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Implementation of Realistic Mathematics Education and Project-Based Learning to Improve Students' Mathematical Thinking Ability and Empathy Skills

Nur Afifah [1] *, Andini Norma Isyati [1], Loviga Denny Pratama [1]
[1]Department of Mathematics Education, Universitas Islam Zainul Hasan Genggong. Kraksaan, Indonesia.

Abstract: The ability to think mathematically is an important aspect in learning mathematics, but many students still experience problems in understanding abstract concepts such as sets and show a lack of empathy in group work, as found. This research aims to improve students' mathematical thinking skills and empathy through the Realistic Mathematics Education approach combined with the Project-Based Learning model. The method used was classroom action research carried out in two cycles in class VIII with 15 students as research subjects. The research procedure refers to Kemmis and McTaggart's spiral model, which consists of planning, implementation, observation and reflection phases. Data collection was carried out through mathematical thinking ability tests, observation of student activities, and empathy questionnaires. The results show that at the initial stage, there were no students who met the Minimum Completeness Criteria (KKM), and the level of empathy was relatively low. After implementing the learning strategy, there was a significant improvement in both aspects, especially in the second cycle. These findings indicate that the integration of the RME approach and the PjBL model is effective in developing mathematical thinking skills and increasing student empathy in learning mathematics.

Keywords: empathy; mathematical thinking; project-based learning; realistic mathematics education.

INTRODUCTION

Mathematics learning is often considered non-contextual, making it difficult for students to understand the concept in depth (Sohilait, 2021). This issue has an impact on the low mathematical thinking skills of students at various levels of education. One of the consequences is the low mathematical thinking skills of students at the junior high school level (Purnaningsih & Zulkarnaen, 2022). Mathematical thinking skills include the ability to reason, analyse, solve problems, and communicate ideas logically and systematically (Al Ghifari, Juandi & Usdiyana, 2022). Meanwhile, mathematics education also does not emphasise enough the development of affective aspects such as empathy, cooperation, and concern for group mates. Empathy is important in 21st-century learning, which not only emphasises learning outcomes but also student character (Bella, Basori & Kurniasari, 2024).

Facts on the ground also show low thinking skills in students' mathematical thinking (Rasmani et al., 2023). Based on the results of preliminary observations conducted in one of the eighth-grade classes at a junior high school in Probolinggo Regency, it was found that students' mathematical thinking skills were still low. This fact was indicated by several factors, such as difficulties in understanding abstract mathematical concepts, inability to connect mathematical ideas, and lack of reasoning when solving problems. In addition, students tended to rely on memory rather than logical understanding.

Furthermore, observations also revealed issues related to students' empathy, such as a lack of cooperation during group activities, minimal willingness to listen to peers' opinions, and low sensitivity to classmates who were struggling (Anjarsari, Lestariningsih & Latifah, 2025). These problems prompted collaborative efforts among mathematics teachers at the school to explore appropriate learning approaches and models that could help address these challenges.

* Correspondence to Author. E-mail:afifah173839@gmail.com Publisher: Department Mathematics Education, Universitas Halu Oleo

To address the identified learning challenges, the researcher applied two instructional approaches: Realistic Mathematics Education (RME) and Project Based Learning (PjBL) (Nurwahid, Ashar & Awantagusnik, 2025). These approaches were selected based on the belief that learning mathematics should be closely related to students' real-life experiences so they can better understand abstract concepts. RME facilitates students in developing mathematical ideas through real-world situations, while PjBL encourages active learning by engaging students in collaborative projects that require problem-solving and critical thinking. Throughout the learning process, RME was used to introduce and explore mathematical concepts contextually, whereas PjBL provided the structure for students to apply these concepts in meaningful group-based projects. The integration of both approaches was intended to improve students' mathematical thinking skills and support the development of empathy through teamwork and peer interaction.

Realistic Mathematics Education (RME) is an approach that emphasises real contexts as the starting point for learning so that students can construct knowledge through meaningful experiences. RME has long been developed in the Netherlands (Tantra, Widodo & Katminingsih, 2022). RME refers to the opinion of Freudenthal that mathematics must be linked to reality and is a human activity (Hidayati & Mashuri, 2024). This approach means having to be close to the child and relevant to everyday situations. Mathematics as a human activity This means that humans must be given the opportunity to rediscover ideas and mathematical concepts (Harahap, 2022). Meanwhile, Project Based Learning (PjBL) enables students to learn actively and collaboratively in solving real problems that are relevant to their lives.

