RESEARCH ARTICLE

# Effectiveness of project-based learning in improving science literacy and collaborative skills of Muhammadiyah middle school students

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**Abstract:** Science literacy abilities and collaborative skills are part of the life skills demands of the 21st century. This research aims to analyze the effectiveness of the PjBL learning model in improving the Science literacy and collaborative skills of students at Muhammadiyah 2 Middle School, Batu City and Muhammadiyah 8 Middle School, Batu City. The research design uses Pretest-Posttest Control Group Design. The research sample consisted of 60 class VIII students taken by total sampling. Data was obtained through observation, questionnaires and tests. Data analysis uses covariance analysis (ANCOVA) to verify the data against the proposed hypothesis. The research results show that the average Science literacy and collaboration in PjBL learning is higher than conventional learning. The results of the analysis can be concluded that the implementation of PjBL effectively influences students' Science literacy and students' collaboration skills. Thus, the PjBL model is recommended to be implemented to support the implementation of the Independent Curriculum at the junior high school level as an effort to develop students' 21st century life skills.

**Keywords**: collaborative skills; junior high school; PjBL model; Science literacy

## Introduction

The current generation must have the 21st century skills, including science literacy (Avikasari et al., 2018; Fakhriyah et al., 2017; Kelp et al., 2023; Milda et al., 2022) and collaborative skills (Afikah et al., 2023; Ilma et al., 2022; Le et al., 2018; Listiana et al., 2023). Science literacy is frequently interpreted as possessing knowledge of fundamental facts established by science, yet the concept encompasses broader dimensions. We have pinpointed three facets of science literacy that are universally applicable to most uses of the term: factual knowledge, comprehension of scientific methodologies, and awareness of science as a social process. Additionally, we have identified four supplementary dimensions of science literacy, which, although less prevalent, shed light on the diverse interpretations of the term: foundational literacy, epistemic knowledge, the ability to recognize and assess scientific expertise, and predispositions and cognitive habits. Given this array of dimensions, it is unsurprising that a unanimous consensus on the most crucial or significant aspects of science literacy remains elusive. The significance of different dimensions may vary depending on the specific context (Snow & Dibner, 2016).

There are five reasons why it is important to understand Science literacy as follows. (1) Utilitarian, understanding the nature of science is necessary to understand science and manage technological objects and processes in everyday life; (2) Democratic, understanding the nature of science is needed to inform decision making on socioscientific issues; (3) Cultural, understanding the nature of science is necessary in order to appreciate the value of science as part of contemporary culture; (4) Moral, understanding the nature of science helps develop an understanding of the norms of the Science community which embodies moral commitments about general values in society; (5) Science learning: understanding the nature of science is used to facilitate understanding of material in science learning (Driver & Erickson, 1983).

Indonesian students' Science literacy is still relatively low. The Science literacy abilities of Indonesian students can be seen from survey achievements in the Program for International Student Assessment (PISA). In 2022, Indonesia's ranking will increase compared to the previous year, but the score obtained will decrease. The PISA 2022 score is among the lowest, especially in science literacy with a score of 383. Indonesia is ranked 67th out of 81 participating countries (OECD, 2023).

On the other hand, collaborative skills are the ability to participate in any activity to build relationships with other people, respect mutual relationships and teamwork to achieve the same goal. Ability to interact by appreciating differences, participating in discussions, providing suggestions, listening and supporting others (Scager et al., 2016). Indicators that show collaborative skills are contributing actively, working productively, showing flexibility and compromise, showing responsibility, and showing an attitude of respect (Greenstein, 2012).

It is known that the level of performance of collaborative skills at various levels of education in Indonesia is still low. In general, junior secondary education in Indonesia does not pay attention to the development of communication and collaborative skills. The results of the study show that the spread of gadgets and social media over the last decade has encouraged people to behave introverted, antisocial and have difficulty interacting with the real world (Priyambodo et al., 2023; Sufianti et al., 2024). This situation contributes to the low level of student collaboration. In one study of biology students at Riau Islamic University, it was stated that students' collaborative skills generally showed at a sufficient level, which means they were not able to collaborate well (Hidayati, 2019; Nurwidodo et al., 2023).

