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Building the Concept of Probability through Realistic Mathematics Education Based on Bruner's Stages in Elementary School

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A B S T R A C T

Understanding the concept of probability among elementary school students remains problematic because instruction tends to emphasize calculation procedures without building conceptual understanding. This condition indicates the need for an instructional approach that connects students' real-life experiences with abstract mathematical concepts. This study aimed to improve sixth-grade students' understanding of the concept of probability through the application of the Realistic Mathematics Education (RME) approach combined with Bruner's stages of learning. The study employed classroom action research following the Kemmis and McTaggart model, conducted in two cycles. Each cycle consisted of planning, action, observation, and reflection. The subjects were 28 students. Data were collected through observation of learning activities, a conceptual understanding test, and documentation, and were analyzed using quantitative and descriptive qualitative approaches. Learning was carried out through the exploration of random events close to students' experiences, which was then developed through visual representations and mathematical symbols. The results showed a gradual improvement in students' understanding of the concept of probability. The class mean score increased from 58.39 at baseline to 75.36 in Cycle I and reached 92.32 in Cycle II. This improvement was accompanied by an increase in the number of students meeting the learning mastery criterion, until all students achieved mastery at the end of the study. Thus, teaching probability through the RME approach combined with Bruner's stages can improve students' conceptual understanding..

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A R T I C L E I N F O

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1. Introduction

Mathematics at the elementary school level is not only oriented toward computational skills but also plays a role in developing the logical, critical, and systematic thinking that students need to face various real-life problems (Gusmarlia, 2025). Therefore, mathematics learning needs to be directed toward conceptual understanding rather than the mere use of formulas. Conceptual understanding enables students not only to obtain answers but also to understand the reasons behind them, connect different representations, and apply concepts in new situations. One of the mathematical topics that remains challenging for elementary school students is the concept of probability. Probability is abstract in nature because it concerns the possibility of an event, the relationship between an event and the whole set of possible outcomes, and the ability to interpret uncertainty. Although the Realistic Mathematics Education (RME) approach has been widely studied and shown to improve conceptual understanding in mathematics through meaningful learning experiences (Apriyanti et al., 2023; Dorisno et al., 2024), most studies still focus on general mathematical ability.

The concept of probability requires not only the ability to perform calculations but also the abilities to make predictions, compare possibilities, interpret results, and give reasons for an event (Kairuddin, 2025). In classroom practice, probability is often introduced through definitions, symbols, and solution steps before students develop a meaningful understanding of the concept. As a result, some students can follow problem-solving procedures but do not yet understand the relationship between an event and its underlying possibilities (Anwar, Rahmad, & Rahmawati, 2026). A similar condition was found in Class VIF of SD Negeri 001 Merdeka, Bandung. The pre-cycle assessment showed a mean score of only 58.39, and only 2 of 28 students (7.14%) reached the Learning Objective Achievement Criterion (Kriteria Ketuntasan Tujuan Pembelajaran, KKTP) of 78. The lowest achievement was found in the indicators of comparing probabilities (55.07) and constructing a probability scale (55.89), as students had not yet understood the relationship between events and the sample space and could not explain the mathematical reasons for their answers. Yet probability is closely related to everyday experiences, such as tossing coins, rolling dice, and randomly drawing objects. Batanero and Alvarez-Arroyo (2024) explained that the teaching of probability should be developed through a gradual process that connects students' informal thinking with the formal concept of probability. In line with this, English (2023) stated that students' understanding of probability can develop through activities such as conducting experiments, making predictions, testing results, creating representations, and providing explanations based on data.

These characteristics of probability highlight the importance of instruction that provides direct experience before students are guided toward formal mathematical concepts. At the elementary school level, students still need concrete experiences to build an understanding of abstract concepts. Nuryati and Darsinah (2021) explained that the cognitive development of elementary school children is closely related to direct experience and interaction with their environment, so learning should give students opportunities to engage in activities that they can observe and experience. Accordingly, probability instruction needs to be designed so that students can experience an event, observe the results, represent the information, and connect it with mathematical concepts.

One approach that suits these needs is Realistic Mathematics Education (RME). This approach is grounded in Freudenthal's idea that mathematics is a human activity, so mathematical concepts are not presented as rules to be memorized but are constructed

through a process of mathematization based on situations that are meaningful to students (Van den Heuvel-Panhuizen & Drijvers, 2020) (Afifah, dkk., 2024). Through RME, students can gradually connect real-life experiences with mathematical models. Various studies show that RME contributes positively to conceptual understanding in mathematics. Sari, Fadiana, and Sumadi (2024), supported by the meta-analysis of Juandi et al. (2022), found that the implementation of RME had a positive effect on students' conceptual understanding of mathematics through meaningful experiences. Nevertheless, the application of RME to probability in elementary schools, with attention to students' developmental stages, still needs to be developed.