The principle underlying the concept of the PBL method, according to Boud, is that learning begins with the provision of a problem, questions, or problems that must be solved by students (Sabar et al., 2023). Real problems and the complex provided will trigger and motivate students to identify and learn the concepts/principles they need to know in order to solve problems (Hasanah, Susilowati & Haryadi, 2022). By using problems as a trigger to learn something, students construct new knowledge in the context of the given problem.

The integration of Realistic Mathematics Education (RME) and Project Based Learning (PjBL) offers a strategic learning model that combines the strengths of both approaches in a complementary manner (Ashar, Nur & Basaruddin, 2025). RME positions itself as a foundation for conceptual understanding by engaging students in real-life, meaningful contexts that make abstract mathematical ideas more accessible. Meanwhile, PjBL functions as a structured framework that guides students to apply the mathematical concepts they have learnt through collaborative, project-based tasks (Effendi, Aprilia & Rosyadi, 2024). In this combined model, learning begins with contextual problem situations in line with RME principles, allowing students to explore and develop their own strategies. These initial explorations then transition into group-based projects, as suggested by PjBL, where students work together to create products or solutions that reflect their understanding. This synergy between RME and PjBL not only strengthens mathematical thinking skills such as reasoning, connecting, and representing but also fosters empathy, as students are required to collaborate, communicate, and respect differing perspectives during the learning process (Tanaya & Yasin, 2024).

The novelty of this research lies in the explicit combination of RME and PjBL to address both cognitive and affective learning outcomes, particularly the integration of empathy into the mathematics instruction aspect that is still rarely explored in previous studies. While earlier research tends to focus on either RME or PjBL independently, this study proposes a comprehensive model that targets both mathematical competence and social-emotional development, which is relevant in 21st-century education. Therefore, this study aims to determine the increase in students' mathematical thinking and empathy skills through the application of both approaches in learning mathematics on the subject of sets (Fitriana & Izzati, 2022).

METHODS

This study uses a qualitative and quantitative approach with a type of classroom action research carried out in two cycles, referring to the Kemmis and McTaggart model (Embong, 2022). This study was conducted in response to the need for learning approaches that develop students' cognitive abilities and foster their social-emotional skills. In particular, the focus is on enhancing students' mathematical thinking skills and empathy—two essential competencies in 21st-century education. To address this, the researcher applied a combination of Realistic Mathematics Education (RME) and Project Based Learning (PjBL), which are believed to be effective in supporting both deep conceptual understanding and meaningful interpersonal collaboration. The subjects of this study consisted of 15 eighth-grade students from one of the junior high schools in East Java, Indonesia, who were actively involved in the learning process.

The initial phase of the research involved planning, which included preparing learning tools such as RPP based on RME and PjBL, mathematical thinking ability test instruments, empathy observation sheets, and affective questionnaires (Nahak & Benu, 2021). In addition, learning activities are designed in such a way that students are active in constructing understanding through contextual problems and projects that are relevant to their lives and have social content to foster empathy. After the planning was completed, measurements of the students' initial conditions were taken through tests and questionnaires, which indicated that the students' mathematical thinking and empathy abilities were still in the low category (Desyana & Sari, 2022). The average cognitive test results in the initial conditions only reached 4,6 and no students achieved the Minimum Completion Criteria (KKM) score of 75. Meanwhile, the average affective value of students is 50,67% which shows that their empathy is also still very low (Siregar et al., 2023).

This study applied classroom action research (CAR) consisting of two cycles. Each cycle included four main stages: planning, action, observation, and reflection. In the planning stage, the researcher collaborated with the teacher to design lesson plans incorporating Realistic Mathematics Education (RME) and Project Based Learning (PjBL).The action stage involved implementing learning activities based on the designed plan, focusing on real-life contextual problems and group project development. During the observation stage, data were collected on students' participation, problem-solving strategies, collaboration, and empathetic behaviour. Finally, the reflection stage was conducted after each cycle to evaluate student progress and revise the teaching strategy for the next cycle. Data collection techniques included observation sheets, student worksheets, cognitive tests, and empathy rubrics. Quantitative data were analysed using descriptive statistics to assess student achievement levels, while qualitative data were used to evaluate students' interactions and emotional responses. Triangulation of data ensured the validity and reliability of the findings.

