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Designing Probability Learning with Volleyball Context through a Problem-Based Learning Approach in Vocational Schools

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ABSTRACT

This study is based on the importance of applied, contextual, and relevant mathematics learning that meets the needs of the workplace and entrepreneurship. This study aims to develop a mathematics learning design for compound probability events by applying a Problem-Based Learning (PBL) model contextualized with volleyball. This study employs a design research method consisting of three stages: preliminary design, teaching experiment, and retrospective analysis, conducted at SMKN 1 Rengasdengklok, involving two classes: a small class with 12 students and a large class with 35 students from class X TJKT 1. Data was collected by recording classroom activities and group work, collecting students' work, administering achievement tests, and interviewing them. This study demonstrates that volleyball as a contextual medium fosters improved conceptual understanding of compound probability among vocational high school students. The retrospective analysis of the learning process showed that through activities linking probability to volleyball games, students developed understanding through experiences such as calculating the probability of a successful serve or the ball entering or exiting the court, facilitated through Student Worksheets with a volleyball context. Based on this research, it is recommended that the Realistic Mathematics Education (RME) approach with a volleyball context be applied in probability learning at vocational high schools.

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1. INTRODUCTION

Mathematics is important in developing students' logical, critical, creative, and analytical thinking skills. However, mathematics education in vocational high schools (SMK) still faces challenges regarding low motivation and conceptual understanding among students. Many students perceive mathematics as a confusing and challenging subject [1] and often fail to see its relevance to their future needs. This situation is exacerbated by the continued dominance of one-sided lecture-based teaching methods that fail to engage students actively [2]. However, vocational school graduates are expected to possess logical thinking skills, work quickly and accurately, and be able to collaborate in groups.

Most vocational school graduates are directed to enter the workforce or become entrepreneurs immediately after graduation. Based on available data, vocational school graduates choose various paths after graduation: employment, further education, and entrepreneurship. Most vocational school graduates need to be equipped with practical skills, such as conceptual understanding, logic, precision, and teamwork, which are essential for the workforce and entrepreneurship. The probability material in vocational high schools can develop the ability to predict how likely they are to pass a job selection based on the skills they possess. Probability is part of mathematics, and its applications can be found in various daily activities because it is used to estimate the likelihood of an event occurring [3].

An important skill that must be developed in learning opportunities is mathematical reasoning, such as recognizing patterns, constructing logical arguments, drawing conclusions, and generalizing concepts. This skill is very much needed in work and entrepreneurship for data-based decision making. Unfortunately, various studies have found that the mathematical reasoning skills of vocational high school students are still low [4], [5], [6]. Therefore, students need learning experiences related to their daily lives to understand probability concepts better.

One approach that can address this need is Realistic Mathematics Education (RME). RME emphasizes the importance of linking mathematical concepts to real-life contexts familiar to students in their daily activities. Through this approach, students actively build their understanding through contextual, exploratory, and reflective activities. This approach is highly suitable for vocational high school students who require concrete, meaningful, and practical learning. One relevant and familiar context for students is volleyball. Many vocational high school students are familiar with or directly involved in this sport, making it a potential context for bridging mathematical concepts, particularly in probability-related topics. For example, through volleyball game scenarios, students can learn about the probability of a successful serve, winning combinations, or match data analysis. Previous research supports the use of sports contexts in mathematics education, such as futsal [7], [8], karate [9], and badminton [10]. Specifically, volleyball is an effective context for introducing concepts of probability and data analysis [11].

Although many studies have proven the effectiveness of RME and PBL in improving mathematical reasoning skills, few studies explicitly link probability learning to the context of sports, especially volleyball, at the vocational high school level. This gap indicates the need to develop probability learning designs that integrate contextual approaches with real-world activities closely related to students. The Realistic Mathematics Education (RME) approach can be combined with Problem-Based Learning (PBL). This collaboration will strengthen the learning process because RME provides a real-world context closely related to students' lives, while PBL offers a systematic framework for problem-solving steps. By integrating these two approaches, students learn mathematics in a relevant context (such as volleyball) and are trained to identify problems, formulate solution strategies, perform calculations, and present their results. This process encourages them to think critically, creatively, and reflectively about their steps. Research findings indicate that the RME and PBL learning models significantly enhance students' mathematical reasoning abilities compared to direct instruction [12].

