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Innovative Strategies in Math Education: The Impact of PBL and TaRL on Concept Mastery and Classroom Dynamics

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ABSTRACT

While many studies evaluate each of the PBL and TaRL learning models separately, there is limited research that comprehensively examines the impact of integrating these two models on mathematics learning. Previous research tends to focus on academic outcomes without exploring how the integration of these learning models affects classroom dynamics, such as interactions between students and teachers, and the level of student engagement and participation. This article explores the integration PBL model and TaRL approach in mathematics education to improve students' understanding of mathematical concepts. This study used qualitative and quantitative approaches with a mixed-methods research design. The research subjects involved seventh-grade students in junior high school. Data collection techniques used test sheets to measure the understanding of mathematical concepts, observation sheets to record student, and teacher engagement to gain in-depth insights. Data were analyzed qualitatively and quantitatively. The results showed a significant improvement in the understanding of mathematical concepts. Observations revealed more active student engagement and more positive interactions between teachers and students. Statistical analysis showed significant differences between pre-test and post-test scores ($p < 0.05$). The research findings are interpreted to provide recommendations and practical implications for improving mathematics learning in schools. The practical implication is the need for teacher training in designing and implementing this learning model and supporting the improvement of the quality of mathematics learning at the secondary school level.

Keywords: Concept Mastery, PBL model, TaRL Approach

DOI: …

INTRODUCTION

According to the heuristic conception of mathematics, mathematics is problem-solving by the analytic method. In the claim of the heuristic conception that mathematics is problem-solving by the analytic method, 'mathematics' is meant the 'real' mathematics of the 'real' mathematicians (Cellucci, 2018). Mathematics in the form of abstract concepts requires problem-solving that is not simple, so it is often considered difficult to understand the concepts. Mathematics education is an important aspect of developing students' critical thinking and problem-solving skills. However, students often have difficulty in understanding mathematical concepts in depth (Mustafa et al, 2019), and students who have difficulty in understanding mathematical concepts, will cause math learning outcomes to not be optimal (Buyung, 2021). To address this, Problem-Based Learning (PBL) and Teaching at the Right Level

(TaRL) approaches have become the focus of attention to improve understanding of mathematical concepts. Problem-Based Learning is a learning method that focuses on practical and active learning to investigate and research real-world problems (Rézio et al., 2022). According to Hmelo-Silver et al. (2017), PBL encourages the development of student's cognitive skills and critical thinking abilities through authentic problem-solving. The research shows that PBL can provide a relevant context and motivate students to be actively involved in the mathematics learning process. This approach emphasizes the role of students in being independent and managing their learning, as well as collaboration between students in solving mathematical problems. One of the advantages of the PBL model is that it can encourage the development of critical thinking skills, problem-solving skills, and communication skills ((van der Vleuten & Schuwirth, 2019). PBL can also allow for working in groups, discovering and evaluating problems, and lifelong learning (Compton et al., 2020).

On the other hand, the TaRL approach aims to tailor learning to students' level of understanding, so that each student learns at a level that is appropriate for him or her (Boye & Agyei, 2023). Teaching at the Right Level (TaRL) is a concept developed by Abhijit V. Banerjee and Esther Duflo (2007) in economics that emphasizes the importance of adapting learning materials to students' level of understanding. This approach ensures that each student understands the concept before moving on to more complex material. A researcher in the field of education policy development, Singh (2018) highlighted the success of TaRL in improving student understanding in India. Furthermore, Ahluwalia et al., (2021) highlighted the importance of adjusting the curriculum to students' level of understanding, which is effectively synchronized with the Teaching at the Right Level (TaRL) principle. TaRL, as proposed by Banerjee and Duflo (2017), prioritizes the customization of teaching for each student so that they can master mathematical concepts before moving on to more complex material.