The implementation of the RME and PjBL models was carried out gradually through two learning cycles. In each cycle, RME served as the foundation by introducing students to contextual problems that reflect real-life situations. Students were encouraged to develop their own problem-solving strategies based on these contexts. Following this, PjBL was used as a continuation, where students collaborated in groups to transform the mathematical problems into concrete projects, which they later presented. This combination created a dynamic learning environment where mathematical reasoning was built through exploration and discussion (RME), while empathy was fostered through group collaboration, peer communication, and social responsibility in completing the project (PjBL). Similar findings were reported by (Listiana, Pasaribu & Julyanti, 2024), who found that integrated learning models like RME and PjBL not only improved mathematical achievement but also developed students' interpersonal skills.

In this study, students showed improved mathematical thinking abilities, particularly in the areas of reasoning, representation, and problem-solving. These outcomes align with research by (Syarifuddin & Nurmi, 2022), who emphasised that RME enhances students' capacity to understand abstract mathematical ideas through contextualisation. Meanwhile, empathy skills improved as students were consistently exposed to collaborative tasks and reflective activities, supporting the findings of (Mbagho & Tupen, 2020), who stated that project-based approaches linked to real social contexts contribute to students' emotional development and awareness of others. Therefore, the combination of RME and PjBL proved effective in enhancing both cognitive and affective competencies.This study offers a novel contribution by demonstrating how these two models can be systematically integrated in a classroom setting to achieve holistic learning outcomes in mathematics education.

RESULTS AND DISCUSSION

This research uses a Classroom Action Research (CAR) approach, which is implemented in four main stages, namely planning, implementing actions (consisting of two cycles), observation, and reflection (Nuraini, 2023). In the learning process, the Realistic Mathematics Education (RME) approach and the Project-Based Learning (PjBL) model are systematically combined to simultaneously enhance students' mathematical thinking skills and empathy. In the planning stage, teachers and researchers developed learning tools that combined RME principles, such as contextual problem presentation and guided discovery, with distinctive elements of PjBL, such as teamwork, project planning, and product-based problem solving (Nu'man et al., 2022). The problems designed are based on real-life situations close to students' lives to stimulate cognitive and emotional engagement. Next, during the implementation phase, learning begins with an exploration of contextual problems (Zakiah, Sunaryo & Amam, 2019). Students are encouraged to understand and solve these problems through group discussions. Through this process, they develop their own problem-solving strategies based on their understanding of the given context (Audia, Rahmawati & Farhurohman, 2024). Thereafter, students continue by developing a group project based on the results of the previous discussion. The project is a tangible product that represents their understanding of the mathematical concepts they have learnt.

During the observation stage, teachers and researchers watch the students' learning process, both in terms of cognitive engagement, such as reasoning ability, connecting concepts, and explaining ideas, as well as affective aspects, such as cooperation, listening skills, and concern for group members (Gusmaneli, Junaidi, and Ranjani 2024).The collected data were then analysed descriptively. Reflection was conducted after each cycle to evaluate the implementation of learning and design improvements for the next cycle (Arianti, Astawan & Krisnaningsih, 2021). The results of the reflection indicated that students began to show improvements in their mathematical thinking and empathetic behaviours, although some students in Cycle I still showed low involvement in group discussions.

The contribution of RME in this learning process was evident in the improvement of students' mathematical thinking skills. By relating mathematical concepts to real life, students found it easier to understand and build knowledge independently. This is in line with the findings of (Syarifuddin & Nurmi 2022), who stated that contextual learning encourages students to develop logical thinking and mathematical modelling skills. On the other hand, the implementation of PjBL provides space for students to work in teams, solve problems collaboratively, and develop and present their projects. Through this process, students not only apply their mathematical knowledge but also develop social skills such as responsibility, communication, and empathy. Research conducted by (Listiana, Pasaribu & Julyanti, 2024) also supports the notion that project activities encourage students to think critically while enhancing positive social interaction within groups.

