

## Application of PBL by Using Manipulative Materials to Determine Students' Collaborative Abilities on Bar Diagram Materials

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<b>Corresponding author:</b>	<b>Abstract</b>
Indri Susilowati <a href="mailto:indrisusilowati500@gmail.com">indrisusilowati500@gmail.com</a>	This study aims to describe students' collaborative abilities through the application of the Problem Based Learning (PBL) model assisted by manipulative materials on bar diagram materials. The study used a descriptive qualitative approach and involved grade VII students working in several groups. Data was collected through observation, LKPD analysis, and documentation of the learning process. The results showed that PBL with manipulative materials facilitated active student involvement, role sharing, flexibility in discussions, group responsibility, and mutual respect. Interaction between students developed positively and encouraged mathematical discussion, although the quality of data analysis and interpretation still varied between groups. This research makes a conceptual contribution to understanding that the development of collaborative skills is not only determined by the structure of group work, but also by the quality of interaction and the use of manipulative materials in mathematics learning.
<b>Keywords:</b> Collaboration; PBL; manipulative material; bar chart	

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### INTRODUCTION

21st century learning requires students not only to master academic content, but also to develop the 6C skills of critical thinking, creativity, collaboration, communication, character, and citizenship as the foundation for facing dynamic global challenges (Shabrina and Astuti, 2022; Khusna et al., 2025). In the context of mathematics learning, collaboration is one of the crucial skills, given that mathematical problem solving often requires the exchange of ideas, negotiation of meaning, and the fair division of roles in groups (Ramdani et al., 2019). Effective collaboration not only encourages deeper conceptual understanding, but also strengthens students' social-emotional abilities to interact and appreciate different perspectives.

However, the implementation of collaboration in the classroom still faces a number of obstacles. Learning observations show that student participation in groups tends to be uneven, with some students being passive, while others dominating discussions, thus hindering the formation of meaningful interactions. In addition, many groups only divide tasks mechanically without really discussing or challenging each other intellectually, conditions that actually weaken the potential for collaboration as a means of developing critical and creative thinking. This gap between the demands of the 21st century curriculum and the reality of the classroom underscores the need for a learning design that intentionally facilitates an inclusive, measurable, and collective-thinking-oriented collaborative structure (Jamil and Murniati, 2025).

Previous research has shown that collaboration skills play an important role in mathematics learning, as they allow students to learn from each other, exchange ideas, and develop solutions to problems together (Nikmah et al., 2025). This ability is necessary so that students are able to adapt and work effectively in a team to reach agreement on solving mathematical problems (Qurratu'ain *et al.*, 2024). However, the reality in the field shows that in mathematics learning there are still many students who have difficulty collaborating and tend to work individually during discussion activities or group work (Widodo and Wardani, 2020). This condition indicates a gap between the demands of 21st-century collaborative skills and the practice of mathematics learning in the classroom. Therefore, a learning strategy or model is needed that is able to facilitate students' active involvement in group work and relate mathematical concepts to real contexts. One approach that has the potential to answer this need is the use of manipulative media, which is a concrete tool that helps students not only manipulate physical objects, but also build a deeper understanding of mathematical concepts through interaction and collaboration (Stuart and Stuart, 2021).

The use of manipulative materials in mathematics learning can make collaborative activities more meaningful, as students focus not only on the final result, but also on the shared process of understanding concepts. Through the use of manipulative objects, students are encouraged to discuss in determining the completion steps, negotiate ideas when differences of opinion arise, and divide roles in groups, such as compiling models, recording results, and presenting findings (Nurita et al., 2025); Graduates, 2021). The activity of holding, arranging, and modeling concrete objects also facilitates interaction between students more intensively so that the problem-solving process takes place actively and collaboratively. However, the effectiveness of manipulative materials will be more optimal if supported by a learning model that explicitly encourages student cooperation in solving contextual and meaningful problems (Martiasari and Kelana, 2022).