Specifically in this article, mathematics is seen as a universal science and has an important role in the development of various disciplines and modern technology (Anisa et al., 2020; Octaviana et al., 2018). According to Anisa et al., (2020), mathematics can develop students' thinking skills which include the ability to think critically, logically, analytically, and systematically in viewing and solving problems. Thus, mathematics is one of the disciplines that can develop students' thinking power in understanding and solving a problem, so it is one of the subjects that takes an important role in learning at school.

The implementation of mathematics learning is closely related to learning outcomes. This is because the success of learning can be seen in student learning outcomes (Octaviana et al., 2018). Furthermore, Fauzia (2018) said that one of the keys to learning mathematics is a good understanding of concepts. That is, a good concept understanding of the material presented in the learning process, will affect the learning outcomes obtained by students. However, learning in schools is not always in line with this. The results of observations made by researchers in junior high schools show that student learning outcomes are still relatively low. In addition, the results of observations of the implementation of mathematics learning showed that the teacher explained the material using the lecture method then, divided students into several groups and gave assignments. However, students tend to be passive when participating in discussion activities. In this case, only students who have high abilities work on the assignments given by the teacher while other students do not show contribution in the discussion activities. Furthermore, when the assignments given are discussed together in front of the class, students' enthusiasm is still lacking and some students have not been active in the learning process. They must be appointed by the teacher first to work on the results of their discussion in front of the class. Students still have difficulty applying the material that has been explained, so the learning process is still not optimal and results in low learning outcomes. The results of these observations show that students' mathematics learning outcomes require serious attention from all circles, especially mathematics teachers.

Some mathematics education experts have highlighted the importance of the integration between PBL and TaRL approaches in the context of mathematics education. They emphasize that the combination of these two approaches can improve students' understanding of mathematical concepts as a whole. In addition, research also shows that the application of PBL in mathematics education can help prospective mathematics teachers to understand the paradigm shift in the process of learning and teaching mathematics, and prepare them for the PBL environment in schools (Lee & Galindo, 2021). Expert opinion, as expressed by Kilpatrick et al. (2018), highlights the need to further personalize mathematics education to suit the needs and level of understanding of each student. This innovation finds common ground with the growing Teaching at the Right Level (TaRL) approach.

According to Pritchett et al. (2019), TaRL emphasizes adapting learning materials to students' level of understanding, bringing a positive impact on academic achievement and learning motivation. Thus, the integration between the PBL model and the TaRL approach in mathematics education is expected to make a significant contribution to improving students' understanding of mathematical concepts. Through this approach, it is expected that students can learn mathematics more thoroughly, actively, and according to their level of understanding, to develop strong problem-solving and critical thinking skills in the context of mathematics However, few studies have examined the integration of PBL and TaRL in the context of mathematics education, for example, Tenri's research (2023) on the integration of PBL and TaRL on Writing Skills focuses on the context of English language learning, Ulfa et al.'s research, (2023) which discusses the training of Teaching at the Right Level (TaRL) based learning models for elementary school teachers in the context of implementing the Merdeka Curriculum, and Amalia et al.'s research, (2024) which discusses the design and implementation of learning by applying the Teaching at the Right Level (TaRL) approach and applying the Culturally Responsive Teaching (CBT) approach which connects students' cultural background with material content.

Therefore, this study aimed to investigate the extent to which the integration of PBL and TaRL can improve the understanding of mathematical concepts among students.

The difference between this research and previous research on PBL or TaRL is this research combines Problem-Based Learning (PBL) with the Teaching at the Right Level (TaRL) approach in mathematics education, which is a new development. PBL emphasizes active learning through real-world problem-solving, while TaRL focuses on ensuring that students receive instruction at their appropriate learning level. Integrating these two approaches can provide a comprehensive method for addressing diverse learning needs in mathematics education.

Literature Review

Problem-based learning (PBL) has long been a focus in the development of problem-solving-oriented mathematics learning approaches. PBL emphasizes providing students with a real-world context, allowing them to develop mathematical understanding through exploration and solving concrete problems (Mustafa et al., 2019).