Students' empathy develops as they interact frequently in teams, listen to their peers' perspectives, and resolve conflicts that arise during the group work process. Structured reflection activities also help students identify the roles and contributions of each team member. This finding is supported by (Sumiyati, 2023) research, which states that group work in project-based learning can foster social awareness and strengthen relationships among students. Thus, it can be concluded that the combination of RME and PjBL creates learning that focuses not only on academic achievement but also on character. Through structured learning stages, students are able to strengthen their mathematical thinking skills while developing an empathetic attitude towards others.

The planning stage is carried out by compiling learning tools that are in accordance with the characteristics of RME and PjBL, including student worksheets, observation instruments, and affective and cognitive assessment rubrics (Amrina et al., 2022). Thereafter, initial condition data collection was carried out as a reference for implementing the action. Based on the results of initial observations, it was found that students' mathematical thinking skills were still low, marked by 13.33% of students being in the "Medium" category, 66.67% in the "Low" category, and 20% in the "High" category. There were no students in the "Very High" category (Hidayat, Siskawati & Irawati, 2023).The following table presents the development of students' mathematical thinking skills from the initial conditions to cycle 2.

Table 1. Cognitive Abilities (Mathematical Thinking)

Cognitive Abilities	Initial Conditions	Cycle 1	Cycle 2
Very high	0	7%	87%
High	20%	26,67%	13%
Currently	13,33%	26,67%	0%
Low	66,67%	40%	0%
Very Low	0%	10%	0%

Based on Table 1, there is a significant development in students' cognitive abilities during the implementation of classroom action research. In general, there is a shift in the distribution of cognitive ability categories from being dominated by the low category to the very high category at the end of the second cycle. In the initial conditions, before the action was given, most students were in the category of low cognitive ability, as big as 66,67%, followed by the categories high (20%) and current (13,33%). There are no students in the categories 'very high' and 'very low'. This reflects that in general, students' understanding of the material given is still relatively weak, and they have not been able to demonstrate a deep thinking process (Syahbana 2012). This low ability can be caused by various factors, such as a lack of active involvement in the learning process, an inappropriate learning approach, or a delivery method that has not optimally stimulated students' reasoning abilities.

After implementing the actions in the first cycle, there was a shift in the category composition. Very high abilities start to appear at 7%, indicating that there are students who are starting to show extraordinary development in understanding the material. The high and medium increased to 26,67% each, indicating that almost half of the students began to experience cognitive improvements. However, the category 'low' still dominates as much as 40%, and the category 'very low' appears as big as 10%. The emergence of this very low category could be the result of some students' unpreparedness in accepting changes in learning strategies or their suboptimal adaptation to new approaches (Amudariya, 2025). This change shows that the implemented strategy has begun to have an impact, but is not yet fully effective for all students. This is the basis for reflection and improvement in action planning in the next cycle.

In the second cycle, the results obtained showed a very significant increase. As many as 87% of students managed to achieve the very high category, while the rest, as many as 13%, are in the high category. Currently, there are no students in the low and very low categories. This condition indicates that the actions implemented in the second cycle succeeded in accommodating students' learning needs more optimally. The success is most likely due to several factors: the improvement of learning methods based on the results of cycle 1 reflection, increasing active student involvement in the learning process, and utilising strategies that are appropriate to students' learning styles (Zakaria, 2024). sing student-centred and problem-based learning approaches, for example, can encourage students to be more active when thinking, exploring, and solving problems, thereby significantly improving their cognitive abilities.

When compared between cycles, it is seen that the actions taken have increased in effectiveness over time. A sharp increase from 7% to 87% in the very high category is an indicator of the success of the action process that is carried out continuously and responsively to the results of reflection. Meanwhile, the elimination of the low and very low categories indicates that all students have achieved an adequate level of understanding of the learning material. The following diagram illustrates the changes in the distribution of students' mathematical thinking ability categories from the initial conditions to cycle 2.