An effective learning model to develop and identify students' collaborative abilities in mathematics learning is Problem Based Learning (PBL) (Octavian, 2022); Nurrohma and Adistana, 2021). PBL is a learning model that begins with the presentation of contextual problems that require students to be actively involved in the problem-solving process through discussion and group work (Kotto et al., 2022). This model is student-centered, where students play the role of the main subject of learning, while teachers function as facilitators and motivators who direct the learning process (Anggraini and Wulandari, 2020); Yesya, Bayu and Leni, 2023). Through the PBL stage, students are encouraged to interact with each other, share ideas, negotiate solution strategies, and work together in groups to build a deeper understanding of mathematical concepts (Andika and Hidayat, 2023). Thus, PBL is relevant to be used as a learning model that supports the development of students' collaboration skills.

In line with existing problems, collaboration skills need to be analyzed through a set of indicators that can describe how students role, interact, and contribute during the learning process. The collaboration skills indicators used in this study were adopted from (Rahmawati et al., (2019), namely: (1) actively engaged, (2) working productively, (3) demonstrating flexibility and compromise, (4) demonstrating responsibility, and (5) demonstrating mutual respect. These indicators reflect the ability of students to actively participate in group activities, manage tasks efficiently, adapt to various ideas or strategies that arise during discussions, and maintain individual responsibility and positive interpersonal relationships. In this study, the indicators of collaboration ability

were operationalized and observed through observation sheets during the learning process and analysis of the Student Worksheets (LKPD) which were done in groups, thus providing a comprehensive picture of the dynamics of student collaboration in mathematics learning.

The novelty in this study lies in the combination of the Problem Based Learning (PBL) model with the use of manipulative materials that are specifically focused on analyzing the process of students' collaborative abilities, rather than on measuring learning outcomes or academic achievement. In contrast to previous research that focused on improving students' conceptual understanding or learning outcomes through the integration of PBL and manipulative materials, as done by Dewanti et al., (2024) In the broad and volume material, this study places collaboration as the main object of study observed through the interactions, roles, and contributions of students during the learning process. Thus, this study expands on previous studies by highlighting how the integration of PBL and manipulative materials facilitates discussion, negotiation of ideas, and student cooperation in solving mathematical problems, especially in bar diagram materials.

The urgency of this research is based on the need to deeply understand students' collaborative abilities in mathematics learning that is designed to be more interactive and meaningful, considering that bar chart material has tended to be taught procedurally and individually. Therefore, the purpose of this study is to find out and analyze students' collaborative abilities through the application of the Problem Based Learning (PBL) model combined with the use of manipulative materials in mathematics learning.

## **METHODS**

This research uses a qualitative approach with a descriptive design. The qualitative approach is understood as a descriptive and analytical process, in which the researcher seeks to trace meaning, identify patterns, and understand the context of the data in depth (Creswell, 2023). This approach was chosen because the focus of the research is to understand the process of student collaboration during problem-based learning with the help of manipulative materials. Descriptive design allows for an in-depth depiction of student activities, interactions between group members, and the role of manipulative materials in supporting collaboration.

The subjects in this study are grade VII students at SMP Muhammadiyah 8 Batu which amounted to 5 groups directly involved in the learning process. Learning is carried out in 1 meeting with a duration of minutes. Research data were obtained from observation, analysis of student worksheets (LKPD), and documentation. Direct observation was carried out to observe the dynamics of collaboration, interaction and student involvement when using manipulative materials. The Student Worksheets (LKPD) that students worked on in groups during the problem-solving process were used to assess how students worked together in solving strategies and visualizing mathematical concepts with manipulative materials. Documentation in the form of photos and videos was used to reinforce the observation results.  $2 \times 40$

The data obtained was then analyzed qualitatively through three stages, namely data reduction, data presentation, and conclusion drawing (Zulfirman, 2022). At the data reduction stage, the researcher selects and focuses data that is relevant to the student's collaborative skill indicators. The indicators of collaboration skills used in this study were adopted from Rahmawati et al. (2019), including: (1) active involvement of

students in group discussions, (2) ability to work productively in completing tasks, (3) flexibility and the ability to compromise in group decision-making, (4) responsibility for roles and tasks assigned, and (5) mutual respect between group members. Each indicator is analyzed based on the results of observation and documentation of student activities during the learning process.

At the data presentation stage, the results of the analysis of each collaboration indicator are presented in the form of a systematic narrative description, making it easier for researchers to identify patterns of collaborative behavior of students. Furthermore, at the conclusion stage, the researcher interprets the entire data to obtain a complete picture of students' collaborative abilities after the implementation of the designed learning.