The results of a preliminary study on collaborative skills show that students' collaborative skills obtained low results. Meanwhile, in another study, collaborative skills were found to be a descriptor of productive work at 15%. Students sometimes work together, but not all members contribute to group work so it is difficult to complete the work. 25% indicate that group members work together well and focus on certain parts in completing his task (Anantyarta & Sari, 2017). The results of this study also show collaborative skills (65.4), lower than collaborative knowledge (70.33). Students have good collaborative knowledge, but collaborative skills or practices still need to be improved. In biology learning, students are not used to demonstrating optimal collaboration skills. As research has been conducted by Hayat et al (2019) that the student's lifelong learning profile is still quite low, especially for effective communication standards, namely only getting a score of 2.89 out of a total score of 4.00.

Students' collaborative skills are low because so far learning has tended to use lecture methods, teacher centered learning, conventional methods, and has not made much effort to explore students' collaborative skills. Collaborative skills as the ability to solve problems in new ways still receive less attention (Keiler, 2018; Kim et al., 2019; Vaughn, 2020). In fact, for a long time, the push to develop collaborative learning has been recommended by many researchers because it is seen as being able to develop higher order thinking, oral communication, self-management and leadership skills (Darling-Hammond et al., 2020; Lopes et al., 2018; van Laar et al., 2020).

Science literacy and collaborative skills are very necessary and are the key to overcoming increasingly complex Science problems and the demands of the 21st century life. It is necessary to implement an appropriate learning model, which is able to develop these two aspects. Project-based learning (PjBL) is a learning model that is thought to be capable, because it uses constructivist principles. In this learning, students actively participate in learning, where students are required to work collaboratively to solve problems, then discuss and reflect on what they have learned (Duke et al., 2020; Loyens et al., 2023; Marnewick, 2023; Şahin & Kiliç, 2023; Sukackė et al., 2022). Project-based learning is a systematic learning model where the main focus is learning through projects, which are monitored and guided by the teacher; and involving students in in-depth investigations to build knowledge, and supported by methods and technology that help students complete assignments independently (Duke et al., 2020; Rahmawati et al., 2020; Rehman et al., 2023; Zhang & Ma, 2023).

Various implementations of PjBL in junior high school learning have been carried out, both in the Indonesian and global contexts. There is research focused on how teachers implement projects (Markula & Aksela, 2022), teach speaking a spoken advertisement (Humairoh & Purwati, 2014), teachers' perception (Sartika et al., 2022), gadget play duration survey (Sitio et al., 2023), EFL classroom (Wijayanti & Budi, 2023), language learning (Ukah et al., 2023), teaching speaking to young learners (Widiyati & Pangesti, 2022), PjBL in in robotics meets (Zadok, 2020), music learning (Banua et al., 2023; Nugroho & Dewi, 2022), and management of project-based learning model at Sekolah Alam (Ahmad, 2021). In terms of abilities or competencies of junior high school students, PjBL research is focused on creative thinking skills (Biazus & Mahtari, 2022), critical thinking skills (Wibowo et al., 2018) and cooperative skills (Indriyana & Susilowati, 2020), students' engagement and speaking competence (Bunyamin, 2022), communication skills (Pratiwi et al., 2020), and collaboration, creativity, and computational thinking (Alkautsar et al., 2023). Several studies generally try to combine OIDDE-PjBL to develop problem-solving skills and product creativity for environmental student teacher candidates (Husamah & Rahardjanto, 2018), Blended-PjBL for problem-solving skills and learning outcomes of prospective teacher students (Yayuk & Husamah, 2019), Hybrid-PjBL to look at learning outcomes, creative thinking skills, and learning motivation of preservice teachers (Rahardjanto et al., 2019), STAD-PjBL to develop motivation, thinking skills, and learning outcomes of biology department students (Husamah & Pantiwati, 2014), and STAD-PjBL to increase product creativity for prospective biology teacher students (Hindun & Husamah, 2019).