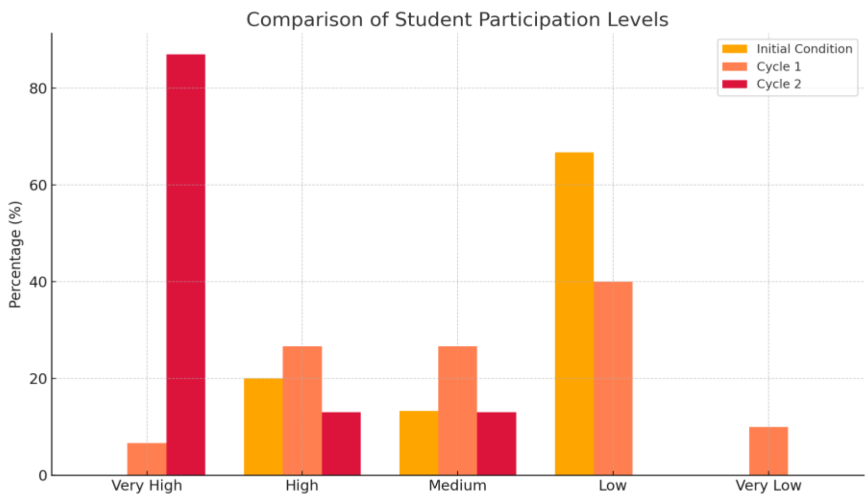

Figure 1. Graph Comparing Students' Cognitive Abilities Per Cycle

Figure 1 shows the development of students' cognitive abilities from the initial conditions to the first and second cycles in the implementation of classroom action research. Visually and quantitatively, there was a significant shift in the distribution of student ability levels. In initial conditions, most of the students are in the category 'low', as many as 66,67%, while only 20% belong to 'high' and 13,33% are in the 'medium' category. None of the students achieved the 'Very high' level. These data show that in the early stages, students' thinking skills in understanding concepts have not developed optimally. Many of them seem to still have difficulty in absorbing material or linking concepts to real situations, which can be caused by a lack of variation in learning methods or low learning motivation (Wahyuningsih 2020).

After the class action was carried out on the first cycle, there is a positive shift in the distribution of cognitive ability levels. The category appears 'very high', as big as 6,67%, which indicates that students are beginning to demonstrate a deep understanding of the material. The “High” and “Medium” categories also increased, each reaching 26,67%, while the “Low” category decreased to 40%. However, there is also a “Very Low” category of 10%, which is likely the result of some students adapting to new methods that are not yet fully effective for all.

Drastic changes occurred in the second cycle, where the majority of students (86,67%) are in the category 'very high'; a temporary 13,33 are in the 'high' category. There are no more students in the categories 'currently', 'low', and 'very low'. This condition reflects the significant success of the applied learning strategy (Nurofi’atin, 2024). The sharp increase indicates that students not only understand the material but are also able to develop high-level thinking skills, such as analysing, assessing, and connecting concepts in a wider context. This success cannot be separated from the role of reflective cycles in classroom action, where teachers actively identify obstacles and improve learning strategies at each stage (Siregar et al. 2024). For example, the use of a more contextual approach, problem-based learning, or collaborative activities can encourage students' active involvement in the learning process, thereby strengthening their thinking skills.

In general, the patterns shown in the diagram reflect that appropriate, consistent learning strategies that are tailored to student characteristics can result in significant transformation of cognitive abilities (Sastradinata & Nuryanti, 2023).These changes not only show academic improvement but also indicate that students have gone through a meaningful learning process and have developed in their way of thinking about the material. In addition, students' empathy abilities measured through affective aspects also showed a significant increase (Saputra & Faridatussalam, 2023). The following is the development of students' average affective scores along with the percentage of achievement of the Minimum Completion Criteria (KKM) of 75.

Table 2. Significant Increase in Affective Abilities

Level	Average Score	Ministry of Health Achieved
Initial conditions	50,67%	0%
Silkus 1	60%	20%
Cycle 2	97,33%	73%

Based on Table 2, there is a significant increase in the affective aspects of students from the initial conditions to the second cycle. The average score of students' affective abilities ininitial conditionsjust reach50,67%, and not a single student met the requirements Minimum Completion Criteria (KKM). This indicates that in the early stages, most students show less than optimal learning attitudes, such as lack of motivation, lack of discipline, low participation in class activities, and lack of empathy or cooperation with peers.

