Exploring Pre-service Teachers' Cognitive Process in Solving Probability Problems Related to the Maritime Context of the Riau Archipelago

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Abstract. This research aims to investigate how pre-service teachers think through the process of solving the probability problem related to the daily life context in the maritime region of the Riau Archipelago. The research methods used descriptive qualitative approach. The research subject is a pre-service teacher who have previously taken the Introduction to Mathematical Statistics course in the Mathematics Education program at UMRAH. Testing and interviews used as data collection methods. Qualitative data analysis carried out in three stages, reduction, data presentation, and drawing conclusions. The results show that there are four phases how the subject process the information to folmulate solution, formulate the travel routes through two different ports in Batam City, identifying an itinerary of possible events, calculate the number of samples space, and calculate the probability of event. The results show that the subjects were unable to accurately indentify the sample space based on context, which had an impact on the subjects' failure to produce the right solution. The maritime context of the Riau Archipelago used was part of the subject's prior knowledge. The knowledge helps them understand the information presented and construct an idea of how to formulate the itinerary.

1 Introduction

Based on Indonesian Law Number 20 of 2003, education is defined as a conscious, deliberate, and organized effort to develop the potential of learners through the learning process within formal and non-formal educational institutions. This development involves acquiring knowledge and technology, fostering attitudes and morals, and various life skills such as communication, collaboration, critical thinking, and problem-solving skills.

The ability to solve problems is one of the 21st-century competencies that learners must possess [1]. Problem-solving skills have become essential in facing various challenges in the era of globalization. Problem-solving skills are needed when learners encounter

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problems, from academic challenges to social relationships, both in school and within the community. Furthermore, problem-solving abilities can significantly enhance a learner's capability to improve his living situation and future career prospects. Various studies have been conducted to seek solutions for enhancing learners' thinking abilities. These studies investigate factors influencing problem-solving abilities [1–4], effective learning models to develop problem-solving skills [5–7], effective learning to promote problem-solving skills [8] and more.

The ability to solve problems is a crucial learning outcome in mathematics education [9,10]. Through the study of mathematics, learners are expected to develop logical, critical, and systematic thinking to solve various problems relevant to the discipline. Additionally, learners are expected to be able to provide explanations and arguments to support the solutions they create. Promoting these goals can be achieved by engaging learners in constructing their knowledge concepts and actively solving various problems relevant to the material. This is supported by previous studies indicating that instructional interventions positively impact the development of learners' problem-solving abilities [11,12].

To leverage their knowledge in solving everyday problems, learners should perceive the subjects they study as part of the phenomena around them. One approach to achieve this is linking the learned knowledge to the local context in which the learner resides. According to Gazali [9], the local context is students' prior knowledge, which can strengthen their cognitive structures and help them understand how new knowledge relates to their experiences. This enables learners to see new knowledge as meaningful, making the learning experiences more significant, as proposed by Ausubel [9]. Moreover, integrating local culture into the learning content is believed to enhance effectiveness in understanding the material.

Various things and activity related to maritime is the local context for students residing in the Riau Islands. In terminology, maritime encompasses the sea surface, a fertile ground for various activities like tourism, shipping, and services [10]. Maritime context based on the Indonesian dictionary, refers to everything related to the sea and its surroundings, including aspects such as marine resources, their utilization, cultivation of marine flora and fauna, maritime transportation, maritime transportation industry, and more. The maritime context can serve as a framework for evaluating students' abilities to apply their knowledge to solve daily problems.

Problem-solving is a complex cognitive process that demands learners to understand the problems, and select and apply relevant scientific concepts to solve them [4]. Learners need systematic and logical thinking to comprehend, analyze, and interpret information in the problems. The logical thinking process is also essential for planning, executing, and evaluating the solutions they devise. According to Polya, learners go through four stages in the problem-solving process: understanding the problem, formulating the strategy plan, implementing the strategy, and reviewing [15,16]. Previous studies show that these four stages occur linearly during the problem-solving process.

Research on how learners think during problem-solving is still limited. Previous studies have typically focused on analyzing the achievement of problem-solving skill indicators [17–19] or analyzing learners' errors when solving problems [15,20,21]. Moreover, similar research rarely employs the maritime context as a problem to be solved by learners, especially among pre-service teachers. Therefore, this study aims to explore the thinking process of prospective teachers when solving probability occurrence problems related to the maritime context of the Riau Archipelago. Thus, the research aims to describe how pre-service teachers think when solving probability occurrence problems associated with the maritime context of the Riau Archipelago.

