the experimental class p-value = 0.568 > α = 0.05, the positive control class p-value = 0.272 > α = 0.05, and the negative control class p-value = 0.065 > α = 0.05. This indicates that the creative thinking skills data is normally distributed. Furthermore, the data was tested for homogeneity to determine the uniformity of the data. The normality test results that the significance value of the creative thinking skills variable is p-value = 0.213 > α = 0.05 which indicates that the data is homogeneous.

Data that have met the prerequisite tests can then be tested with parametric statistics, namely One Way Analysis of Covariance (ANCOVA). The results of One Way Analysis of Covariance are presented in table 2.

Table 2. ANCOVA Test Results of Creative Thinking Skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1655.407[a]	3	551.802	22.450	.000	.398
Intercept	759.247	1	759.247	30.890	.000	.232
Pre	1040.742	1	1040.742	42.342	.000	.293
Model	330.916	2	165.458	6.732	.002	.117
Error	2507.093	102	24.579			
Total	561325.000	106				
Corrected Total	4162.500	105				

Explanation:
Df = Degrees of freedom
F = F-statistic
Sig. = Significance (level of significance, usually p-value)
Partial Eta Squared = Effect size in ANOVA analysis

Based on Table 2, it is known that the p-value = 0.002 < α = 0.05, which means that H0 is rejected, meaning that there is a significant difference in the average value of creative thinking skills between one class and another. This shows that there is an effect of POPBL model assisted by AI on students' creative thinking skills.

Collaboration Skills

The data on the results of the collaboration skills obtained were analyzed descriptively. The mean scores of the initial and final tests of creative thinking skills are presented in Table 3.

Table 3. Average Pretest and Posttest Score of Collaboration Skills

Class	Pretest	Std. Dev.	Posttest	Std. Dev.
Experiment	76,83	6,8	84,05	6,6
Positive Control	76,79	4,3	82,30	5,0
Negative Control	75,04	4,2	78,36	5,1

Explanation:
Std. Dev. = Standard Deviation

The average collaboration skills in the experimental class (POPBL assisted by AI) increased by 7,22. The positive control class (POPBL) experienced an increase in value of 5,51. The negative control class (lecture method with assignment) experienced an increase in value of 3,32.

Data on creative thinking skills were then tested for normality to determine the distribution of research data. The normality test results show that the significance value of the collaboration skills variable in each class, namely the experimental class p-value = 0.878 > α = 0.05, the positive control class p-value = 0.064 > α = 0.05, and the negative control class p-value = 0.092 > α = 0.05. This shows that the collaboration skills data is normally distributed. Furthermore, the data was tested for homogeneity to determine the uniformity of the data. The normality test results that the significance value of the collaboration skills variable is p-value = 0.439 > α = 0.05 which indicates that the data is homogeneous.

Data that have met the prerequisite tests can then be tested with parametric statistics, namely One Way Analysis of Covariance (ANCOVA). The results of One Way Analysis of Covariance are presented in Table 4.

Table 4. ANCOVA Test Results of Collaboration Skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1592.192[a]	3	530.731	23.540	.000	.409
Intercept	663.051	1	663.051	29.409	.000	.224
Pre	1002.268	1	1002.268	44.455	.000	.304
Model	376.517	2	188.259	8.350	.000	.141
Error	2299.651	102	22.546			
Total	710229.703	106				
Corrected Total	3891.843	105				

Explanation:
Df = Degrees of freedom
F = F-statistic
Sig. = Significance (level of significance, usually p-value)
Partial Eta Squared = Effect size in ANOVA analysis

Based on table 3, it is known that the p-value = 0.000 < α = 0.05, which means that H_0 is rejected, meaning that there is a significant difference in the average value of collaboration skills between one class and another. This shows that there is an effect of the AI-assisted POPBL model on students' creative thinking skills.

Creative Thinking Skills

The application of POPBL learning model assisted by AI technology in the form of chatbot can develop and empower students' creative thinking skills. The AI-assisted POPBL model encourages students to be actively involved in exploring contextual and complex problems related to Biology learning, gather ideas to solve problems that have been found, and can design and create appropriate solutions to problems in the form of projects.