It can be said that there is still very little research focused on implementing PjBL to develop Science literacy, develop collaboration skills, let alone combine the two. Therefore, the aim of the research is to analyze the effectiveness of the PjBL learning model to improve the Science literacy and collaborative skills of Muhammadiyah Middle School students in Batu City. The research is expected to contribute theoretically and practically to the need to implement PjBL in Muhammadiyah schools, especially at the junior high school level in an effort to prepare students to be able to live and compete in the 21st century.

## Method

This research is a quasi-experiment, with a Pretest-Posttest Non-equivalent Control Group Design. Sample determination was carried out by total sampling to determine research subjects. The learning model applied is project-based learning with the syntax as in Table 1 (adapted by Suradika et al., 2023).

Table 1. Syntax of the PjBL Model

| No | Stages | Learning activity | |
|---|---|---|---|
| | | Lecturer | Students |
| 1. | *Start With the Essential Question* | Introduce the topic, examine relevant issues, and ask essential questions | Convey opinions, ideas and formulate essential problems |
| 2. | *Design a Plan for the Project* | Directing students to work collaboratively to solve problems through project work | Students plan projects, choose activities, determine tools and materials to complete the project |
| 3. | *Create a Schedule* | Guiding students in preparing activity schedules in completing projects | Create a schedule for completing the project, timeline, choose the method or way of completing the project |
| 4. | *Monitor the Students and the Progress of the Project* | Monitor student project work, provide resources and guidance, prepare rubrics to record all important activities | Work collaboratively to complete project work, carry out exploration and investigation by utilizing various learning sources, and create products (artefacts) resulting from the project |
| 5 | *Assess the Outcome* | Assessing the achievement of student project work, evaluating learning progress, and providing feedback | Each group presents the results of project work, written reports, and products (artefacts) resulting from project work |
| 6 | *Evaluate the Experience* | Guiding students to reflect on the activities and results of projects that have been carried out | Reflect yourself by making a reflective journal on a series of project tasks carried out |

The instruments used include: 1) observation sheets, to observe the implementation of semester learning plans in the learning process, 2) tests, used to obtain data on learning outcomes for critical thinking, communication and collaboration skills. The dependent variable instruments in this research are the Science Literacy understanding test instrument and the collaborative skills scoring rubric. Data on understanding Science Literacy is collected using questionnaires or test instruments. Science Literacy understanding questionnaire adapted from Lederman et al (2002). There are seven aspects of Science Literacy measured in this research, namely: science is tentative (can change), empirically based, subjective, is the result of inference, imagination and human creativity, is embedded socio-culturally, the difference between observation and inference, the relationship between theory and Science law. Specification tables, questionnaires and Science literacy assessment rubrics. Students' Science literacy is divided into five categories, namely: excellent, good, sufficient, less and poor.

The collaborative skills assessment instrument was developed from Greenstein (2012) with measurement variables including working productively, showing respect, compromise, and responsibility. This research instrument is in the form of a questionnaire which is structured as a closed questionnaire, namely a questionnaire that has provided alternative answers so that respondents just have to choose. This will make it easier for respondents to answer. The questionnaire is guided by the indicators of the research variables which are described in several questions. All the questions in the questionnaire are objective questions so that the respondent just has to put a check mark (√) on one of the alternative answers which is considered most appropriate to the situation. This questionnaire provides four alternative answers. Each question item is given its own score, namely: score for the answer Very Good = 4, Good = 3, Fair = 2, Poor = 1.

Quantitative data were analyzed using inferential analysis to determine the significance of differences between the control and treatment classes. The proposed hypothesis was tested using ANACOVA with the independent variable PjBL learning model. Meanwhile, the dependent variable is Science literacy skills, collaborative skills.

# Results and Discussion

## Science Literacy

The pretest and posttest results of the effectiveness of the PjBL and conventional learning models on science literacy are seen in Table 2.