Problem-based learning models have been proven to create a learning environment that requires students to be actively involved, as they must work together to solve a problem [13]. Using real-life situations as a learning context, as RME offers, further develops students' critical thinking and problem-solving skills, increasing their motivation to participate in the learning process actively. Thus, mathematics education is not solely focused on the outcome but also emphasizes strengthening the reasoning process, an important foundation for their readiness to enter the workforce or entrepreneurship. By combining the RME approach, the PBL model, and the volleyball game context, mathematics learning, particularly compound probability events, can be designed to be enjoyable, contextual, and relevant to the workforce, entrepreneurship, and further education. This aligns with the policy direction of “Work, Continue, and Entrepreneurship,” which is today's foundation for vocational high school education.

2. METHOD

This study uses a qualitative approach by applying the design research method. This method examines and articulates learning trajectories, learning process theories, and steps to support mathematics learning. According to Gravemeijer and Eerde [14], design research consists of three stages, namely (1) preparing for the experiment, (2) teaching the experiment in the classroom, and (3) retrospective analysis.

This study was conducted at a public vocational school in Karawang Regency in the 2025/2026 academic year. The research subjects were 47 tenth-grade students with expertise in Computer and Network Engineering (TKJ), divided into two groups: 12 students for the preliminary experiment and 35 students for the main experiment.

The first stage is known as Preparing for the experiment. In this phase, researchers conduct literature studies on learning materials, namely reflection, using the Problem-Based Learning (PBL) model. The aim is to develop initial assumptions about students' strategies in learning. In addition, researchers also coordinate with teachers to understand the classroom situation, analyze needs and curriculum, and design schedules and methods to be used. According to Fanani [15], learning objective analysis is a careful and critical review of all components in formulating learning objectives, beginning with reformulating these objectives. This analysis helps provide an overview of the conditions between learning components, which becomes the basis for designing and developing learning and determining the supporting tools needed. The Hypothetical Learning Trajectory (HLT) and other learning tools, such as Student Worksheets, learning media, and evaluation questions, are also developed at this stage. The HLT serves as a guide for developing the implementation guidelines for learning.

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The second stage is the design experiment, which is divided into two parts: the preliminary teaching experiment (pilot experiment) and the main teaching experiment. The preliminary experiment is conducted on a small group of students to test the HLT that has been developed, to collect data that will be used to revise and refine the HLT before it is applied in the next stage of the experimental learning process [16]. At this stage, 12 students were involved, and the researcher directly acted as the teacher, implementing the designed learning approach. Following this stage, the main teaching experiment was conducted, which involved analyzing data from the preliminary experiment [17]. This teaching experiment involved 35 students grouped into seven groups.

The third stage is retrospective analysis, a process by researchers to evaluate whether the learning design in HLT has been effective and beneficial [18]. At this stage, researchers examine the experiment's results, including documentation of learning activities, student work, and test results. The ultimate goal is to improve and refine the previously designed HLT.

The research instruments include student activity observation sheets, interview guidelines, and probability learning outcome tests. The learning support instrument is a student worksheet on probability in volleyball. The observation sheet records student activities and engagement during the learning process, while the interview guidelines explore students' responses, opinions, and learning experiences after participating in the learning process. The Student Worksheets and learning outcome tests are used to assess the development of students' mathematical abilities based on the designed learning trajectory. Data is collected through video recordings of classroom activities and group work, collecting students' work, administering learning outcome tests, and interviewing students. Data analysis in this study uses retrospective techniques. Data analysis was conducted by the researcher in collaboration with experts and mathematics teachers to enhance the validity of this study.

Data was collected through video recordings during the learning process, documentation of group work results, learning outcome tests, and individual and group student interviews. To ensure the validity and reliability of the data, source and method triangulation techniques were used, and cross-checking was conducted with partner teachers and mathematics education experts. The data analysis process involved researchers, experts, and mathematics teachers to enhance the credibility of the findings.

From a research ethics perspective, researchers obtained permission from the school principal and approval from subject teachers. All students and parents were explained the research objectives and procedures, and consent to participate was collected through written permission letters. The confidentiality of participants' identities was maintained throughout the research process and reporting.