The problem-based learning model is learning that is oriented towards students as learners through providing authentic problems and solving them using their knowledge or other learning resources. Fauzia (2018), Fanzeka et al., (2023), and Asdar et al., (2023). PBL has been proven effective in improving understanding of mathematical concepts. According to Hmelo-Silver et al., (2017), this approach allows students to engage in deep and critical thinking processes when facing problems relevant to their daily lives. Meanwhile, the use of learning models can be supported by the application of learning approaches that are by the characteristics of diverse learners. One of the learning approaches that can be used is the Teaching at the Right Level (TaRL) approach.

The Teaching at the Right Level (TaRL) approach brings a new dimension to addressing students' understanding gaps. Banerjee et al., (2018) explain that TaRL focuses on tailoring learning materials to students' levels of understanding, ensuring that each student gets a learning experience that suits their needs. The TaRL approach is one of the learning approaches that orient students to learn according to their ability level. Ahyar et al., (2022) said that learning using the TaRL approach does not organize students based on grade level and age, but learning is designed in groups according to the characteristics of students' ability levels. Furthermore, Cahyono (2022) said that the reference in the TaRL approach is learning outcomes, but it is adjusted to the characteristics, potential, and needs of students. Likewise with learning outcomes, where learner learning outcomes are determined based on learning evaluations according to their phase or ability level. Learners who have not achieved the learning outcomes in their phase will be assisted by educators to achieve their learning outcomes. Thus, the TaRL approach is a learning approach that can be used to overcome the understanding gap that occurs in the classroom during the learning process. Learning using the TaRL approach is learning that organizes learners not tied to grade levels, but grouped based on developmental phases or according to

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the same level of ability of learners (Cahyono, 2022). Grouping learners can be done by giving a diagnostic test to determine the level of ability of students to learn the material. The test results obtained can be used as a reference in grouping students in the low, medium, and high ability categories.

The integration of PBL and TaRL emerges as a potential solution to improve mathematics learning. Boaler (2016) mentioned that through PBL, students can engage in problem-solving while TaRL ensures that learning is tailored to each student's level of understanding. Although the integration of PBL and TaRL is promising, some challenges need to be overcome. According to Sembiring (2019), the difficulty in designing and presenting problems that suit both models can be a major obstacle.
Measuring the effectiveness of PBL and TaRL integration requires a holistic evaluation approach. Research by Anderson et al., (2019), shows the importance of using various evaluation methods to understand the impact of the integration of these models. Case studies of PBL and TaRL integration implementation in various educational contexts are important. Research by Fernández et al., (2021) tries to explore the experiences and challenges in implementing the integration of these learning models in various educational environments. This research has significant implications in the context of improving mathematics learning. Understanding the current literature review is expected to provide a strong foundation for designing and implementing the integration of PBL and TaRL effectively, improving students' understanding of mathematical concepts.

METHOD

This study uses qualitative and quantitative approaches with a mixed-methods research design. The qualitative approach was used to gain an in-depth understanding of students' and teachers' experiences in implementing the integration of the learning model, while the quantitative approach was used to measure the impact of the integration on the understanding of mathematical concepts by combining classroom observation data during the learning process, pre-test, and post-test, which were then analyzed thoroughly to provide a comprehensive picture of the effectiveness of the learning strategy. Qualitative data was obtained through observations of student participation, interaction with the material, and responses to the learning strategy. Quantitative data was collected through pre-tests and post-tests to assess the improvement of mathematical concept understanding by statistical tests.

The subjects of this research were seventh-grade students at a state junior high school in South Sulawesi, Indonesia. The instruments used in this study were observation sheets and test sheets. The Observation Sheet contains several aspects of observation used to record activities during learning, which include student participation, interaction with the material, and responses to learning strategies. Furthermore, the test sheet was developed to measure students' understanding of mathematics concepts. The test includes questions designed according to the curriculum and involves problem-solving applications.