The project work carried out by students is assisted by advances in Artificial Intelligence technology. In the form of chatbots trains students to be able to balance their creative thinking skills with current technological developments. This process is made easier with the help of AI technology so that the projects produced can vary because the information obtained by students is broader and more comprehensive. Through the process of exploring ideas to create solutions to problems that have been identified, students can practice to be skilled in analytical and creative thinking to create solutions to the problems found.

The first stage of the AI-assisted POPBL model is to orient and formulate the problem with the help of an AI chatbot. Students in groups read and look at articles given by the teacher regarding real issues or problems about dwarf disease in plants related to the material of Movement of Substances Through Cell Membranes and Growth and Development of Living Things to find questions that are contextual, complex, relevant to the material, and require a solution. The activity of reading and looking at the news or articles presented can train students in creative thinking such as fluency in making ideas in the form of questions about the problems that must be solved. In addition, the formulation of questions raised by students is original which comes from the results of constructing student thinking so that they can formulate a complex question with the help of AI as a comparison material. Students are directed to analyze the problem formulation presented by AI so that they can formulate and reformulate questions that meet the criteria for proper problem formulation.

AI can help find real problems that need to be addressed by students (Kurniawan et al., 2024). Creative thinking can be enhanced through open-ended questions during class discussions and directing problem-based learning in student learning activities (Orozco & Yangco, 2016). Contextual problems used in project-based learning can train and improve students' creative thinking skills through exploring and expressing ideas to solve a problem (Rahmazatullaili et al., 2017). Learning outcomes with the POPBL model are not only general knowledge but include analytical thinking, argumentation skills, presenting solutions, and answering various complex problems (Yasin & Rahman, 2011). The application of the AI-assisted POPBL model to develop students' creative thinking skills is in line with constructivism learning theory which emphasizes that students build their own knowledge to achieve goals through learning experiences that have been obtained (Schunk, 2012).

The second stage of the AI-assisted POPBL model is organizing students to learn with the help of an AI chatbot. Students are directed to study and explore essential concepts related to the problems that have been identified as well as the material of Movement of Substances Through Cell Membranes and Growth and Development of Living Things. Students are directed to search and sort information relevant to the material from various sources such as textbooks, scientific articles, the internet, as well as with the help of AI chatbots. Information that has been obtained from AI and other sources is analyzed and examined to be in accordance with

the material studied and related to the formulation of the problem that students will solve. Through this activity, students are trained to think creatively in determining and evaluating information so that the information obtained is quality and relevant to the problem. Creative thinking skills that are empowered at this stage include flexibility, elaboration, and metaphorical thinking. Students are directed to sort out various alternative information, detail each information obtained, and can compare information to create new ideas to be used as a reference in solving problems.

AI can be used as a tool to understand complex Biology concepts (Kurniawan et al., 2024). The ability of students to build their own understanding of the material aims to enable students to solve problems in learning (Oncu, 2016). Students who have creative thinking skills can develop new and original knowledge concepts (Zulyusri et al., 2023). The teacher's role in learning according to constructivism theory is as a facilitator who creates a learning atmosphere that encourages students to be actively involved by exploring the subject matter (Schunk, 2012).

The third stage of the AI-assisted POPBL model is designing and implementing projects with the help of chatbots in the process of designing and implementing projects to be carried out. Students through LKPD are directed to develop ideas and develop alternative solutions in groups. This stage involves AI assistance in the form of suggestions for alternative project ideas, the tools and materials needed, and the steps of project work so that it can help students to design the project to be done. Students collaboratively determine a project theme followed by designing, collecting data, and implementing the project.

The process of designing and implementing this project involves a creative thinking process where students are trained to create new ideas related to the right solution and have a positive impact on the problem to be solved. Overall, the indicators of creative thinking skills ranging from fluency, flexibility, originality, elaboration, and metaphorical thinking can be trained to students in project design and implementation. The project produced by students to overcome the problem of dwarf disease in plants is in the form of making natural fertilizers and pesticides. Students first collect data and conduct investigations related to the content of natural fertilizers and pesticides that can overcome dwarf disease in plants with the help of AI, through articles, journals, textbooks, and the internet. After knowing the right ingredients to overcome the disease, students are directed to make projects according to a predetermined theme such as making compost, liquid organic fertilizer from banana peels, natural pesticides from betel leaves, natural pesticides from garlic extract, natural pesticides from chili extracts, and natural pesticides from soursop leaves. Making this project makes students trained to generate creative ideas when faced with real and complex problems in the future.