2 Methods

This research is a descriptive study aimed at explaining the thought process of prospective teacher students in solving probability occurrence cases related to the maritime context in the Riau Islands Archipelago. Sugiyono [6] stated that descriptive research using a qualitative approach is a method used to obtain broader and more in-depth meanings regarding a research object. Hence, this study utilizes a qualitative approach to gain a more comprehensive and profound understanding of the thought processes involved.

The subject of the research is a pre-service teacher student in the Mathematics Education program at Raja Ali Haji Maritime University. These subjects have previously studied probability concepts in the Introduction to Statistics course. The probability topic covers combinatorial concepts, the probability of an event, and its applications in various contextual problems in everyday life.

Data collection techniques in this research involve tests and interviews. The test method aims to obtain information regarding the subjects' thinking processes, represented as written solutions. The interview technique is used to delve into how the subjects think when generate the solutions. The probing questions seek to explore information more deeply. According to Guba and Lincoln, probing questions are used for clarifying previous information, seeking further explanation from the respondent, or desiring the respondent to assess or respond to something [23].

The test instrument contains probability problems within the maritime context of the Riau Islands. The maritime context focuses on the route and schedule of travel using sea transportation from Tanjungpinang City to Tanjung Balai Karimun. The detailed probability problems used are presented in **Fig. 1**.

Mr. Ahmad plans to travel from Tanjungpinang to Tanjung Balai Karimun on Monday to attend an event at Hotel Holiday Karimun. To be present at the venue before the event begins, he must arrive at the Tanjung Balai Karimun Harbor no later than 14:00. The ship transportation scedules on Monday from Sri Bintan Pura Port at Tanjungpinang City, Harbor Bay Port at Batam City to Tanjung, and Sekupang Port at Batam City, are presented below.

Sri Bintan Pura Port, Tanjungpinang City – Telaga Punggur Port, Batam City Ship: Mv Oceanna Duration: 60 Minutes Depart:		Harbor Bay Port, Batam City – Tanjung Balai Karimun Port Ship: Mv Oceanna Duration: 90 Minutes Depart:	Sekupang Port, Batam City – Tanjung Balai Karimun Port Ship: Dumai Express Duration: 75 Minutes Depart:
07:30	13:15	07:00	07:00
08:15	14:00	09:00	07:30
09:00	15:00	11:00	09:30
10:00	15:45	13:00	12:30
10:45	16:00	15:00	14:30
11:30	17:00	17:00	
12:30			

He also learned that the journey from Telaga Punggur Port to Harbor Bay by car takes 45 minutes while arriving at Sekupang Port takes 50 minutes:

Based on the information above, calculate the probability of an event where Mr. Ahmad could arrive at the venue before the event starts!

Fig.1. The probability problem related to the maritime context of the Riau Archipelago

Solving the given problem requires the subject to be able to define the sample space of events within the context of the question. All possible travel plans that could lead to reaching Tanjung Balai Karimun on Monday are defined as the population of events. The desired sample events represent travel plans that could lead to arrival before 14:00. The subject should interpret the available information to identify all potential travel plans on

Monday. The classical probability formulas could be used to determine the likelihood of the event occurring.

The data analysis technique used in this research is qualitative analysis, as expressed by Miles and Huberman in Sugiyono (2020), which involves data reduction, data display, and conclusion drawing. Data reduction is carried out by mapping the stages of the resolution process, interpreting data, and classifying the cognitive processes performed, to providing a clear overview of the data. The results are then presented as a brief description, allowing the researcher to conclude the subjects' thought processes in problem-solving.

In the initial stage, subjects were asked to write solutions to probability occurrence problems involving the maritime context of the Riau Archipelago. The subjects' answer sheets were then analyzed to gain an initial insight into the subjects' thought processes based on the established work stages. Subsequently, interviews were conducted to extract information on the subjects' thinking processes when addressing the problems. The interview results were then analyzed and linked to the results of the written test answers to obtain comprehensive information regarding the subjects' thought processes in solving probability problems within the maritime context of the Riau Archipelago.

3 Results and Discussion

The content of the problem-solving task addressed in this research pertains to a real-world problem occurring in the Riau Archipelago. The issue concerns sea transportation involving three different islands in the Riau Archipelago, Bintan Island, Batam Island, and Karimun Besar Island. Solving real-world problems is crucial to becoming accustomed to applying their knowledge to resolve relevant everyday problems [11]. In the following explanation, the code S1 refers to the research subject.