3. RESULTS AND DISCUSSION

3.1. Research Preparation

Researchers coordinated with teachers to understand the classroom situation, analyze needs and curriculum, and design schedules and methods to be used. The needs and curriculum analysis stage showed that many students had negative views of mathematics, with scores below the Learning Objective Achievement Criteria. They prefer practical, contextual, discussion-based, and simulation-based learning over abstract approaches. This aligns with the Merdeka Curriculum Phase E Learning Outcomes requirements for probability material, which mandates that students not only understand concepts but also be able to apply them to real-world situations. The analysis also considers the policy direction of Work, Continue, and Entrepreneurship, given that most vocational school graduates immediately enter the workforce or become entrepreneurs. Therefore, it was concluded that the design of mathematics learning in probability material needs to be contextual, applicable, and support logical thinking, problem-solving, accuracy, and teamwork skills to meet the needs of students, the curriculum, and the workforce.

Next, the researchers conducted a literature study on learning materials, namely reflection using the Problem-Based Learning (PBL) model. The results of this study served as the basis for designing an initial solution in the form of a learning design tailored to the characteristics of vocational high school students. The literature reviewed, such as Fauzan [19] and Zulkardi and Putri [20], supported the selection of the PMRI and PBL combination because it has been proven effective in enhancing conceptual understanding and active learning in mathematics. The books of Trianto [21] and Suparman [22] also provide practical guidelines for developing the learning sequence and assessment instruments. As a result, a RME-PBL-based learning design was obtained that is relevant, contextual, and supports the needs of vocational high school students.

Determining objectives, models, approaches, methods, and learning media was conducted concerning the Merdeka Curriculum implemented at SMKN 1 Rengasdengklok. As a result, the objective was formulated so that students could determine the probability of multiple events in the context of volleyball. The Problem-Based Learning (PBL) model was chosen because it effectively encourages students to actively solve problems and collaborate, while the RME approach was used to connect probability concepts with their real-life experiences. The methods used include group discussions and presentations, which aim to develop mathematical communication skills while enhancing students' confidence in expressing their opinions, and have proven to increase learning engagement. Student Worksheets and context-based volleyball game videos complement the learning design in Table 1.

Table 1. Initial Design of Mathematics Learning Design

Learning Design Steps	Activities
Orienting students to problems	Students observe contextual issues surrounding volleyball matches presented by teachers through worksheets, stimulating them to think critically and reason.
Organizing students for learning	Students are grouped heterogeneously and given worksheets; this encourages cooperation, communication, and discussion among students.
Guiding individual or group investigations.	Peserta didik melakukan eksplorasi dari sumber

Learning Design Steps	Activities
	literatur seperti buku penunjang, *google* atau www.youtube.com., dan mengolah informasi melalui aktivitas berbasis 4C. Ini meningkatkan literasi, kreativitas, dan keterampilan bernalar kritis.
Developing and presenting results	Group representatives report on the results of their work, accompanied by responses from other groups; this activity trains communication, responsibility, cooperation, and critical thinking skills.
Analysis and evaluation of problem-solving processes	Teachers provide clarification, feedback, and reinforcement of concepts to reflect the learning process and correct misconceptions.
The Overall Steps of Problem-Based Learning (PBL)	The learning activity begins with presenting contextual problems, such as a volleyball match, to stimulate students' curiosity and critical thinking. Next, students are divided into heterogeneous groups to discuss and solve problems using worksheets. They then investigate information from various sources independently or in groups, developing creativity, communication, and critical thinking skills. After that, each group presents its findings and discusses them together. Finally, the teacher provides feedback and clarification to reinforce understanding and correct misconceptions.

After creating the initial draft, the researchers held discussions with expert lecturers to obtain advice on the feasibility of the learning design. The following are some suggestions from experts and colleagues, as well as follow-up actions related to the drafts created in Tables 2 and 3. The mathematics learning expert referred to is a mathematics education lecturer with expertise in integrating sports into mathematics learning, and the colleague is a mathematics teacher at a secondary school in Bekasi Regency.

Table 2. Suggestions from Expert Lecturers and Follow-up Actions

Recommendations	Follow-up
The instructions in the WORKSHEET are unclear and confusing for students, especially when it comes to understanding the context of the questions.	Improvements were made by clarifying work instructions, adding examples of steps to complete the task, and providing context relevant to the students' experiences (e.g., volleyball).
The evaluation questions do not yet reflect indicators of mathematical reasoning ability and are not accompanied by appropriate scoring.	The questions were revised to align with mathematical reasoning indicators, such as identifying patterns, making generalizations, and constructing logical arguments. An analytical scoring rubric accompanied each question.