Table 2. Mean Pretest Posttest Science Literacy Scores

| No | Variable | Pretest | Posttest |
|---|---|---|---|
| 1 | PjBL | 58.41 | 77.78 |
| 2 | Conventional | 57.14 | 66.01 |

The results of the Anakova test on the Science Literacy variable show that the learning model has a significance value of 0.000, smaller than alpha 0.05 (p<α). The research hypothesis is accepted, meaning that there is an influence of the PjBL learning model on students' understanding of science literacy. A summary of ANACOVA results on the variable understanding of Science Literacy is presented in Table 3.

Table 3. Results of ANACOVA Variables Understanding Science Literacy

| Source | Sum ofSquare | Df | Mean Square | F | Sign |
|---|---|---|---|---|---|
| Corrected Model | 7150.868 | 6 | 1191.811 | 10.282 | 0.000 |
| Intercept | 15867.985 | 1 | 15867.985 | 136.903 | 0.000 |
| Science Literacy | 269.181 | 1 | 269.181 | 2.322 | 0.131 |
| Learning model | 6126.142 | 2 | 3063.071 | 26.427 | 0.000 |
| Error | 10547.545 | 91 | 115.907 | | |
| Total | 581519.274 | 98 | | | |
| Corrected Total | 17698.413 | 97 | | | |

R squared= 0.404 (Adjusted R Squared= 0.365)

The ANACOVA results for the learning model show significant results, namely that there is an influence of the model on students' understanding of Science Literacy. The analysis was continued with the LSD test at a significance level of 0.05 to determine the corrected mean differences in each learning model. The results of this test can be seen in Table 4.

The LSD test results show that there are differences in the average corrected scores of students' Science literacy in each learning model. The corrected mean of the PjBL model compared to conventional (65.479). The difference in notation between the two learning models can be interpreted as meaning that the average corrected score is significantly different from conventional.

Table 4. LSD Model Test Results on Science Literacy

| Model | Average | | Corrected Average | Enhancement (%) | LSD notation |
|---|---|---|---|---|---|
| | Pretest | Posttest | | | |
| PJBL | 58.412 | 77.777 | 77.492 | 33.15 | a |
| Conventional | 57.142 | 66.005 | 65.479 | 15.51 | b |

The research results show that the application of Project based Learning has a positive effect on students' science literacy. The PjBL stages contribute to increasing understanding of Science Literacy because indicators of understanding science literacy are trained from the beginning to the end of learning. In the first stage, starting with the essential question combined with mind mapping, students identify problems from environmental and social issues around them. Socioscientific issues are interesting contextual problem themes, and can be used to teach understanding of Science Literacy.

Students carry out several activities to formulate essential questions that will be answered through the project. Students observe phenomena and facts around them, make inferences, use Science theories and laws as a basis for thinking. At this stage, students prepare a mind map at the beginning of the project. Mind mapping directs students to develop creativity and imagination, and helps students create idea associations. Environmental themes and social issues studied in learning bring students closer to the context that science is influenced by social and cultural influences in society. Here several indicators of understanding Science Literacy have been studied and integrated in a real way.

Second stage, design a plan for the project. The activity of designing a project plan directs students to develop creativity in solving problems. Students use Science theories and laws as a basis for developing research frameworks and theoretical foundations. Students are encouraged to determine and choose various alternatives to solve problems, as well as determine appropriate research methods. Actual problems in project-based learning can provide broad learning experiences and are useful for improving student attitudes.

Project work directs students to think using metacognitive awareness, namely planning, organizing and monitoring project tasks to achieve the expected goals. As was done in stage three, students prepare a schedule, make a list of tools/materials needed, compile instruments and carry out investigations/investigations to solve project problems. Metacognitive awareness is needed to create effective learning and is a predictor of successful learning. Next, in stage four, monitor the students and the progress of the project. Students obtain empirical data through research and investigations carried out. At this stage, students are trained to prepare project progress reports based on empirical data obtained, using creativity and imagination during and after collecting data. In stages five and six, namely assess the outcome, followed by evaluation of the experience, evaluate the experience.