## RESULT AND DISCUSSION

The application of the Problem Based Learning (PBL) model assisted by manipulative materials showed that students' collaborative skills developed on most of the observed indicators, especially in the aspects of active involvement and mutual respect. Meanwhile, indicators of flexibility and compromise and responsibility show variations in achievement between groups. These findings indicate that the use of manipulative materials in PBL learning is able to encourage student interaction and cooperation, but the level of collaboration displayed is still influenced by group dynamics.

The application of the PBL model in this study aims to identify students' collaborative abilities which include aspects of active involvement, working productively, showing flexibility and compromise, showing responsibility, and mutual respect with the help of manipulative materials. The use of manipulative materials allows students to be directly involved in the problem-solving process in the bar diagram material, thus encouraging more intensive discussions and group work. The following image shows students' activities in using manipulative materials during the learning process.



Figure 1 manipulative material



Figure 2 Use of manipulative materials

The results of student work in LKPD and group activities during the learning process were analyzed to assess the level of students' collaborative ability in solving PBL-based problems. The analysis focused on five groups selected to represent a variety of collaborative abilities, either showing high, medium, or low collaboration. Each group was analyzed comparatively based on indicators of active engagement, work productivity, flexibility and compromise, responsibility, and mutual respect, so that a picture of the pattern of collaboration that emerged during learning was obtained.

### Group Analysis 1

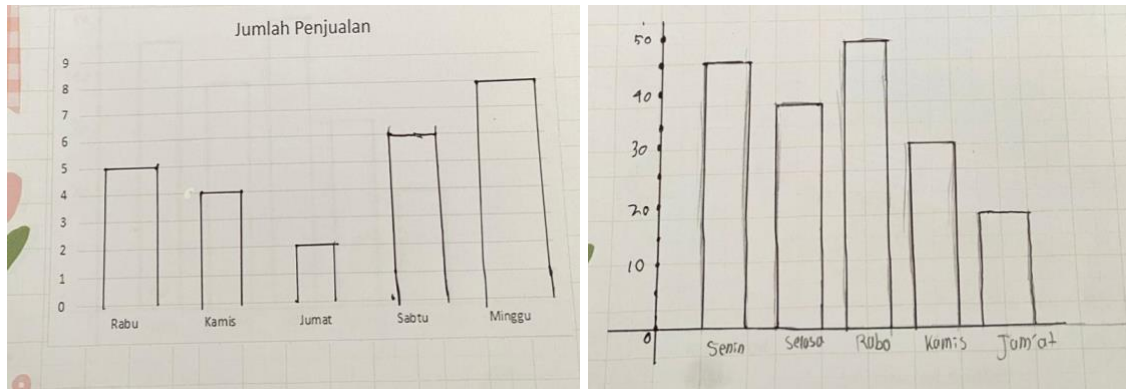


Figure 3 Work Results of Group 1

#### a. Description of Student Worksheet Results (LKPD)

Group 1 has not been able to solve all the demands on the LKPD analytically. The resulting solution is still limited to the representation of the bar chart using manipulative materials and has not been followed by calculations that show a deeper conceptual understanding. This condition indicates that although collaborative activities have been developed, the quality of collaboration has not fully led to a deepening of mathematical understanding.

#### b. Collaboration Indicators

##### 1) Actively Engage

Group members show active involvement through joint contributions in the LKPD work process. This participation is reflected in the involvement of more than one student in compiling and revising the work, which indicates that the collaboration process is not dominated by one individual.

##### 2) Work Productively

Group productivity can be seen in the division of roles in completing tasks. Each member contributes according to his or her role, so that the group is able to produce a diagram representation even though it is not complete. This shows that collaboration runs at the task completion level, but is not yet fully effective in integrating manipulative representation with analytical completion.

##### 3) Demonstrate flexibility and compromise

The group shows flexibility through members' willingness to adjust the way they record and improve their work together. This negotiation process reflects a compromise

in decision-making, although the discussions that have taken place have not optimally encouraged the development of a more appropriate settlement strategy.

#### 4) Showing Responsibility

The responsibility of individuals in the group can be seen from the implementation of the role of each member. Each student carries out the agreed task, so that group activities continue to take place in a coordinated manner even though the final result does not fully meet the learning objectives.