Table 3. Peer Recommendations and Follow-up Actions

Recommendations	Follow-up
During the Apperception activity, the questions can be stated in detail.	Perception is improved by adding a provocative question: "Have you ever thought about how likely your team is to win?" "In every volleyball match, many decisions are made. Who serves? Who is good at smashing? Furthermore, how often does your team score points? It turns out that all of that can be calculated using mathematics?" "Ready to be a strategy coach? Let us calculate the odds using"
In motivational activities, the benefits can be written in detail.	The teacher explains the importance of the material to be studied (Probability) in daily activities using the context of volleyball, which helps us estimate the likelihood of an event occurring. For example, we can predict where the opponent will direct the ball in a volleyball game. Similarly, in real life, we often make probability-based decisions, such as choosing the right time to travel to avoid getting caught in the rain. Learning about probability teaches us to think logically and critically and make more rational decisions.
The closing activities are described in detail.	1. The teacher reinforces the material related to the probability of compound events, which helps us understand how two or more events can occur simultaneously or alternately. For example, we can calculate the probability of a player successfully serving the ball and their team immediately scoring a point in volleyball, the probability of the ball entering the opponent's area, or the opponent making a mistake. By understanding the concepts of addition and multiplication in compound probability, we can analyze game strategies more logically and mathematically. This concept is also helpful in many other real-life situations, such as estimating the probability of passing a selection process and being hired by a specific company. 2. Teachers conduct learning evaluations through tests based on material that has been taught previously. 3. The teacher appoints a student to lead the prayer to reinforce religious values. 4. The teacher concludes the lesson by saying goodbye.

3.2 Results of Teaching Experiment: Small-Scale Test

The first experiment was conducted on a small group of students to test the initial design that had been revised based on expert and peer advice. This trial was conducted on a small group of 10th-grade students. The activity began with an apperception in the form of a volleyball match video, as an effort to build context and foster students' interest in learning. Next, the students completed the Student Worksheet, which was designed using the RME approach and the Problem-Based Learning (PBL) model. The Student Worksheet was designed to help students relate events in volleyball to the concept of probability, particularly the probability of compound events. In its implementation, the Spin Wheel media was used to randomly determine the groups presenting their discussion results in front of the class. This media aimed to create a more engaging and interactive learning environment and encourage the participation of all groups in the presentation activity. The design of the Student Worksheet aligns with the research [23], which shows that the use of

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Student Worksheets can promote systematic and collaborative understanding. Table 4 shows the predictions and responses of students from the small-class trial.

Table 4. Predictions and Responses of Students in a Small Class

Activities	Predicting Student Responses	Student Responses
The teacher provides the context of volleyball to introduce the probability of compound events.	Students are interested and begin to associate the game with the concept of probability.	The students seemed enthusiastic, with some immediately asking how the odds were calculated from the game results.
The teacher asks students to mention the possible outcomes of two volleyball serves.	Students name all possible combinations of outcomes (in/out, points/balls out, etc.).	Some students mentioned several possibilities, while others were confused and needed further guidance.
Students are asked to calculate the probability of compound events using the addition and multiplication rules.	Students try to use the formulas they have been taught.	Some students immediately applied the formula but were still confused about independent and dependent events.
Group discussion about each group's results	Students actively discuss and compare their results.	The discussion went well, but some groups were less active and needed facilitation from the teacher.
Reflection at the end of learning	Students can explain the concept of compound probability.	Most students can explain it in their own words, while some still repeat the teacher's terms without deep understanding.

Challenges during the small-scale trial process were still encountered, despite students appearing enthusiastic while watching the apersepsi video and using the Spin Wheel application. Some students struggled to understand the instructions on the Student Worksheet. Additionally, some students could not accurately connect the context of the volleyball game with the concept of probability, particularly in identifying types of probability and their applications. The allocation of time for group discussions was also deemed suboptimal. The observation results recommended that the researcher integrate interactive quizzes into the learning process to assess students' understanding and provide more interactive and engaging learning experiences. These findings served as the basis for the researcher to revise the learning design. Improvements focused on rewriting the instructions on the Student Worksheet to make them more transparent, simplifying the numbers in the questions, and adjusting the time allocation to make the learning process more effective. These revisions ensure that the developed learning design aligns with the Merdeka Curriculum and supports students' understanding of probability concepts in a more concrete, meaningful, and contextual manner. Notes on the improvements and follow-up actions are shown in Table 5.