If we describe Science literacy based on its components, the average Science literacy score in the conventional learning model and PjBL is as presented in Figure 1.

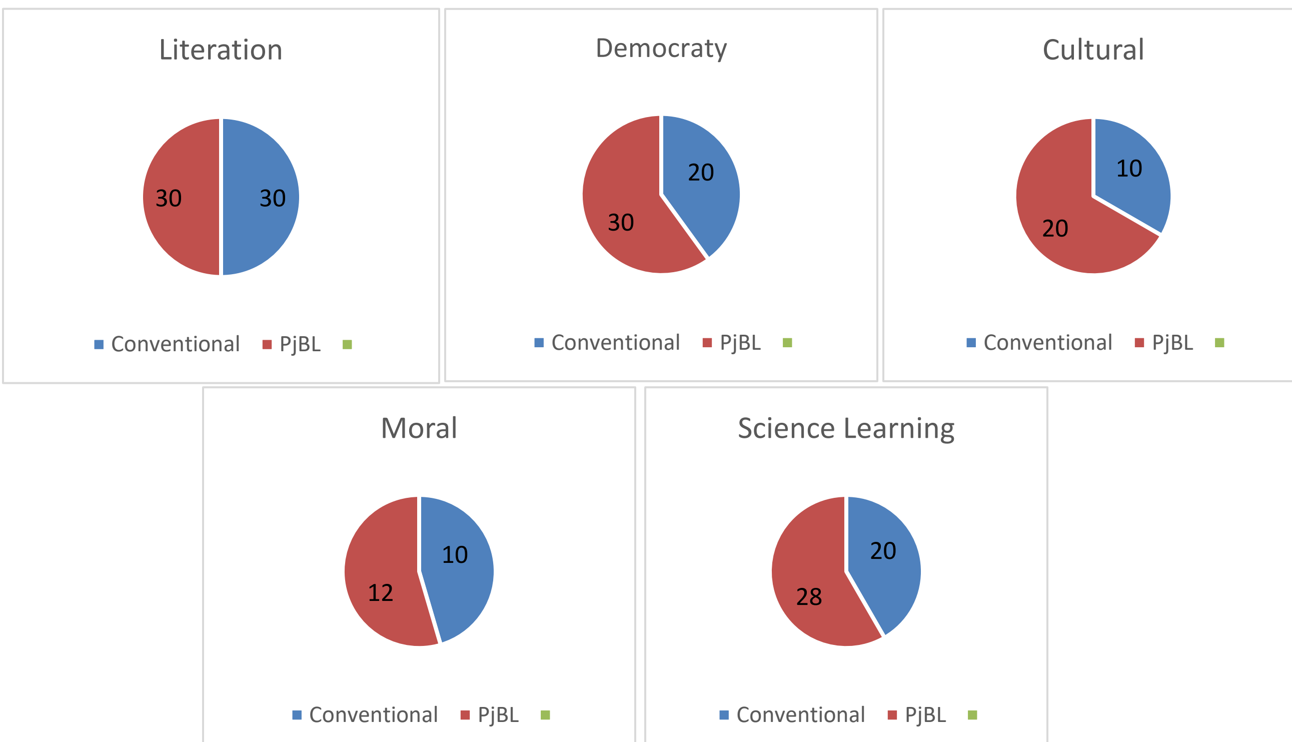


Figure 1. Average Science literacy score in the PjBL and Conventional Learning Model

Figure 1 shows the students' science literacy score with a maximum score of 100. Aspect 1) Utilitarians understand the nature of science in all classes achieving the maximum score. The conventional class got the lowest score in 2) the Democratic aspect, understanding the nature of science with a score of 50. Meanwhile the PJBL class got the maximum score. The highest score in 3) the Cultural aspect, understanding the nature of science, was achieved by the PjBL class, which got a score of 75. Meanwhile, the lowest score was obtained by the conventional class, which got a score of 31. The highest score in 4) the Moral aspect, understanding the nature of science, was achieved by the PJBL class, which got a score of 63. The lowest score was obtained by the conventional class which got a score of 25. The highest score in 5) the Science learning aspect: understanding the nature of science was achieved by the PJBL class which got a score of 92. The conventional class got the lowest score of 42.