Data collection techniques were conducted through observation during the learning process in the classroom. Observations took place during the math learning period with a focus on student interactions, the use of PBL methods, and student responses to learning. Furthermore, tests were given before and after the implementation of the learning model. The initial test provides an initial picture of students' understanding, while the final test assesses the impact of the integration of PBL and TaRL. In this study, one whole class was selected as the sample because the focus was on the effectiveness of the integration of learning models in one particular classroom context. By using one class as the sample, the study was able to gain an in-depth understanding of the effect of the intervention on the whole group of students in a homogeneous learning environment. This approach allows the researcher to track the changes that occur before and after the intervention in more detail, as well as understand the dynamics of the classroom as a whole. Although this study involved only one class, the mixed qualitative and quantitative approach can provide rich and comprehensive insights into the impact of the integration of learning models on students' and teachers' understanding of mathematical concepts and learning experiences in a real context. The initial process of instrument validation was reviewed by experts in the field. The review was conducted through consultation to ensure its relevance and validity. Next, a pilot test was conducted on a small number of student groups to evaluate the clarity and accuracy of the instrument. After that, a reliability analysis was conducted, either through statistical tests for tests or the consistency of observation sheets. Finally, the results of these stages were used to revise and refine the instrument before it was used in the overall study.

Qualitative data analysis, namely observation data, was carried out using the thematic analysis method to identify patterns and main themes including student interactions, level of engagement, and effective PBL learning strategies, while quantitative data analysis, namely pres-test and post-data, used statistical tests to compare learning outcomes before and after the intervention. The results of qualitative and quantitative analysis were used to evaluate the effectiveness of the integration of PBL and TaRL models. The research findings were interpreted to provide recommendations and practical implications for improving mathematics learning in schools.

RESULTS & DISCUSSION

Result

The integration process of PBL and TaRL was implemented in classroom learning. Using rigorous measurement instruments, namely observation sheets to record classroom interactions and specially designed test sheets to measure understanding of mathematical concepts, the study collected relevant qualitative and quantitative data. Before looking at the detailed results of the study, it is important to remember that this approach was designed to improve the quality of mathematics learning and provide a more personalized approach to students, taking into account their levels of understanding.

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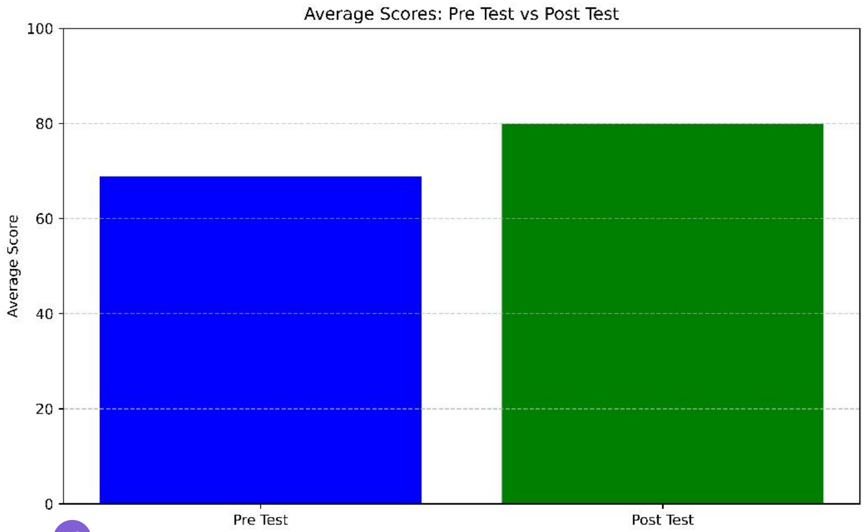
The first step is to give a pre-test. This step aims to measure the knowledge aspects of students before they receive the intervention or learning model under study. The pre-test provides a basis for comparing post-test results after the application of PBL and TaRL so that researchers can assess how much improvement in concept understanding and changes in classroom dynamics are produced by PBL and TaRL. In addition to measuring aspects of initial knowledge, this step also observes learning activities (attitudinal and psychomotor aspects). Observations help assess how students respond to learning through participation, interaction with the material, and responses to learning strategies.