To strengthen the transition from concrete experience to abstract understanding, this study integrates the RME approach with Bruner's theory. Bruner explained that learning proceeds through three stages: enactive, iconic, and symbolic (Bruner, 2017). Hatip and Setiawan (2021) explained that Bruner's stages of representation help learners construct knowledge gradually through direct activity, thinking, and representation. The integration of RME and Bruner's theory is relevant because RME provides a real-life context as the starting point of mathematization, while Bruner's theory helps guide the development of students' understanding toward formal mathematical concepts.

The novelty of this study lies in the integration of the RME approach with Bruner's stages in teaching the concept of probability to elementary school students. Unlike previous studies that mostly examined the effectiveness of RME on general mathematical ability, this study emphasizes how concrete experience gained through contextual activities can be developed into an understanding of probability through systematic Bruner stages. Based on the above explanation, this study aims to improve sixth-grade students' understanding of the concept of probability through the application of the RME approach integrated with Bruner's stages. This study is expected to contribute theoretically to the development of experience-based mathematics learning and to provide practical benefits for elementary school teachers in designing probability lessons that are more contextual, meaningful, and aligned with students' cognitive development.

2. Research Method

This study employed Classroom Action Research (CAR) with a qualitative approach supported by quantitative data. The study was conducted in mathematics lessons on the concept of probability in Class VIF of SD Negeri 001 Merdeka, Bandung, from 7 to 25 September 2026. The participants were all 28 students of Class VIF. All students in the class were involved because the intervention was intended to improve the learning process in the class where the study took place; therefore, the participants were selected using saturated sampling (total sampling) (Sugiyono, 2014). The study followed the Kemmis and McTaggart (1988) model, which consists of planning, action, observation, and reflection. It began with a pre-cycle diagnostic assessment to obtain an initial picture of students' understanding, followed by two action cycles. The reflection results of each cycle were used to determine the instructional improvements for the following cycle.

The instructional intervention was designed by combining the Realistic Mathematics Education (RME) approach with Bruner's stages of representation, namely enactive, iconic, and symbolic. Data were collected through tests, observation, and documentation. A written test was administered in the pre-cycle and at the end of each cycle to determine changes in students' understanding of the concept of probability. The test items were developed based on five indicators: the ability to explain the concept of probability, identify applications of

probability in everyday life, explain and construct a probability scale, compare the probability of events, and use probability information as a basis for making choices. Before being used in the pre-cycle and subsequent cycles, the test instrument was empirically validated through a try-out with sixth-grade students who had already studied probability and were not participants in the study. The validity of each item was tested by correlating the item score with the total score using the Pearson Product Moment correlation, and an item was considered valid when the calculated r value exceeded the critical r value at the 5% significance level (Arikunto, 2013). Subsequently, the reliability of the instrument was calculated using Cronbach's alpha, and the instrument was considered reliable when the coefficient was at least 0.70. Items that met the validity and reliability criteria were used as the research instrument, whereas items that did not were revised or discarded.

The test results were analyzed by scoring each answer according to a prepared rubric and then converting the scores into a 0–100 scale by comparing the obtained score with the maximum score. Changes in students' understanding were examined by comparing the mean scores and the percentage of mastery in the pre-cycle, Cycle I, and Cycle II, both overall and for each indicator of conceptual understanding. Individual mastery was determined based on the KKTP of 78, while classical mastery was calculated as the percentage of students who reached this score. The test, observation, and documentation data were analyzed interactively through data condensation, data display, and conclusion drawing and verification (Miles, Huberman, & Saldaña, 2014). The results from these various sources were compared to obtain a more complete picture of the learning process and the changes in students' understanding.

The study was considered successful if at least 75% of students obtained a score of at least 78 and the mean understanding of the concept of probability increased from the pre-cycle to the subsequent cycles. Improvement was also examined across the five predetermined indicators of conceptual understanding. In addition to these achievements, changes in students' engagement during learning and in their ability to connect concrete experience, visual representations, and mathematical symbols were taken into account in determining the success of the intervention.

3. Result and Discussion

This study aimed to improve sixth-grade students' understanding of the concept of probability through the application of the Realistic Mathematics Education (RME) approach integrated with Bruner's stages of representation. The study was conducted with 28 students in three stages, namely the pre-cycle, Cycle I, and Cycle II, using the Learning Objective Achievement Criterion (KKTP) of 78 as the indicator of success.