Base on S1's response on the answer sheet he does not explicitly indicate whether he understood the presented information. However, during the interview, S1 explained that he could interpret the given information to understand the problem. He re-read the question, pointed out what he considered important information, and then interpreted information based on context.

> "Mr. Ahmad was going to attend an event at the Holiday Karimun Hotel. … Based on the presented information, Mr. Ahmad is going to Tanjung Balai Karimun by ship on Monday where he should arrive at Tanjung Balai Karimun harbor before 14.00 so he could present at the venue before the event starts. We were asked to calculate the probability that Mr. Ahmad could arrive at Tanjung Balai Karimun harbor before 14.00."

S1's response indicates that he could interpret the information in the question to build their understanding of the problem being discussed. He understood that the question referred to travel plans from Tanjungpinang City to Tanjung Balai Karimun using maritime transportation. He comprehended that "arrive at the venue before the event starts" meant arriving at Tanjung Balai Karimun harbor before 14:00. The information above indicates that he engaged in the process of selecting and processing relevant information to interpret the question's intent.

3.1 Formulate the travel route

To solve the given problem, the first step S1 took was formulating the travel route from Tanjungpinang City to Tanjung Balai Karimun. He began by identifying relevant information which is the travel routes connecting two different ports mentioned in the problem. In **Fig. 2**., five travel routes and their corresponding travel durations were identified by S1. These five routes will be used to create a new travel route from Tanjungpinang City to Tanjung Balai Karimun.

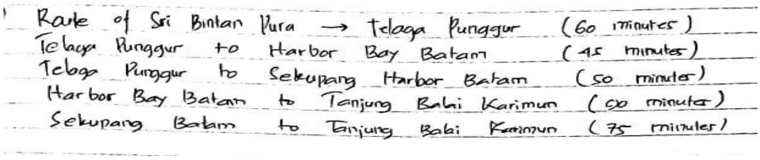

Fig. 2. Five routes identified by S1

Next, S1 studied the connections between the four travel routes. He noticed that there were two optional routes from Batam City to Tanjung Balai Karimun that could be selected to form the travel route. "… we only need to select one to formulate the travel route from Tanjungpinang City to Tanjung Balai Karimun."

S1 assigned codes A, B, C, D, and E to the five ports in sequence. This is done to simplify the process of analyzing existing information relationships. Next, he created a diagram illustrating the connections between the five ports to form the travel route from port A to port E. Based on **Fig. 3**., S1 successfully formulated two travel routes: route A – B – C – E and route A – B – D – E. S1 expressed confidence that both routes he devised were correct.

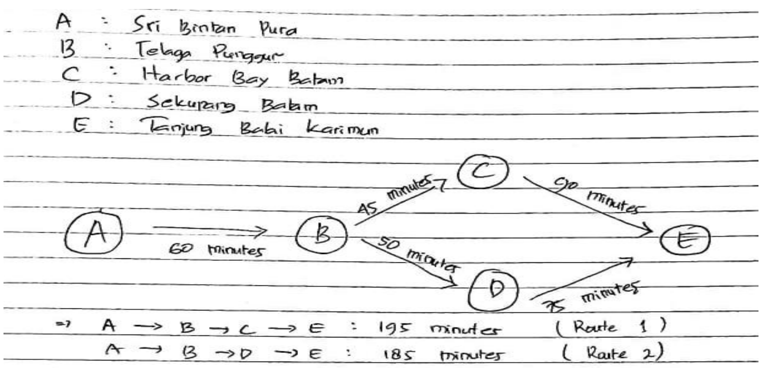

Fig. 3. Two routes connecting Tanjungpinang City to Tanjung Balai Karimun

In the process of formulating the travel route from Tanjungpinang City to Tanjung Balai Karimun, the subject engaged in the cognitive process of selecting and analyzing relevant information. Selecting and analyzing relevant information is necessary to gain a clear picture of the specific goal [24]. The analyzing process in this case studying the connections between relevant pieces of information to construct the travel route. Additionally, S1 engaged in the cognitive process of assessing information to ensure that the travel routes he created were accurate.