#### 5) Showing Mutual Respect

Interaction between students shows mutual respect, which is reflected in the way members improve their work without negating previous contributions. This attitude creates a positive work climate and supports the continuity of collaboration in the group.

### Group Analysis 2

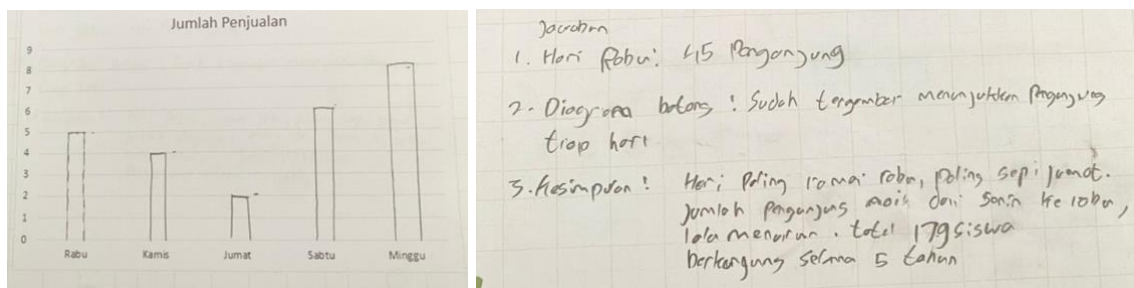


Figure 4 Results of Group 2

#### a. Description of Student Worksheet Results (LKPD)

Group 2 shows difficulties in constructing a representation of manipulative diagrams that correspond to the demands of the task. The resulting representation does not fully contain the necessary components, so a visualization of the problem has not yet been clearly formed. In addition, the integration between the use of manipulative materials and analytical calculations has not yet been seen, indicating that conceptual understanding and problem-solving strategies in this group are still in their infancy.

#### b. Collaboration Indicators

##### 1) Actively Engage

The involvement of group members appears to be uneven. The results of the LKPD show the dominance of one form of writing, which indicates that recording activities are more carried out by one member. This condition shows that active participation in the work process has not fully involved all group members.

##### 2) Work Productively

The group works in a physical unit, but the contribution to the completion of the task appears to be centered on some of the members. This situation shows that groupwork has been formed, but collaborative productivity has not been optimally developed due to the unbalanced distribution of roles and contributions.

##### 3) Demonstrate flexibility and compromise

Based on the LKPD, there is not much evidence of any revision or adjustment of the strategy during the work process. This indicates that the process of discussing and negotiating ideas in groups is still limited, so the opportunity to explore alternative solutions has not been utilized to the fullest.

#### 4) Showing Responsibility

The responsibilities of individuals in the group do not appear to be clearly distributed. Work activities that tend to focus on a few members show that the group's roles and responsibilities are still not evenly coordinated.

#### 5) Showing Mutual Respect

Interactions in groups have not shown many indicators that can indicate the exchange of ideas between members. Limited involvement in the use of manipulative materials and note-taking indicates that the space for participation among members can still be improved to support more inclusive collaboration.