Table 5. Notes on Learning Design Improvements in Small Class Trials and Follow-up

Repair Notes	Follow-up
Adding visual media or concrete aids when explaining the concept of compound probability	Teachers will use or create short videos simulating volleyball games that show events (e.g., serves, smashes, blocks, and ball drops). They will then calculate the probability of combining these events using the rules of addition or multiplication of probabilities.
Need to increase student participation in group discussions	Teachers will divide groups based on ability heterogeneity and provide more structured discussion guidelines.
The discussion time was too long, so the reflection time was limited.	Teachers will allocate time more proportionally between discussion and reflection.
Unclear initial instructions confused students.	Teachers will revise assignment instructions using simple sentences and provide examples first.
It is necessary to strengthen the concept before applying it to the context of volleyball.	The teacher will provide a brief theoretical introduction or basic exercises before entering into the game context.

3.3 Results of Teaching Experiment: Large-Scale Testing

The researcher conducted a larger trial after revising the learning design based on notes from the small-scale trial. The following learning experiment was conducted in another 10th-grade class without involvement in the previous activities. There were 35 students involved. This trial aimed to see the extent to which the revised learning design could be applied in a large class and to measure its effectiveness in helping students understand the material on probability.

This trial showed that the learning design with a volleyball context helped students understand the material. The class felt more lively and responsive. Even some students who were previously passive began to show a high level of interest in learning activities. Interaction between students was more dynamic, and the classroom atmosphere was conducive to collaborative learning. This reinforces the finding that contextual and interactive learning can enhance students' motivation and active engagement in understanding the material. The average student score also reached 80, indicating that most students have met or even exceeded the Learning Objective Achievement Criteria.

3.4. Discussion

During the small-scale trial, the material used was compound probability using student worksheets based on the context of volleyball. During the small-scale trial, the average score of students in completing individual problems on the Student Worksheet was 75, while the average score for group problem-solving was 81. Thus, the overall average score for completing the Student Worksheet reached 78. Considering the learning objective for students to determine the probability of compound events using addition and multiplication in the context of volleyball, the students' achievement has exceeded the Learning Objective Achievement Criteria of SMKN 1 Rengasdengklok, which is 78. Although the results indicate success, several important notes for improvement were identified. For example, at the initial stage of learning, some students struggled to understand the difference between mutually exclusive and non-mutually exclusive events.

The initial Student Worksheet did not include visualizations or explicit clues about the relationships between these events. Therefore, the design of the Student Worksheet was revised by adding visual illustrations of volleyball games and comparison tables of events to help students understand the situations concretely.

During implementation in large classes, the revised Student Worksheets were presented in the context of conversations between students while discussing volleyball game strategies. In this implementation, the average score for the Student Worksheet completed in groups was 88, while the average score for individual evaluations after the lesson was 80. This means that the results met the school's Learning Objective Achievement Criteria and demonstrated that students could apply the concept of probability in a real-world context.

Students in large classes also appeared to be more active in asking questions and discussing with their groupmates. This was reinforced by the observation results, which showed that students were actively involved in learning activities. When asked by the teacher or researcher, students could answer well and did not hesitate to present the results of their group discussions in front of the class. Based on the researcher's observations and assessment sheets, out of 35 students, more than 80% of students showed active participation in group discussions and when asked to answer the teacher's questions. In group activities, almost all groups were seen to work together optimally to complete the questions in the Student Worksheet.

During individual evaluations, students achieved an average score of 80, with some students achieving the maximum score and only a few scoring below the minimum. This indicates that the learning design was used effectively in group work and impacted individual understanding.