3.2 Identifying an itinerary of possible events

The next step involved identifying all possible travel itineraries to arrive at Tanjung Balai Karimun Port before 14:00. To understand how the routes and departure schedules work, S1 tried to relate the information in the problem with their knowledge of choosing the correct travel plan among the Riau Islands. Drawing from experiences connecting more than two islands in a day, S1 understood that the departure time from the port of the first island would influence the departure time from the port of the second island. The departure time from the port of the second island could be chosen from the departure schedule after arriving at that port.

S1 explained that he first searched for all possible itineraries through routes A – B – C – E. He began by selecting the departure time from Sri Bintan Pura Port at 07:30. He estimated the arrival time at Telaga Punggur Port by adding the departure time from Sri Bintan with a travel duration of 60 minutes. Next, he calculated the arrival time at Harbor Bay Port by adding the arrival time at Telaga Punggur with a car travel duration of 45 minutes to Harbor Bay Port. The departure time from Harbor Bay to Tanjung Balai Karimun Port was estimated by adding the expected departure time plus a travel duration of 90 minutes. If it was estimated that the arrival time at Tanjung Balai Karimun Port was before 14:00, then the time schedule was chosen as the departure time. The same process was repeated to examine the travel plan from Sri Bintan Pura Port for schedules after 07:30.

After obtaining all the itineraries through routes A – B – C – E, S1 then process the same procedure to determine possible itineraries to arrive at Tanjung Balai Karimun Port before 14:00 via the second route, A – B – D – E. Figure 4 shows a set of the itinerary for each route.

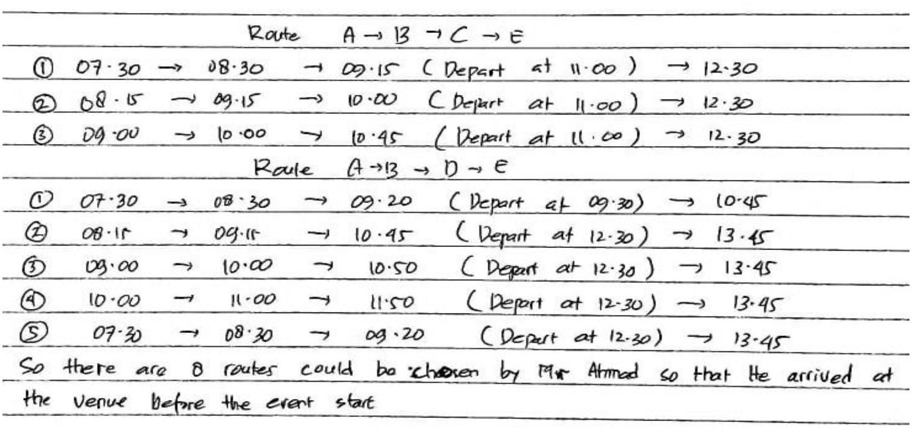
Route A → B → C → E
① 07·30 → 08·30 → 09·15 (Depart at 11·00) → 12·30
② 08·15 → 09·15 → 10·00 (Depart at 11·00) → 12·30
③ 09·00 → 10·00 → 10·45 (Depart at 11·00) → 12·30
Route A → B → D → E
① 07·30 → 08·30 → 09·20 (Depart at 09·30) → 10·45
② 08·15 → 09·15 → 10·45 (Depart at 12·30) → 13·45
③ 09·00 → 10·00 → 10·50 (Depart at 12·30) → 13·45
④ 10·00 → 11·00 → 11·50 (Depart at 12·30) → 13·45
⑤ 07·30 → 08·30 → 09·20 (Depart at 12·30) → 13·45
So there are 8 routes could be chosen by Mr Ahmad so that He arrived at the venue before the event start

Fig.4. Itinerary that satisfies as a sample space of events

Based on **Fig. 4**., there are eight itineraries available on both travel routes to arrive at Port E, Tanjung Balai Karimun, before 14:00. This means there are eight itineraries that Mr. Ahmad could choose to arrive at Tanjung Balai Karimun Port before 14:00.

During the phase of seeking possible itineraries to arrive at Tanjung Balai Karimun Port before 14:00, subject S1 engaged in the cognitive process of arithmetic operations, calculating departure times and travel durations to determine arrival times at the destination port. He also conducted the cognitive process of assessing information by evaluating the alignment of departure times from the first port, arrival times at the second port, and departure times for the next port. He then synthesized feasible travel designs. Another Cognitive process of making an assessment was when S1 evaluates the suitability of the itinerary to meet the criteria of a sample event. Making an assessment, matching related information, and synthesizing information were cognitive processes present when solving a problem [25].