### Group Analysis 3

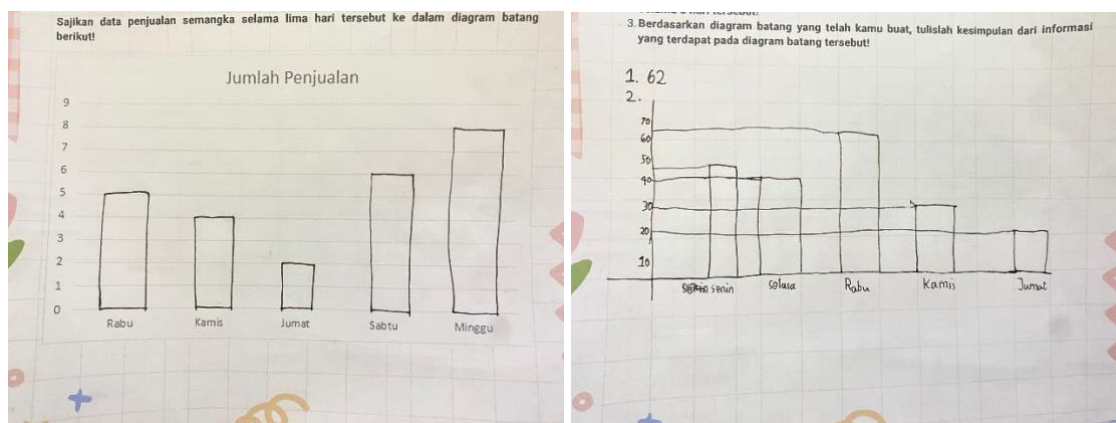


Figure 5 Results of Group 3

#### a. Description of Student Worksheet Results (LKPD)

Group 3 showed collaborative ability that developed consistently on almost all indicators. This group was able to solve all problems with complex work steps and utilize manipulative materials appropriately in building bar diagrams. Nonetheless, the drawing of conclusions from the diagram has not fully illustrated the mathematical meaning of the data presented. The findings in Group 3 show that effective collaboration is characterized by equitable engagement, responsibility sharing, and the ability to compromise decision-making. This pattern indicates that the application of PBL assisted by manipulative materials has the potential to be a learning strategy that supports the formation of meaningful collaboration. However, the students' difficulty in interpreting the mathematical meaning of the diagram suggests that the teacher's facilitation at the reflection and conclusion drawing stage is still necessary so that the collaborative process is not only oriented to the procedure, but also to conceptual understanding.

#### b. Collaboration Indicators

##### 1) Actively Engage

All members of the group are actively involved in the discussion and decision-making process. Equitable participation shows that PBL learning with the help of manipulative materials is able to create an inclusive dialogue space, where every student feels they have an equal opportunity to contribute.

2) Work Productively

Group productivity is reflected in the completeness and regularity of the work results. Systematic completion of LKPD shows that effective collaboration can drive work efficiency without neglecting procedural accuracy. This indicates that the division of roles and coordination between students is going well.

3) Demonstrate flexibility and compromise

The group demonstrates negotiable ability in determining a settlement strategy. Each proposal is considered before the group reaches a mutual agreement, so the decision taken is the result of compromise. This interaction pattern reflects healthy collaboration and can be used as an example in problem-based learning.

4) Showing Responsibility

Collective responsibility can be seen from the involvement of all members in every stage of the work, from diagramming to checking results. The absence of individual dominance indicates that the student understands his or her role as part of a team, not as an individual task executor.

5) Showing Mutual Respect

Mutual respect is reflected in the way the group treats the ideas and work of other members. The improvement process is carried out through discussion and deliberation, not by negating previous contributions. This positive interaction climate supports the continuation of effective collaboration.

**Group Analysis 4**

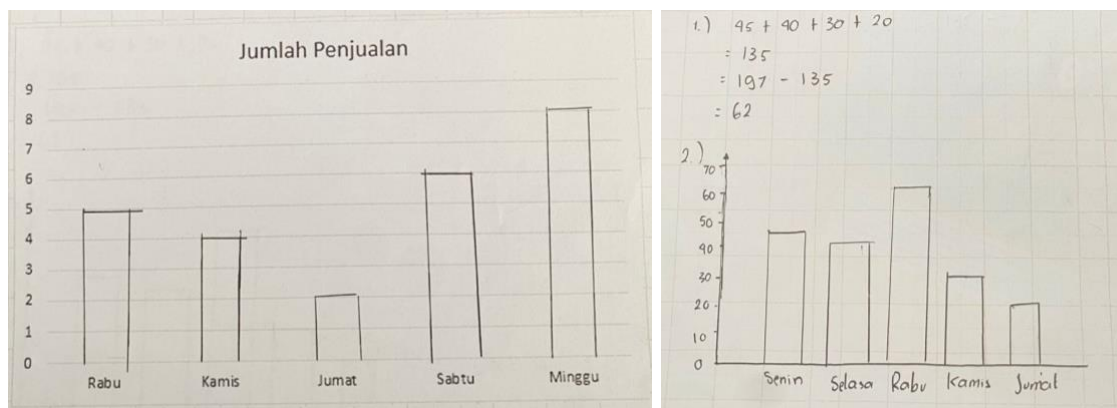


Figure 6 Results of Group 4

a. Description of Student Worksheet Results (LKPD)

Group 4 shows good concept mastery in solving the problem of bar diagrams assisted by manipulative material. The resulting visual representation is appropriate to the context of the problem and supports the resolution process. However, in the analytical calculations, some symbolic inaccuracies were still found, such as errors in the writing of symbols or step sequences, although the final result obtained was still

correct. These findings show that students' conceptual understanding has been formed, but the accuracy in representing mathematical ideas symbolically still needs to be strengthened.

b. Collaboration Indicators

1) Actively Engage

Group member involvement appears to be relatively even, especially in the use of manipulative materials and the preparation of bar diagrams. Collaborative activities are not concentrated on one individual, but are spread across several members according to the stages of task completion.