In the next step, the researcher designs the learning according to the initial data by identifying areas that need special attention or improvement. This helps in implementing PBL and TaRL that better suit the needs of the students, and the last step is to give a post-test, including making final observations (attitudinal and psychomotor aspects) after PBL and TaRL are implemented. The data of the research results are described as follows.



Average Pre-Test Score	Average Post-Test Score	Average Change
68.85	79.85	+11

Figure 1. Results of Pre-Test and Post-Test Statistical Analysis (Knowledge Aspect)

The average value of the pre-test score measured before the implementation of the learning model was 68.85, while the average value of the post-test score measured after the implementation of the learning model was 79.85. The average difference between the post-test score and the pre-test score is +11. A positive value indicates an increase in the average score after the implementation of the learning model. Thus, the results in Table 1 illustrate that there is a significant increase in the knowledge aspect of students after following the implemented learning model. The higher average post-test score (79.85) compared to the average pre-test score (68.85) indicates that the learning model made a positive contribution to students' understanding of mathematical knowledge concepts. The average change of +11 indicates a significant improvement from the beginning to the end of learning.

Furthermore, teacher activities in managing learning before the PBL Model and TaRL approach are implemented there are differences after the implementation of the model and approach.

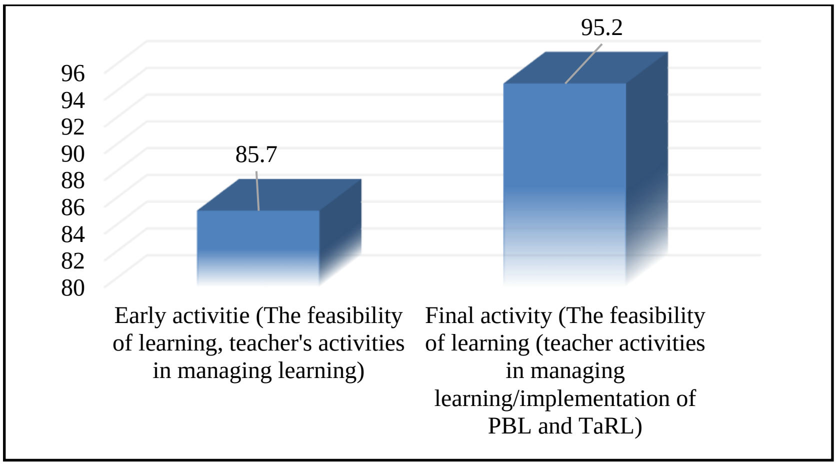
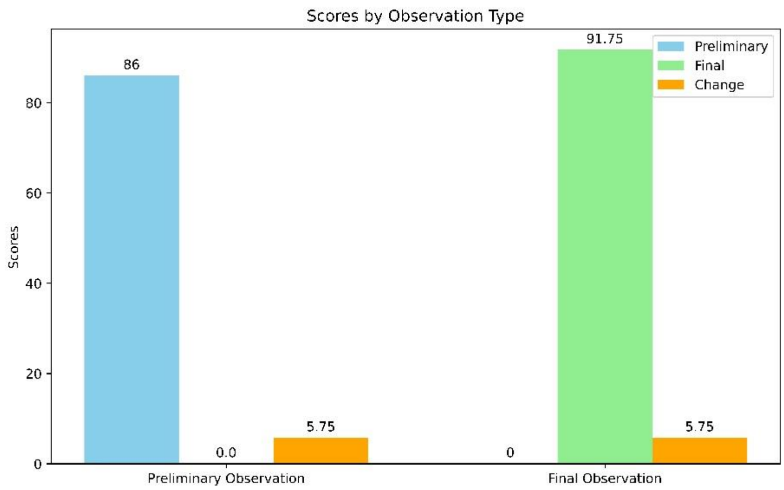