## Collaboration Skills

The results of variations in the effectiveness of the PjBL and conventional learning models on collaboration skills are seen in Table 5.

Table 5. ANCOVA Results of Collaboration Skills

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 71232.590[a] | 3 | 23744.197 | 127.249 | .000 | .786 |
| Intercept | 20741.292 | 1 | 20741.292 | 111.156 | .000 | .517 |
| X collaboration | 1.460 | 1 | 1.460 | .008 | .930 | .000 |
| Class | 60205.225 | 2 | 30102.612 | 161.325 | .000 | .756 |
| Error | 19405.957 | 104 | 186.596 | | | |
| Total | 329869.000 | 108 | | | | |
| Corrected Total | 90638.546 | 107 | | | | |

a. R Squared = .786 (Adjusted R Squared = ,780)

Table 5 shows the differences in learning models [F count = 254.00 with p-value = 0.00. P-value < α (α = 0.05)]. Therefore, the hypothesis that the learning model influences students' collaboration skills is accepted, then the LSD test is carried out and the results can be seen in Table 6.

Table 6. LSD Collaboration Skills test results

| Class | Pretest | Posttest | Corrected Average | BNT notation | Enhancement |
|---|---|---|---|---|---|
| PjBL | 11.3056 | 78.9444 | 78.887 | a | 598.28 % |
| Conventional | 15.5278 | 16.0556 | 16.119 | c | 3.40 % |

Table 6 shows significant differences in learning models, and this can be seen from the highest posttest average scores in the PJBL (15.40) and conventional (6.72) classes. Based on these results, the PJBL class has the highest average value, and the average value is presented in Figure 2.

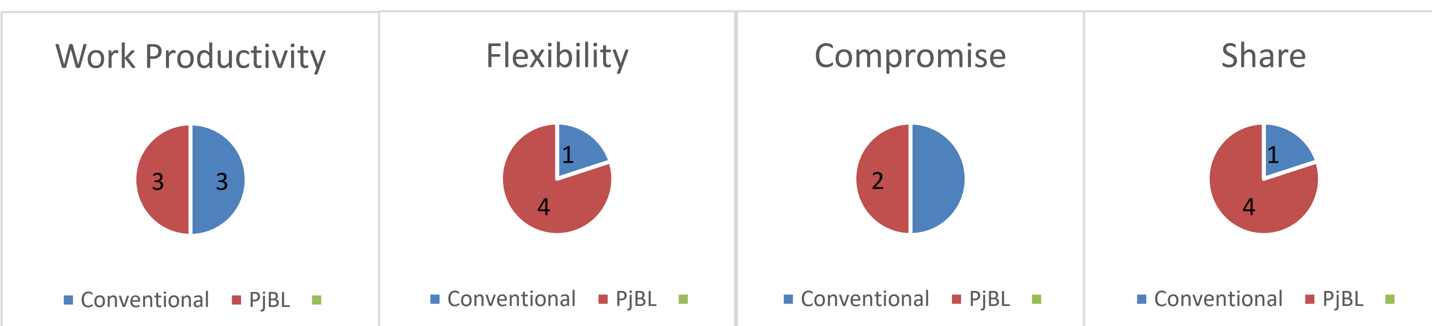


Figure 2. Average scores for collaboration skills in conventional learning models and PJBL

Figure 2 shows the student collaboration skills score with a maximum of 4. The productive work aspect has an average score of 2, 3, 2, and 4, where the highest in the very good category is in the PJBL class and the lowest is conventional in the sufficient category. The respect shown was 2, 3, 1, and 4, while the highest was in the PJBL class in the very good category and the lowest was in the poor category. Compromise has a value of 1, 2, 3, and 4, where the highest is in the PJBL class with a very good category and the lowest is conventional with a poor category. Shared responsibility has scores of 2, 4, 3, and 4, where the highest is in the PJBL class with the very good category, the lowest is in the conventional class with the sufficient category.
Based on these results, the PJBL class has the highest average value, and the average value for each aspect is presented in Figure 3.