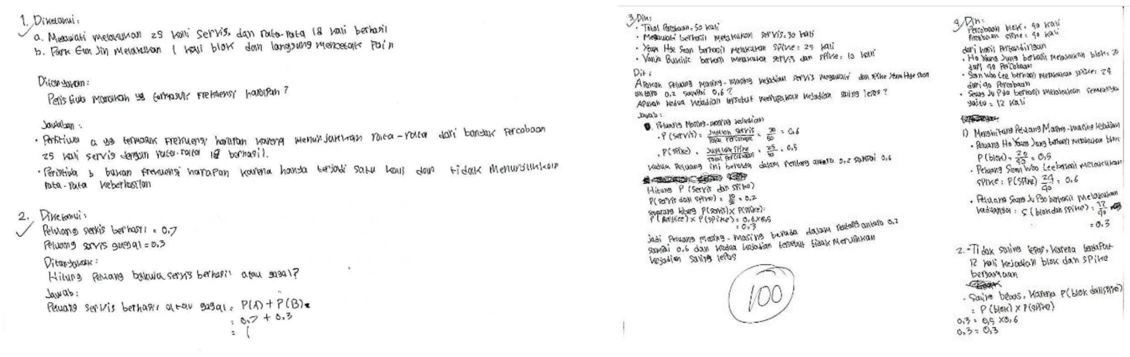

Figure 1. Results of the Evaluation Questions with the Highest Scores

Figure 1 shows that the students correctly answered all questions, scoring 100 points. Each answer reflects good mathematical reasoning skills, following the indicators in each question [24]. This shows that applying the RME approach and the PBL model successfully supported the optimal achievement of student competencies.

In question 1, students were able to make assumptions by identifying contextual information about Megawati's serve and Park Eun Jin's block. This ability reflects the success of the RME approach, which prioritises conceptual understanding through real contexts (in this case, volleyball) and the application of the PBL model, which encourages students to actively observe and formulate problems from everyday situations.

Question 2 demonstrates that students can perform mathematical manipulations correctly, calculating probabilities accurately (P = 0.7 + 0.3 = 1). This indicates that problem-based learning has encouraged students to think logically and systematically, in line with the problem-solving stages in PBL, and demonstrates the success of RME in helping students connect mathematical symbols with relevant contextual meanings.

In question 3, students demonstrated their ability to compile evidence and provide logical reasoning by referring to data: service probability 30/50 = 0.6 and spike probability 25/50 = 0.5. The students concluded that the two events are not mutually exclusive because of an overlap (evidence: Vanja performed both). This performance reflects the principle of guided reinvention in RME, which involves building concepts through exploration and discussion, and underscores the effectiveness of PBL in developing critical thinking and argumentative skills through group activities.

Question 4 shows that students can conclude from mathematical statements by stating complete probability information, calculating the probabilities of blocks and spikes, and concluding the properties of independence and interdependence based on the data (0.5 × 0.6 = 0.3). This understanding shows that students memorize formulas and can construct meaningful knowledge, as emphasized in RME. Additionally, the skills of drawing conclusions and presenting discussion results in groups are also outcomes of the PBL syntax, which emphasizes collaborative investigation and reflection.

Thus, students not only successfully achieved the learning objectives, namely determining the probability of compound events using addition and multiplication in the context of volleyball, but also demonstrated high performance in mathematical reasoning skills, which were developed through the effective integration of the RME approach and the PBL model.

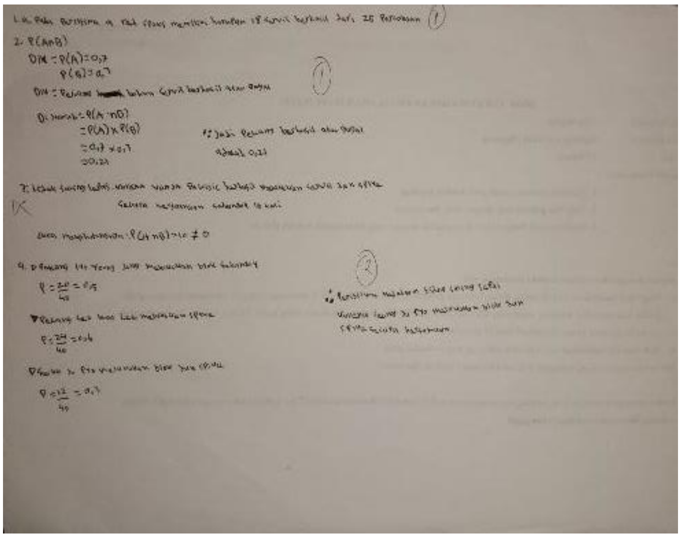

Figure 2. Results of the Evaluation Questions with the Lowest Scores

Figure 2 shows that students with low final scores could not answer all questions correctly. The answers indicate that students' mathematical reasoning skills have not

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developed optimally in each question indicator, according to Vebrian et al. [24], as explained below: Question 1 was unable to make a complete guess. They only mentioned some information about Megawati's serve but did not explicitly include Park Eun Jin's block. The explanation did not demonstrate a complete understanding of the problem, and the students did not fully explain the events included in the expected frequency and those not included. The reasons given were general and lacked depth.