Figure 2. Practical Score

The interpretation of the initial score of 85.7 indicates that this score reflects the feasibility of learning at the initial stage of implementation. The higher the score, the better the feasibility of learning at the beginning of implementation. Teachers' activities in managing learning or implementing PBL and TaRL in the early stages can affect the quality of learning and student engagement. The interpretation of the final score of 95.2 indicates that this score reflects the feasibility of learning at the final stage of implementation. An increase in the score from the initial to the final stage shows the effectiveness of improvements or adjustments made during the learning process. A high score in the final stage can reflect the teacher's success in managing learning well or implementing PBL and TaRL effectively. The change in scores from the initial to the final stage indicates the extent to which learning has progressed and the effectiveness of teacher activities in managing learning. The greater the difference between the initial and final scores, the more positive the impact achieved in improving learning quality and student engagement.

In the aspect of assessing student attitudes, the data in Figure 3 is obtained.

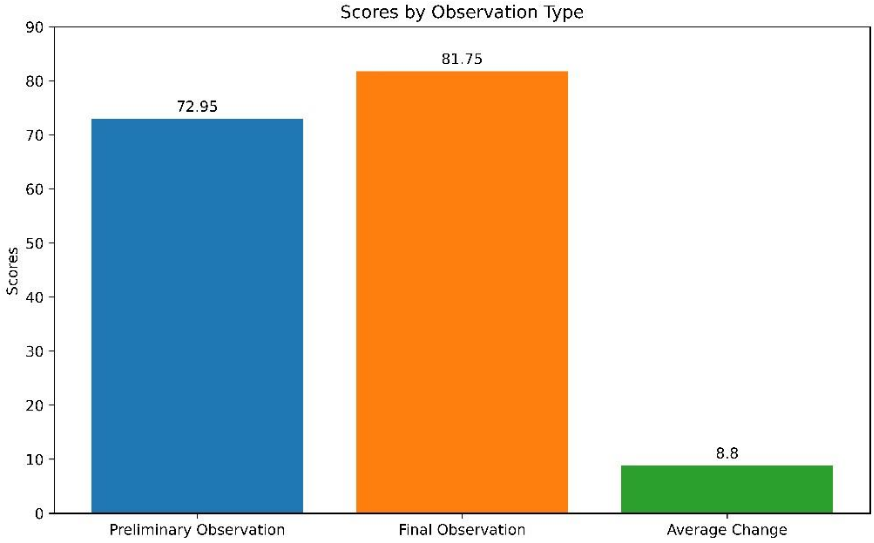


Average preliminary observation Score	Final Observation Score	Average Change
86	91.75	+5.75

Figure 3. Results of Statistical Analysis of Preliminary and Final Observations (Affective Aspect)

Figure 3 shows that the average value of the initial observation score measured before the implementation of learning by implementing the PBL model and TaRL approach was 86, while the average value of the final observation score measured after the implementation of the PBL model and TaRL approach was 91.75. Average Change +5.75. The acquisition of the score is the average difference between the final observation score and the initial observation score. A positive value indicates an increase in the average affective score after going through the observation period.

Thus, the results in Figure 3 reflect that there was a significant improvement in the affective aspect based on the comparison between the initial observation score and the final observation score. The higher average final observation score (91.75) compared to the average initial observation score (86) indicates an improvement in the affective responses or attitudes of the research subjects. The average change of +5.75 indicates an improvement in the affective aspects during the observation period. In the aspect of assessing students' skills, the data in Figure 4 is obtained.