AI systems encourage creative thinking and provide constructive feedback improving problem-solving abilities leading to increased student creativity (Amiruddin et al., 2025). In Biology learning, collaborative projects using digital tools allow students to brainstorm, share perspectives, and co-create solutions based on information obtained and processed creatively (Muhidinovna, 2023). Creative thinking skills provide students with meaningful learning for students in problem solving and solution development (Sumarni et al., 2019). Empowering creative thinking in learning aims to train students to overcome various problems in a rapidly changing life (Häkkinen et al., 2017). Learning activities that are in line with constructivism learning theory include observing phenomena, collecting data, formulating and testing hypotheses, and working with others (Schunk, 2012).

The fourth stage of the AI-assisted POPBL model is presenting results and evaluation. The process at this stage is assisted by an AI chatbot as a tool to provide advice and input from the project results that students have done before being presented in front of the class. Students present the project results in the form of various fertilizers and pesticides that can overcome dwarf disease in plants in the form of posters. Previously, students had worked on a project to make natural fertilizers and pesticides as a solution to the problems that had been identified. Each group is asked to present and evaluate the solution based on the learning experience that has been obtained. Students provide suggestions and feedback on other groups' solutions, check the validity of the information presented, and ensure the effectiveness of the proposed solutions. This activity trains students' creative thinking skills in providing original suggestions and feedback by comparing and evaluating diverse solution ideas between groups so that students' knowledge increases. In-depth evaluation serves as a potentially important stimulus for further creative problem solving. Criticism and suggestions of others' work that focus on underlying issues can facilitate one's creativity (Gibson & Mumford, 2013).The evaluation process in AI-assisted POPBL is in line with Ausubel's meaningful learning theory which emphasizes that students are able to find integration between existing knowledge and new knowledge that is concrete and relevant to everyday life through each stage in the learning process (Ausubel, 2000).

Developing creative thinking skills can be done by involving collaboration between students in learning. Interaction in groups has a positive influence on the development of students' creative thinking skills because they share ideas and solve problems collaboratively. An environment that supports collaboration is very supportive of increasing student creativity in biology learning (Khalid et al., 2020).

Based on the learning results, the Problem Oriented Project Based Learning (POPBL) model assisted by

Artificial Intelligence (AI) is proven to be influential in developing and empowering students' creative thinking skills through the learning stages carried out, namely orienting and formulating problems, organizing students to learn, designing and implementing projects, and presenting results and evaluation.

Collaboration Skills

Learning with the Problem Oriented Project Based Learning (POPBL) model assisted by Artificial Intelligence (AI) can develop and empower students' collaboration skills. The AI-assisted POPBL model is oriented towards active and collaborative learning in carrying out projects to produce solutions to contextual and complex Biology problems. Through this model students can be trained to collaborate when working on projects so that teamwork is formed which aims to solve problems in learning. The collaboration process is important to develop because it facilitates students in sharing ideas and knowledge through social interaction in groups.

The first stage of the AI-assisted POPBL model is orienting and formulating problems assisted by chatbots. At this stage, students identify problems collaboratively based on the articles presented in the LKPD. The collaboration process at this stage involves several indicators of collaboration skills such as contribution, time management, team support, problem solving, and interaction with others. Each student is given the opportunity to express their opinions in the form of questions. Efforts to achieve the objectives at this stage one, each group can formulate a problem formulation that is formulated collaboratively through a discussion process from various problem formulations that have been raised. This requires the collaboration of each student so that one question is obtained that meets the criteria for the formulation of the problem that has been determined. According to Nurdin et al. (2025) through collaboration with others listen to students' perspectives actively, and solve problems collaboratively. Vygotsky's learning theory states that interactions with others in the surrounding environment such as collaborating can stimulate the development process and encourage students' cognitive growth (Schunk, 2012).