At baseline, before the intervention, students' understanding of the concept of probability was still low. The initial assessment showed that most students were not yet able to connect everyday experiences with the concept of probability in mathematical terms, particularly in understanding the relationship between events and the sample space. This was reflected in the pre-cycle results, which showed a class mean score of 58.39, with only 2 of the 28 students (7.14%) reaching the KKTP.

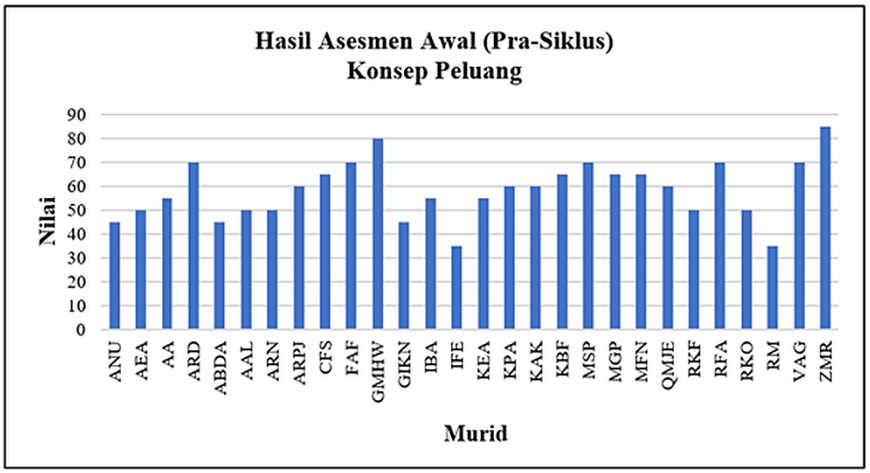


Figure 1. Results of the Pre-Cycle Assessment

The low results in the pre-cycle indicate that most students did not yet have an adequate understanding of the concept of probability. Based on these results, students still had difficulty understanding the relationship between an event and the sample space, determining the probability of an event, and explaining the mathematical reasons for their answers. As a result, most students scored below the KKTP because the concept of probability had not yet been understood. This condition shows that students still needed learning experiences that could help them connect real situations with formal mathematical concepts. Therefore, this study applied the RME approach based on Bruner's stages through contextual activities that enabled students to discover and construct the concept of probability gradually.

Learning began with experiments using coins, dice, and colored chocolate snack pieces that were familiar to students' daily lives, providing concrete experience before students were guided toward formal mathematics. Through these activities, students were given the opportunity to observe the possible outcomes of an event, present their observations, and connect them with the concept of probability. This is consistent with the RME principle that places real-life contexts as the starting point of mathematics learning so that students can mathematize, moving from informal situations toward formal concepts (Van den Heuvel-Panhuizen & Drijvers, 2020).



Figure 2. Learning Activity Using Concrete Objects

In the early stage of Cycle I, these experimental activities served as the enactive stage of the learning process. Students directly observed the results of tossing coins, rolling dice, and randomly drawing objects, and then recorded the results. This activity helped students build an initial understanding that every event has a certain possibility. However, observations during the lessons showed that some students still focused on the results obtained by their own group and had not yet fully understood the relationship between the experimental results and the concept of probability in mathematical terms.

Next, in the iconic stage, students were guided to present the experimental results in the form of tally marks, tables, and visual representations. The use of these representations helped students organize information and see patterns in the data they obtained. Nevertheless, some students still had difficulty connecting the frequency of an event with the theoretical probability based on the sample space.

The difficulties became more apparent when students began to be guided toward the symbolic stage, that is, expressing probability as a fraction or ratio. Some students were able to determine the probability value from their observations but did not yet fully understand that the fraction in probability represents the relationship between the number of favorable outcomes and the total number of possible outcomes. Therefore, the teacher provided guiding questions and reflective discussions to help students understand the mathematical meaning of probability before performing calculations.

These Cycle I findings show that the formation of mathematical concepts requires systematic stages of representation. This is consistent with Bruner's theory, which explains that learners' understanding develops through three stages of representation: enactive, iconic, and symbolic. The enactive stage allows learners to gain experience through direct action on objects, the iconic stage helps learners connect that experience through images or visual representations, and the symbolic stage enables learners to use mathematical language and symbols formally (Bruner, 1966).

The implementation of the intervention in Cycle I subsequently showed an improvement in students' understanding of the concept of probability compared with the baseline. The Cycle I assessment results are presented in the following figure.