Average preliminary observation Score	Final Observation Score	Average Change
72.95	81.75	+8.8

Figure 4. Results of Statistical Analysis of Preliminary and Final Observations (Psychomotor Aspect)

Figure 4 provides the results of statistical analysis for the initial and final observations on psychomotor aspects. The average score in the initial observation was 72.95. This reflects the average value of all data taken at the initial stage of observation related to psychomotor aspects, while the average score at the final observation was 81.75. This reflects the average value of all data taken at the final stage of observation related to psychomotor aspects. The average change was +8.8. This reflects the difference between the average score in the final observation and the average score in the initial observation. In other words, there was an average increase of 8.8 points in psychomotor aspects during the observation period. This result illustrates that there was a significant improvement in psychomotor aspects between the baseline and final observations. A positive number on the mean change indicates an improvement in the psychomotor skill or response observed during the study period. This change may reflect the effectiveness of an intervention or program implemented during the observation.

Learning assessment during this study covered three aspects, namely knowledge, affective, and psychomotor. The overall data is organized as follows.

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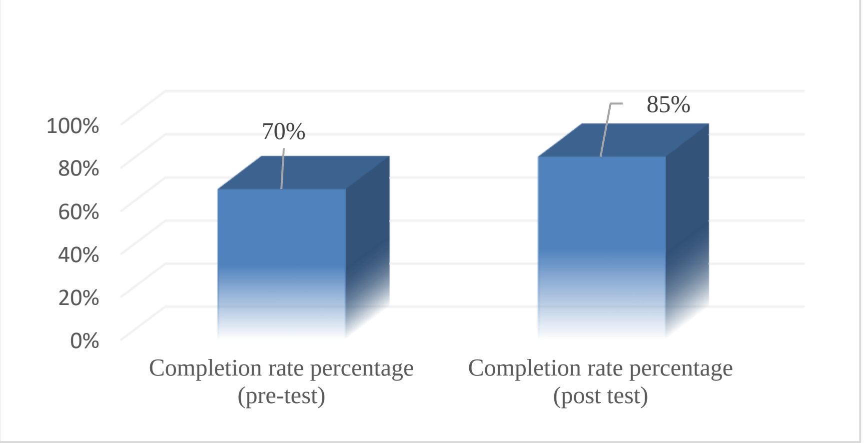

Figure 5. Learning Completion Percentage

Figure 5 illustrates the percentage of learning completion by comparing the initial and final completion rates. Learning Completion Percentage (Initial) is the percentage of learning completion at the initial stage. In this example, the initial learning completion rate is 70%. It reflects how much learning material has been mastered or completed by participants at the beginning of a certain period. Completion Rate Percentage shows the percentage of learning completion at the end stage or after a certain period has passed. In this example, at the end of the period, the learning completion rate increases to 85%. This reflects the extent to which participants have completed the learning material during the period. Percentage Change is the difference between the Learning Completion Percentage at the end of the period and the Learning Completion Percentage at the beginning of the period. In this example, the percentage change is +15%, which indicates a 15% increase from the beginning of the period to the end of the period. This indicates a significant improvement in the learning completion rate during the period.

By looking at Figure 5, we can conclude that there is a positive increase in the percentage of learning completion from the beginning to the end of a given period. This indicates the progress of the participants in completing the given learning materials. A decrease in the percentage of learning completion in the final stage would indicate that participants have not completed most of the learning materials. Based on the results of data analysis involving knowledge, affective, and psychomotor dimensions in the context of integrating Problem-Based Learning (PBL) and Teaching at the Right Level (TaRL) models in mathematics learning, it can be concluded that Analysis of test data shows a significant increase in understanding of mathematical concepts, Students who follow learning with PBL and TaRL approaches show a higher increase in post-test scores. Student affective observations indicated higher levels of engagement and activeness. In addition, changes in the level of student participation and interaction between teachers and students reflected the development of psychomotor skills. The integration of PBL and TaRL provided opportunities for students to apply mathematical concepts in problem-solving, improving their practical skills. Thus, the results of data analysis consistently show that the integration of PBL and TaRL models is effective in improving the understanding of mathematical concepts in the knowledge dimension. Meanwhile, observations on the affective and psychomotor dimensions illustrate the positive impact on students' motivation and practical skills. Given the improvements in these three dimensions, this approach holds promise as a holistic learning method to improve the quality of mathematics learning at the secondary school level.