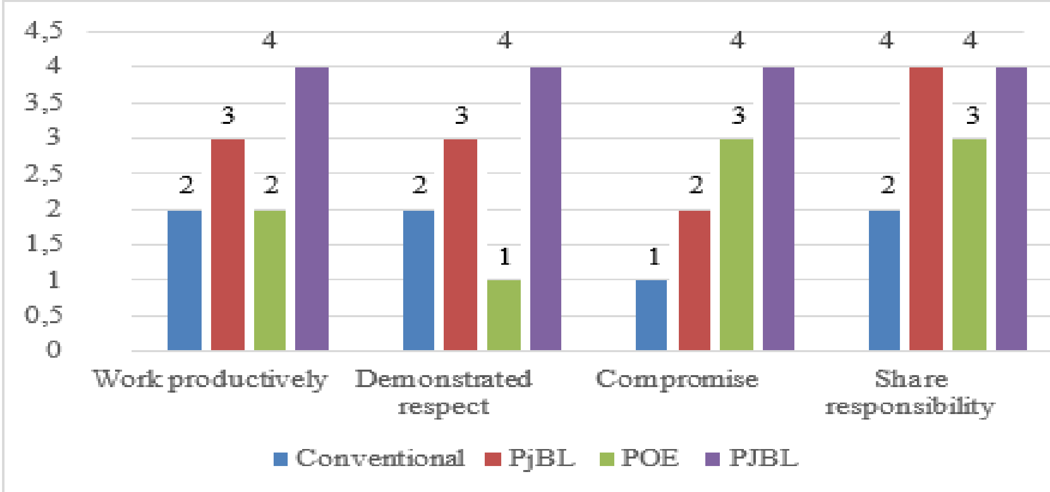


Figure 3. Average score of collaboration skills in the Conventional Learning Model and PjBL

Figure 3 shows the student collaboration skills score with a maximum of 4. The productive work aspect has an average score of 2, 3, 2, and 4, where the highest in the very good category is in the PJBL class and the lowest is conventional in the sufficient category. The respect shown was 2, 3, 1, and 4, while the highest was in the PJBL class in the very good category and the lowest was in the poor category. Compromise has 1, 2, 3, and 4, where the highest is in the PJBL class with the very good category and the lowest is conventional with the poor category. Shared responsibility is 2, 4, 3, and the lowest is in the conventional class with the adequate category. Where the highest is in the PjBL and PJBL classes with the very good category

The research results show that the learning model influences students' collaboration skills. The PJBL learning model provides the highest contribution to students' collaboration skills compared to conventional PJBL involves students in productive work, mutual respect, compromise, and responsibility in completing group assignments. Students must express their own opinions and discuss together to determine the right solution to overcome environmental problems. This is in accordance with the research results Sturner et al (2017) which conveys that students who are active in a group at least have knowledge about something.

Collaboration skills in aspects of productive work appear when students identify and analyze problems, plan action steps and carry out actions. Problem identification and analysis activities are carried out when students have succeeded in determining the factors that influence the emergence of the problem being studied. Productive work is recorded when students design action planning activities regarding solving problems encountered. Each group has a leader who helps the lecturer to divide tasks within the group. The activity of designing an action plan is carried out by preparing tools and materials, compiling work procedures, and making an activity schedule. Productive work can be achieved through dividing tasks in groups. Dividing tasks into groups will train students to be responsible. Responsibility is not only about punctuality in submitting assignments, but more about achieving the best work (Assbeihat, 2016; Green & Johnson, 2015; Rosen et al., 2018).