The second stage of the AI-assisted POPBL model is organizing students to learn. At this stage, students are directed to find essential information and materials related to the formulation of the problem that has been determined and relevant to the subject matter. Each student plays an active role in the process of finding information through various sources such as textbooks, scientific articles, the internet, or with the help of chatbots with appropriate prompts. This process can develop collaboration skills where each student can share in finding information. Students are trained to help each other in the process of finding information so that the objectives at this stage can be achieved properly. Furthermore, the information is shared between students in the group so that the information obtained is complete and comprehensive. Furthermore, the information that has been obtained is used as a basis or reference in solving the problems that have been identified. Collaborative learning provides opportunities for students to seek information from various learning sources to build their knowledge. The process of building student knowledge obtained during small group discussions can be the basis for solving problems in everyday life (Ramdani et al., 2022). Activities in empowering students' collaboration skills are in line with Vygotsky's sociocultural learning theory which emphasizes that students learn many concepts when socially interacting with others (Schunk, 2012).

The third stage of the AI-assisted POPBL model is designing and implementing projects with the help of a chatbot. Each student in the group collaboratively designs the project to be implemented. This process starts from determining the theme of the project, the tools and materials needed, the steps of working on the project, collecting data, analyzing data, and carrying out the project in accordance with predetermined procedures. Each student is actively involved in the implementation of the project collaboratively between group members.

Collaboration skills have an important role at this stage, namely training students to be sensitive to the surrounding environment so that they can work well together. Collaboration skills at this stage include student contributions in project implementation according to the agreement of group members. Good time management is needed because project implementation tends to take a long time so that students can use time effectively and efficiently. Team support and interaction with others have an important role in order to achieve common goals in implementing the project as a solution to the problems identified. Problem solving and interaction in this stage are important to develop because students are trained to determine the right solution to Biology problems that occur around collaboratively based on the learning experience gained by each student.

According to Hizqiyah et al. (2023) project-based learning requires students to go directly to the environment, make direct observations conduct research, and understand and reason more deeply about the surrounding environment with direction from the teacher and collaboration between friends. The collaboration process is based on Bandura's social cognitive learning theory which emphasizes that almost all information that humans obtain comes from interactions with others (Hergenhahn & Olson, 2017). This is also in line with Vygotsky's sociocultural learning theory which states that organizing the right learning environment to increase interaction with others will support learning (Schunk, 2012).

The fourth stage of the AI-assisted POPBL model is presenting results and evaluation with the help of a chatbot. Each group is given the opportunity to present the results of the project that has been done in the form of

a poster to make it easier for students when conveying to others. This process requires good collaboration skills so that the project results can be conveyed well. It is necessary to cooperate between group members so that the implemented project can be presented to others. Students who are good at collaborating must also be able to evaluate the results of the project that has been carried out which will then be reinforced by the teacher as a facilitator in learning. This evaluation can be directed to other groups or to oneself as a form of self-reflection based on the learning experience that has been carried out. An active collaboration process in learning will provide learning experiences that increase students' knowledge.

Students create their own work and give feedback and suggestions to other students' work. The teacher encourages students to review by giving ideas and improvements. The goal is that students can provide useful feedback to improve student abilities and project results without teacher assistance so that collaboration between students can occur (Mora et al., 2020). Organizing the right learning environment to increase interaction with others will support learning. One of the features of Vygotsky's sociocultural learning theory is scaffolding, which is the process of support or assistance provided to students to help them reach higher levels of understanding (Schunk, 2012).

An active collaboration process in students will provide a good learning experience to increase their knowledge. Based on the learning results of the Problem Oriented Project Based Learning (POPBL) model assisted by Artificial Intelligence (AI), it is proven to be influential in developing and empowering student collaboration skills through the learning stages carried out, namely orienting and formulating problems, organizing students to learn, designing and implementing projects, and presenting results and evaluation.

4. CONCLUSION

The application of the POPBL assisted by AI model has a significant effect on the creative thinking and collaboration skills of MA students. The POPBL assisted by AI model can facilitate students in developing creative thinking and collaboration skills through a collaborative project process with the assistance of AI at each stage of the model. Therefore, teachers can use the POPBL learning model combined with technological advancements (AI) in teaching and learning activities to develop 21st-century skills such as creative thinking and collaboration skills. The findings of this study can be further developed by expanding appropriate and wise AI training for students, as well as involving more types of AI technology capable of providing detailed and specific feedback. Further research is expected to test the application of this model at different educational levels, with more diverse AI integration, and in the context of other learning materials to assess the generalization and consistency of its impact.

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