On the first cycle, there was an increase in the average score to 60%, with 20% of students starting to reach KKM. This increase, although not yet significant overall, indicates an initial positive shift in students' attitudes towards the learning process (Pujiati, 2022).These are likely due to a new approach that encourages students to be more active and involved. In this phase, students are likely to begin to show greater interest in participating in learning as well as become accustomed to methods that emphasise interaction, group work, or self-reflection. The most prominent changes occurred in the second cycle, where the average score increased drastically to reach 97,33%, and 73% of students managed to achieve KKM. This spike is real evidence that learning actions carried out reflectively and gradually can have a significant impact on the formation of positive attitudes in students during the learning process.In an affective context, this improvement reflects an increase in internal motivation, sense of responsibility, discipline, cooperation, and empathy between students. Students are not only physically present in learning but also emotionally and socially involved.

This condition shows that the learning approach used in classroom action is able to encourage students to be more aware of the importance of their role in learning. Strategies that provide space for active participation, discussion, and collaborative activities have helped students build positive social relationships and develop learning attitudes that support the achievement of academic goals. This increase also shows that a positive and supportive learning environment has a big role in shaping students' character and learning attitudes.

Overall, the trends shown in Table 1 provide an illustration that strengthening affective abilities through appropriate learning actions is very possible and can produce significant changes. With a learning style that not only emphasises cognitive aspects but also fosters attitudes and behaviours, students can grow into individuals who are not only intellectually intelligent but also emotionally and socially mature. This development is visualised in the following figure 2.

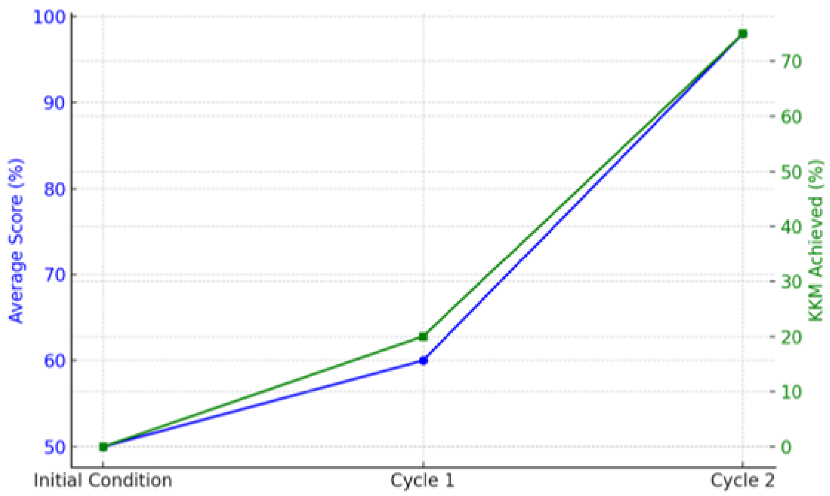

Figure 2. Average Increase in Student Empathy

Figure 2 showed a gradual increase in the average empathy of students, from 50.67% in the initial condition to 97.33% in cycle 2. A drastic increase also occurred in the achievement of KKM, from 0% to 73%, which indicates that most students began to show an empathetic attitude in the learning process. The success of this action cannot be separated from the characteristics of the approach used. RME encourages students to think through real contexts and situations that are relevant to everyday life, while PjBL invites students to solve problems through groupwork, collaboration, and empathetic communication in compiling and presenting projects. This combination creates a learning atmosphere that not only shapes academic competence but also the social character of students (Ibrohim, 2023).

With a planned, reflection-based, and responsive action strategy to students' needs, this study shows that the RME and PjBL approaches can effectively improve students' mathematical thinking skills and empathy. This success provides a real contribution to the innovation of humanistic, contextual, and participatory mathematics learning (Fiangga et al., 2023).

CONCLUSION

The implementation of Realistic Mathematics Education (RME) and Project-Based Learning (PjBL) approaches has proven effective in enhancing both mathematical thinking skills and empathy among students. Through two cycles of action research based on the Kemmis and McTaggart model, students showed significant improvements in cognitive and affective aspects. The average mathematical thinking score increased from 4,6 in the initial condition to 72,13 in Cycle II, with 73% of students meeting the Minimum Completion Criteria (KKM). Likewise, students' empathy improved from 50,67% to 97,33%, with 73% achieving the affective KKM. These findings indicate that the combination of RME and PjBL, when implemented in a structured and reflective manner, not only strengthens students' understanding of mathematical concepts but also develops their social awareness and empathy. This research contributes to the growing evidence that integrative and contextual learning models can holistically support student development.

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