Collaboration skills in the aspect of mutual respect are seen when students have discussions with fellow group members and when presenting results outside the group. Students carefully listen to suggestions or ideas given by other groups. Mutual respect can be done through group learning activities. Mutual respect can provide positive energy to others. Similar things were recorded when students reported group progress, students conveyed the obstacles they faced and then other groups provided solutions (MacDonald et al., 2022; Tørring et al., 2019; van Jaarsveldt & Joubert, 2015).

There were significant differences found between PjBL and conventional learning in improving students' collaboration skills. It turns out that PjBL steps make a big contribution to developing students' collaboration skills through the process of observation, identification and analysis, action plans, implementation of monitoring and evaluation actions and follow-up plans. This is in accordance with previous research which explains that student collaboration can be improved through making identification, preparing action plans, carrying out actions, analyzing and carrying out monitoring and evaluation (Delgado et al., 2017; Hamilton et al., 2009; Schildkamp, 2019).

PjBL is significantly different from conventional learning. Conventional classroom learning is unable to facilitate the development of students' collaboration skills. Learning in conventional classes only carries out knowledge transfer activities, which are carried out individually without actively involving students in learning. Learning in conventional classes only provides assignments in the form of questions with a lower level of cognition (Dhawan, 2020; Nguyen et al., 2022; Yeh et al., 2019). Students' collaboration skills are difficult to develop in learning that only emphasizes memory, understanding and analysis.

PjBL has several characteristics. PjBL provides students with opportunities to explore, make judgments, interpret, and synthesize information in a meaningful way. PjBL allows students to investigate phenomena, facts or problems in a more real and meaningful way. Students have different learning styles, so they need concrete experiences that are combined during PjBL. Completion of projects in the field, experiments, making models, posters, and making multimedia presentations are appropriate and typical activities in PjBL. PjBL also provides various ways for students to show their knowledge by providing many alternative answers, and not just one correct answer (Aránguiz et al., 2020; Darmuki et al., 2023; Descovich et al., 2013; Miller & Krajcik, 2019; Paschalis, 2017; Wakhid & Budiyanto, 2023).

Collaboration skills and science literacy have a close relationship in the context of project-based learning. In project-based learning, students are not only invited to develop a deep understanding of science concepts, but are also invited to collaborate actively with their friends. Collaboration skills are key in completing complex projects, where students need to share ideas, solve problems together, and utilize individual skills to achieve common goals. Science literacy supports collaboration by providing a critical foundation of knowledge regarding project topics, enabling students to contribute more effectively and make informed decisions. Thus, the combination of collaboration skills and Science literacy creates a holistic learning environment and prepares students to become critical thinkers and productive collaborators in the real world.

## Conclusion

There is an influence of PjBL learning on students' Science literacy and collaboration skills. This is shown by the results of the ANCOVA hypothesis test with F count = 1.667 with a p value = 0.000 while the p value <α (α = 0.05). Then the LSD test showed a significant difference between the conventional learning model and PjBL. This was reflected in the average posttest score. The PjBL score is the highest (24.66), followed by conventional learning (21.18). There is an influence of the PjBL learning model on students' collaboration skills. This is shown by the results of the ANCOVA hypothesis test F count = 254.006 with p-value = 0.000. P-value < α (α = 0.05). Then the LSD test shows a significant difference between the PjBL and conventional learning models. It can be seen from the highest posttest average score in the PjBL (13.08) and conventional (6.72) classes. It is necessary to develop the impact of the PjBL model of learning on students' critical thinking, creative thinking and communication skills. This research needs to be expanded by comparing other innovative learning models, such as PBL, Discovery, Inquiry and cooperative models.

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## Author of Interest

**I. Hindun:** methodology, review and revision; **N. Nurwidodo:** conducting the research, collecting data, writing original article, and revision; **S. Wahyuni:** writing original article, collecting data and review**,** revision; and **N. Fauziah:** collecting data and review.

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