Figure 3. Result of the Cycle I Assessment

The Cycle I assessment showed an improvement in students' understanding of the concept of probability. The class mean score increased from 58.39 in the pre-cycle to 75.36 in

Cycle I, while the number of students reaching the KKTP increased from 2 to 13. Although there was an improvement, the mastery percentage in Cycle I reached only 46.43%, which did not yet meet the study's success indicator of 75%.

Based on the reflection, some students still had difficulty connecting the experimental results with the formal concept of probability. Students were able to obtain and present the experimental data but did not yet fully understand that the probability of an event is determined by the relationship between the favorable outcomes and the total number of possible outcomes. This indicates that the transition from concrete experience to symbolic understanding still required more directed guidance.

These findings are in line with English (2023), who explained that teaching probability at the elementary level is not sufficient through experimental activities alone but needs to be followed by interpretation, the use of representations, and reasoning based on observations so that students can build probabilistic reasoning. In addition, Batanero and Alvarez-Arroyo (2024) emphasized that students' difficulties in understanding probability often arise when they cannot yet connect experimental results with theoretical concepts, so instruction needs to provide opportunities to compare empirical data with probability models.

Based on this reflection, the instruction in Cycle II was improved by providing more systematic guiding questions and strengthening discussion activities to help students interpret the experimental results. Students were also guided to make predictions before the experiment and to compare the actual results with their initial predictions. These improvements aimed to ensure that students not only obtained the probability value but also understood the mathematical reasons underlying that value. As an illustration of the improvement, the following are examples of guiding questions from the Cycle II Student Worksheet (LKM) for the activity of drawing colored chocolate snack pieces from a closed container holding 5 red, 3 blue, and 2 yellow pieces. Before the experiment, students were asked to make a prediction through the question, "Which colored piece do you think is most likely to be drawn? Why?" After recording the experimental data, students compared the results with their predictions through the question, "Is your experimental result the same as your prediction? What is different?" Next, to help students interpret the probability value, they were asked to write the probability of drawing a red piece as a fraction and then to explain the meaning of the numbers in the numerator and denominator through the question, "What do the numbers above and below the fraction mean?" These questions guided students not only to state the probability value but also to explain that the value describes the relationship between the number of favorable outcomes and the total number of possible outcomes.



Figure 4. Learning Activity of Completing the Student Worksheet with Guiding Questions

The improvements made in Cycle II led to a more optimal improvement in students' understanding of the concept of probability. A comparison of students' results at each stage of the study is presented in the following table.

Tabel 1. Comparison of Students' Understanding of the Concept of Probability (n = 28)

Stage	Mean	Min.	Max.	Median	Mastered ≥78	% Mastered	Not Yet Mastered	% Not Yet Mastered
Pre-cycle	58,39	35	85	60	2	7,14%	26	92,86%
Cycle I	75,36	50	100	75	13	46,43%	15	53,57%
Cycle II	92,32	80	100	92,5	28	100%	0	0%

This improvement shows that the instructional intervention was able to address the initial problem, namely students' low ability to understand the concept of probability mathematically. The change in achievement was evident not only in students' ability to obtain correct answers but also in the development of their ability to understand the relationship among events, the sample space, and probability values. To examine the development of conceptual understanding more specifically, the next analysis was conducted based on the five indicators of understanding the concept of probability used in this study.

Table 2. Comparison of Assessment Results by Indicator

Indicator	Pre-Cycle	Cycle I	Cycle II
Explaining the concept of probability	60,25	78,14	93,86
Identifying applications of probability	62,36	77,14	92,64
Constructing a probability scale	55,89	72,86	92,39
Comparing probabilities	55,07	72,32	91,79
Using probability information	58,39	76,32	90,93
Overall Mean	**58,39**	**75,36**	**92,32**

Based on Table 2, all indicators of understanding the concept of probability showed positive development after the implementation of learning based on Realistic Mathematics Education (RME) integrated with Bruner's stages of representation. The improvement across all indicators shows that the intervention affected not only students' ability to obtain calculation results but also their ability to understand, represent, and use the concept of probability in various situations.

In the pre-cycle, students' abilities were limited, particularly in aspects related to probabilistic reasoning, such as understanding the relationships among possible outcomes and comparing probabilities. This suggests that some students still viewed probability as the result of a calculation rather than as a mathematical relationship between an event and the whole set of possible outcomes. After the intervention, the improvement across all indicators shows that students began to build a more conceptual understanding of probability.