Question 2 shows an error in performing mathematical manipulation. The student did not identify the probability of a successful and failed serve. The calculation of probability $P = 0.7 + 0.3 = 1$ was not written, and the conclusion that the total probability is one also did not appear in the answer. This shows that the student still has difficulty understanding the basic principles of compound probability.

Question 3 was unable to compile evidence and provide accurate reasoning. The student did not calculate the probabilities from the available data, such as $30/50=0.6$ or $25/50=0.5$, and did not explain the range of probability values. The conclusion regarding whether the events were independent was also not provided, and there was no evidence or logical reasoning in the answer.

Question 4 does not provide complete information about probabilities. Calculations such as: probability of block = 0.5; probability of spike = 0.6; or block ∩ spike = 0.3 are not found. Additionally, the student did not conclude whether the events were independent. The explanation is largely irrelevant and does not demonstrate an understanding of compound event probabilities.

The low performance of these students indicates that they have not fully utilized the potential of the Realistic Mathematics Education (RME) approach and the Problem-Based Learning (PBL) model applied in the learning process. In principle, RME aims to enable students to build conceptual understanding through meaningful real-world contexts, such as volleyball games. However, for these students, the provided context has not been fully utilized as a foundation for independently reconstructing the concept of probability. This may occur because students are not yet accustomed to using context as a tool for mathematical thinking.

Meanwhile, from the PBL perspective, the students did not demonstrate their maximum ability to formulate and solve problems systematically. However, PBL is designed to train students to solve real-world problems through discussion, exploration, and collaboration. Answers that lack data, calculations, and logical reasoning indicate that students' critical and reflective thinking skills still need to be improved. Thus, although the learning strategy has adopted the RME and PBL approaches, its implementation still depends on students' cognitive readiness and the intensity of teacher guidance in facilitating students' thinking processes.

Thus, based on the average scores of students exceeding the Learning Objective Achievement Criteria of 80 and supported by observation results showing active student engagement during the learning process, it can be concluded that the learning design of multiple event probability using a Problem-Based Learning model based on the context of volleyball successfully improved students' conceptual understanding significantly. Students demonstrated the ability to connect probability concepts with real-life situations, engage in more systematic mathematical reasoning, and present arguments more clearly. This success is also reflected in increased learning interest, marked by active participation in group discussions, enthusiasm for solving contextual problems, and growing confidence when presenting ideas in front of the class. These findings align with the views of Mentari and Syarifuddin [25], who state that context-based learning strengthens cognitive understanding and positively impacts affective aspects, such as motivation, self-confidence, and student engagement in learning.

4. CONCLUSION

This study concludes that developing mathematics learning design on compound probability using the RME approach and the Problem-Based Learning (PBL) model with a volleyball game context has proven effective in improving conceptual understanding, mathematical reasoning, and active engagement of 10th-grade vocational school students. The average student score reached 80, exceeding the school's Learning Objective Achievement Criteria, and most students could complete tasks on time in a conducive group discussion environment. The familiar volleyball game context created an enjoyable yet meaningful learning experience, as it helped students connect probability concepts with real-life situations.

This learning model differs from conventional designs as it integrates the contextual approach characteristic of RME with the problem-solving strategies characteristic of PBL, and directly links them to activities close to the lives of vocational high school students. This advantage demonstrates that mathematics learning can be designed to be more applicable and relevant to the profile of vocational graduates, especially in preparing them to face the challenges of the workplace and entrepreneurship.

These findings open up opportunities for further development, such as using alternative contexts appropriate to the characteristics of specific regions or majors and exploring digital adaptation through interactive platforms or Augmented Reality (AR)-based media. This study has limitations in terms of location and sample size, being restricted to a single school, so further research is recommended to be conducted on a broader scale to test the scalability and effectiveness of this learning design in various conditions and other vocational education settings.

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