2) Work Productively

The group was able to complete all parts of the LKPD consistently. The productivity of the group was reflected in the precision of the use of manipulative materials and the accuracy of the final results, although the analytical writing process still showed symbolic inconsistencies. This indicates that productivity is more supported by conceptual understanding than procedural precision.

3) Demonstrate flexibility and compromise

The flexibility of the group can be seen from the ability to integrate the work of each member after the division of tasks. The follow-up discussion process is used to align the diagrams, calculations, and final answers, so that the decisions taken are the result of mutual agreement.

4) Showing Responsibility

Individual responsibility is realized through the implementation of the agreed role. Each member contributes to a specific part of the completion, and the work is then put together. The variety of writing shows that the process is collaborative and authentic, not the work of one person.

5) Showing Mutual Respect

The group shows mutual respect by providing a contribution space for each member. Differences in writing styles and discussions in agreeing on final answers reflect acceptance of other members' ideas and work before the final decision is made.

**Group Analysis 5**

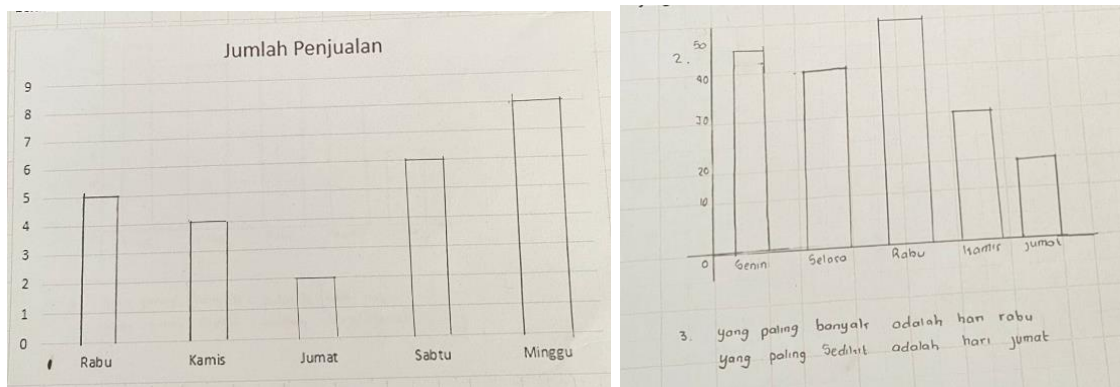


Figure 7 Results of Group 5

a. Description of Student Worksheet Results (LKPD)

Group 5 has not been able to do all parts of the LKPD correctly. There are some errors in the analytical calculations, so the numerical results obtained are not accurate. This analytical error then has an impact on the interpretation of the bar chart which is also not in accordance with the context of the problem. Nonetheless, group 5 was able to use manipulative materials quite skillfully. Manipulative representations seem to help them understand the initial part of the problem, although it has not been fully translated into accurate calculations.

Group 5 shows a pattern in this study, namely the existence of relatively active collaboration but not fully accompanied by analytical accuracy. This group has not been able to complete all parts of the LKPD correctly due to errors in calculations, which further has an impact on the inaccuracy of the interpretation of the bar chart. However, the use of manipulative materials seems to help students understand the initial structure of the problem. These findings indicate that collaboration and manipulative representation alone do not guarantee completion accuracy if not followed by strengthening analytical understanding

b. Collaboration Indicators

1) Actively Engage

The group showed quite visible engagement, especially when facing difficulties in calculations. Group members engage in discussions and exchange opinions, although participation rates are not yet fully evenly distributed among all members.

2) Work Productively

Group productivity is at a moderate level. The group is able to generate manipulative representations and try to complete calculations, but the effectiveness of the work is still limited by analytical errors. This condition suggests that collaborative efforts have been formed, but have not yet fully resulted in an accurate solution.