This development shows that the use of real-life contexts in learning helped students connect everyday experiences with formal mathematical concepts. Through experiments and the representation of data, students had opportunities to observe an event, organize information, and draw mathematical relationships from their observations. This finding is consistent with the characteristics of RME, which places context as the starting point of learning

so that students can mathematize, moving from informal experience toward formal concepts (Van den Heuvel-Panhuizen & Drijvers, 2020).

In addition, the improvement in the conceptual understanding indicators shows that Bruner's stages of representation supported the change in students' ways of thinking. Direct experience through concrete activities helped students understand probability phenomena, while the use of tables and mathematical symbols helped them develop their understanding toward a more abstract form. Thus, the integration of RME and Bruner's representations created a learning process that enabled students not only to know how to determine probability but also to understand the mathematical reasons behind the concept.

The findings of this study reinforce previous research showing that RME-based learning can improve conceptual understanding in mathematics through students' engagement in meaningful activities. Nurrahmah, Paloloang, and Sukayasa (2026), in a meta-analysis, showed that the implementation of RME had a positive effect on students' mathematical conceptual understanding in Indonesia. This is because RME gives students opportunities to build connections among real experiences, mathematical models, and formal concepts through the process of mathematization. These results are in line with the present study, in which the improvement in understanding of probability was evident not only in the increase in mean scores but also in the development of students' ability to interpret probability information and use it in meaningful contexts.

In the context of probability learning, the findings of this study also support the view that understanding of probability cannot be built merely by providing formulas. Learning probability requires experience in facing uncertain situations, conducting experiments, interpreting results, and connecting empirical data with theoretical concepts. English (2023) explained that the development of elementary students' probabilistic reasoning can be supported through activities such as making predictions, conducting experiments on random events, using representations, and explaining reasons based on observations. This process corresponds to the learning stages in the present study, in which students experienced probability situations through experiments, presented their observations, compared possibilities, and then formalized the concept of probability in mathematical form.

In addition to supporting the improvement in learning outcomes, this study also shows that the reflection process in classroom action research plays an important role in the success of the intervention. The improvement in Cycle II did not occur merely because the lesson was repeated but because of the improvements made based on the difficulties found in Cycle I. In Cycle I, the main obstacle was students' ability to connect experimental results with the formal concept of probability. Therefore, the intervention in Cycle II focused on strengthening data interpretation, providing guiding questions, and developing students' ability to give mathematical reasons. These improvements show that instruction responsive to students' conceptual difficulties can produce a more optimal change in understanding.

The use of RME combined with Bruner's representations in this study provides a picture of how the concept of probability can be built gradually at the elementary school level. RME provides contexts and meaningful experiences that enable students to mathematize, while Bruner's stages provide a developmental structure of representations from concrete experience to mathematical symbols. Thus, the results of this study show that probability instruction should not be directed only at the ability to calculate probability values but should also develop students' ability to understand the meaning of probability, explain relationships among concepts, and use probability information in simple decision making.

Although this study shows positive improvement, several limitations need to be noted. The study was conducted in one class with a limited number of students, so the results cannot yet be generalized to all characteristics of elementary school students. In addition, the study focused only on probability, so the application of the integration of RME and Bruner's representations to other mathematical topics still requires further investigation. The study also did not use a comparison group or inferential statistical analysis, so the results mainly describe changes in students' abilities within the context of the instructional intervention implemented.

Overall, the results show that the integration of the Realistic Mathematics Education approach with Bruner's stages of representation was able to improve sixth-grade students' understanding of the concept of probability. This improvement was evident in the change in learning outcomes from the pre-cycle to Cycle II and in the development of students' abilities on each indicator of conceptual understanding. These findings show that mathematics instruction that combines real-life experience, the use of representations, and reflection can help students understand abstract concepts more deeply. Therefore, the RME approach based on Bruner's representations can serve as an alternative instructional strategy for developing conceptual understanding of mathematics in elementary schools.

4. Conclusion

The application of the Realistic Mathematics Education (RME) approach integrated with Bruner's stages of representation was shown to improve sixth-grade students' understanding of the concept of probability. This improvement was evident in the gradual development of students' learning outcomes from the pre-cycle to Cycle II, as well as in the achievement of the study's success indicator. The integration of RME and Bruner's representations helped students understand probability by connecting real-life experience, mathematical representations, and formal concepts, so that the understanding formed was oriented not only toward calculation procedures but also toward the mathematical meaning of an event.

Based on the findings, teachers are advised to use instructional approaches that are context-based and employ gradual representations, especially for mathematics topics that are abstract in nature. Schools can support the implementation of innovative instruction by developing teachers' competencies. Future research may apply RME based on Bruner's representations to other mathematical topics or on a broader scale to enrich the study of how conceptual understanding in mathematics develops..

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