3.3 Calculating the number of sample space

Based on the interview, S1 explained that all possible travel routes on both paths represent the sample space of events. The number of sample spaces can be calculated by multiplication operation between the number of available departure schedules at the ports along the route. He derived this method based on experience with similar problem-solving.

> "Based on the problem I've encountered before, if there are m ways to travel on route 1 and n ways on the second route, then the total ways to travel on routes 1 and 2 simultaneously are m x n ways. Using the same method, the total sample space is obtained by adding the number of ways to travel through A-B-C-E and A-B-D-E routes..."

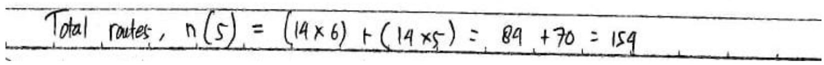

Fig.5. Multiplication operation to calculate the number of sample space

Based on the calculations shown in **Fig. 5**., the number of sample spaces is 154 itineraries.

S1 engaged in the cognitive process of connecting new information with old information to conceptualize the idea of how to calculate the number of the sample space. Then he interpreted it within the context of the problem. Subsequently, he performed arithmetic operations to calculate the total number of elements in the sample space.

3.4 Calculating the probability of events

S1 mentioned that having obtained the number of the sample space and the sample event he proceeded directly to use the classical probability formula to calculate the probability of the desired event.

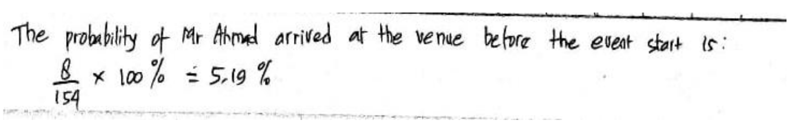

Fig.6. The calculating process of the probability of the event

Based on **Fig. 6**., the probability of Mr. Ahmad arriving at Tanjung Balai Karimun Port before 14:00 is 5.19%. At this stage, the subject engaged in the cognitive process of connecting the information with probability concepts. He chose the classical probability formula to determine the probability of the desired event. Subsequently, he performed arithmetic operations to calculate the probability of Mr. Ahmad arriving at Tanjung Balai Karimun Port before 14:00.

Upon evaluating the subject's thinking process and the results, the researcher suspected a thinking process in determining the sample space of events. Therefore, the researcher asked the subject to review the meaning of the sample space as the total possible travel plans on Monday from Tanjungpinang City to Tanjung Balai Karimun. Were the multiplication results accurate in indicating the number of possible travel routes? To investigate this, the researcher asked the subject to identify other itineraries that could be part of the sample space. As a result, he found there were several impossible itineraries. For instance, departing at 07:30 from Sri Bintan Pura Port was neither possible to select a departure schedule from Harbor Bay Port at 07:00 nor from Sekupang Port at 07:00.

Consequently, there was an error in identifying itineraries occurred on Monday as the sample space of events. As a result, the subject failed to provide the correct probability as requested by the problem.

4 Conclusion

Based on the evaluation results, it can be concluded that the subject goes through four stages in solving probability problems related to maritime transportation in the Riau Islands region. These four stages include the first stage is interpreting information and formulating travel routes from Tanjungpinang City to Tanjung Balai Karimun, the second stage is identifying an itinerary of possible events where Mr. Ahmad arrives at Tanjung Balai Karimun before 14:00, the third stage is calculating the number of sample space of events, and the fourth stage is calculating the probability using the classical probability formula.

In the first stage, the subject engaged in the cognitive process of identifying inter-island routes, analyzing the connections between these routes to form a new unified route connecting Tanjungpinang City to Tanjung Balai Karimun, formulating and evaluating the resulting routes. In the second stage, the subject performed the cognitive process of arithmetic operations to calculate time, assess information, formulate itineraries, and assess the itineraries that satisfy sample events. In the third stage, the subject engaged in the cognitive process of connecting and interpreting old information with new information and performed arithmetic operations to calculate the number of elements in the sample space. In the fourth stage, the subject employed relevant classical probability concepts and performed arithmetic operations to determine the probability of Mr. Ahmad arriving at Tanjung Balai Karimun Port before 14:00. Based on the evaluation result, the subject makes an error in determining the elements of the event sample space. As a result, the subject failed to provide the right solution.

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