3) Demonstrate flexibility and compromise

Group flexibility is seen when students try to adjust their coping strategies when encountering obstacles. The discussions and exchanges of ideas that took place showed a willingness to accept alternative solutions, even though the chosen strategy had not led to the right outcome.

4) Showing Responsibility

Individual responsibilities appear through the division of roles in the group, such as the use of manipulative materials, record-keeping, and calculations. Even though the quality of the final results is not optimal, the group still tries to complete the task collectively, which reflects a sense of responsibility for the group's work.

5) Showing Mutual Respect

The attitude of mutual respect is reflected in the discussion process that takes place when the group is experiencing difficulties. Group members give each other space for opinions and try to evaluate answers together, even if an agreement has not yet been reached.

The results of the group work process analysis showed that students' collaborative skills appeared in real life during Problem Based Learning (PBL)-based mathematics learning with the help of manipulative materials. Students are actively

involved in group discussions, share roles in completing assignments, and show mutual respect in the decision-making process. Role divisions such as writing, drawing diagrams, calculating, and presenting results were found in almost all groups, which shows that indicators of collaboration in the aspects of active engagement, work productivity, and collaborative flexibility have been realized in the learning process.

Although the collaboration indicators are generally met, the quality of the final results produced by the group shows considerable variation. Some groups still have difficulties in the analysis and interpretation of the data, such as miscalculations and inaccuracies in representing the diagrams. These findings show that collaboration that runs well from a process side is not always followed by the accuracy of mathematical results.

The findings of this study are in line with the results of the study Rosnawati et al., (2019) which states that the PBL model is able to improve students' collaborative performance through active involvement in collective task completion. In addition, the results of this study also support the findings Nuraydah et al., (2023) which emphasizes the importance of mastery of basic concepts in producing the right solutions in group work. Without conceptual understanding and adequate analytical skills, good collaboration does not necessarily produce accurate outputs (Siswanto and Meiliasari, 2024).

The use of manipulative materials in learning also strengthens students' social interaction. This is in line with research Juhari and Muthahharah, (2020) and Anggriyani and Zulkarnaen, (2023) which states that manipulative materials can encourage discussion, negotiation, and cooperation in problem solving. Activities of sharing ideas and listening to friends' opinions that arise during learning also support indicators of mutual respect in collaboration (Oni) *et al.*, 2022).

Based on the results of research and studies of previous research, it can be concluded that PBL-based learning assisted by manipulative materials is effective in fostering students' collaborative skills, especially in the aspects of the work process and the dynamics of group interaction. However, the success of collaboration from a process point of view does not fully guarantee the accuracy of mathematical results. Therefore, it is necessary to strengthen conceptual understanding and analytical skills so that collaboration is not only socially effective, but also produces solutions that are accurate and in accordance with learning objectives. In addition, intensive interaction in group discussions also contributes to the development of students' mathematical communication skills, especially in explaining procedures, clarifying ideas, and conveying mathematical reasons orally (Susilowati *et al.*, 2025).

## **CONCLUSIONS**

This study shows that the application of Problem Based Learning (PBL) assisted by manipulative materials is able to facilitate the development of students' collaborative skills, especially in the aspects of active involvement, work productivity, flexibility and compromise, responsibility, and mutual respect. These collaborative skills are seen through the process of interaction, communication, and decision-making during group work, which are identified through LKPD analysis, observation, and video recordings of learning.

The main contribution of this study lies in the finding that actively and positively built collaboration is not always directly proportional to the accuracy of mathematical results. Although students are able to discuss, share roles, and make effective use of manipulative materials, limitations in conceptual understanding and analytical abilities still affect the accuracy of problem-solving. These findings expand the study of PBL by emphasizing that strengthening collaboration needs to be balanced with the facilitation of reflection, reasoning, and drawing mathematical conclusions so that collaboration produces a deeper understanding.

Although this study has utilized video data to capture the dynamics of student interaction more fully, the study still has limitations in the relatively short duration of learning and limited scope of the classroom context. Therefore, further research is recommended to observe the continuous development of students' collaborative skills and analytical abilities in multiple meetings or learning cycles, as well as to combine video analysis with more structured collaborative assessment instruments to reinforce the findings.

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