Discussion

The results of this study support the literature showing the effectiveness of PBL and TaRL models in improving mathematics learning. Observations and test analysis imply that this approach provides a more relevant learning context and is responsive to students' diverse levels of understanding. The results showed that the integration of Problem-Based Learning (PBL) and Teaching at the Right Level (TaRL) models significantly improved the understanding of mathematical concepts. According to Hiebert and Carpenter (2019), the PBL approach can stimulate deep mathematical thinking, allowing students to build a solid understanding of concepts. This can be seen from the consistent increase in post-test scores. The PBL approach allows students to face real-world problems, motivating them to understand math concepts more deeply. According to Boaler (2022), active engagement in the mathematics learning process can increase students' interest and motivation, creating a more positive learning experience. The integration of PBL and TaRL has a positive influence on students' affective dimension. In addition, the integration of PBL with TaRL can improve students' writing skills (Tenri, 2023), this skill is good for students to have, especially in understanding contextual mathematical problems to be modeled in mathematics. TaRL is a learning approach that directs students to learn based on their ability level, while PBL is a problem-based learning model that can be applied to train students in analytical skills. Both can be used together to increase students' interest in learning and skills in problem-solving (Nabella et al., 2023). TaRL focuses on orienting students to learn based on their ability level, while PBL is a problem-based learning model that can be applied to train students in analytical skills. Kanyesigye et al., (2022) suggested the importance of teachers understanding PBL in PBL increasing their knowledge of PBL concepts, increasing competence in PBL, increasing the perceived value of PBL, and making PBL implementation.

The successful integration of PBL and TaRL models can also be attributed to the active role of students in learning. Engaging students in real-world problem-solving and presenting materials according to each student's level of understanding can improve motivation and learning outcomes. Despite the positive results, it should be noted that challenges can arise in designing appropriate PBL problems and customizing materials according to student's level of understanding. Therefore, this approach requires strong support from teachers and a careful approach to designing and presenting materials. The relevance of PBL and TaRL integration in improving mathematical understanding can be

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found in the concept of "Teaching at the Right Level." This approach, developed by Banerjee et al., (2018), emphasizes the importance of aligning learning materials with students' level of understanding, thus giving relevance and significance to each stage of learning.

Integrating PBL and TaRL can be a holistic approach that addresses not only the knowledge aspects but also the affective and psychomotor aspects of students. This is in line with the view of NCTM (National Council of Teachers of Mathematics), which emphasizes the importance of developing the whole individual through meaningful mathematics learning (NCTM, 2022). According to NCTM (2023), PBL integration can help students develop critical thinking skills and the ability to apply mathematical concepts in real contexts.

Understanding the results of this study can contribute to the development of a more effective mathematics learning model. The practical implication is the need for teacher training in designing and implementing this learning model, as well as supporting the improvement of the quality of mathematics learning at the secondary school level.

CONCLUSION

From the discussion above, it can be concluded that the application of a problem-based learning model with teaching at the right level approach can improve learning outcomes. The integration of PBL and TaRL models has been proven to improve students' understanding of mathematics concepts. The PBL model provides a real-world context that encourages critical thinking, while TaRL adapts learning to students' level of understanding. Classroom observations showed an improvement in learning dynamics. Interactions between teachers and students became more engaged and collaborative, creating a more dynamic and interactive learning environment. Adjustment of learning materials and strategies based on students' prior understanding is crucial. This is especially important in the context of PBL and TaRL to ensure that each student gets a learning experience that suits their needs. The role of the teacher in directing the learning process, providing support, and providing continuous feedback is very important. Teachers are not only facilitators but also adjusters to students' individual needs. This research provides a foundation for the development of mathematics learning strategies that are more contextual, dynamic, and responsive to the diversity of students' levels of understanding. The practical implications of this research can help educators and policymakers in designing a more adaptive and effective curriculum to improve the quality of mathematics learning in schools.

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