Probability problem-solving: the role of probabilistic thinking of undergraduate mathematics education students with feminine female gender and field-independent cognitive style

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ABSTRACT

Introduction. Problem-solving involves tackling non-routine tasks without prior knowledge of the necessary schemes or algorithms, making it a key focus in mathematics education, particularly in probability. Cognitive differences, including those between male and female students, can influence behaviors and outcomes, highlighting the need to develop students' thinking potential. This study explores the role of probabilistic thinking and the Field-Independent cognitive style in female undergraduate mathematics students' probability problem-solving. It aims to support mathematics education by helping teachers and curriculum developers address related challenges, fostering effective learning both on and off campus to enhance educational professionalism.

Study participants and methods. The study involved 4th semester students (12 total: 11 females, 1 male) and 6th semester students (15 total: 13 females, 2 males). A non-probability, purposive sampling technique was used, selecting samples based on predefined criteria. The selection process included a math ability test using valid and reliable UTBK SBMPTN questions, known for their standardized results. Additional instruments, such as Gender Questionnaires and GEFT tests, categorized students by gender and cognitive style. From 27 students, 20 were identified as feminine with a Field-Independent cognitive style. Data were collected via a probability problem-solving test, analyzed quantitatively, and followed by a qualitative analysis of one representative student, coded MPI, using a sequential explanatory mixed methods design.

Results. Quantitative testing of 20 feminine female students with a Field-Independent cognitive style showed significant results, with multiple regression analysis yielding $F = 23.429$ and a significance of $0.000 < 0.05$. This confirms the important role of probabilistic thinking in solving probability problems. Qualitatively, in-depth interviews were conducted with one representative student, MPI, selected based on predefined criteria. In the Polya-based problem-solving test, MPI understood the problem, devised a plan, and used the binomial distribution formula directly without applying the combination formula. While MPI did not rewrite the final answer, the interview revealed that she had accurately reviewed her work, from given data to the probability value obtained.

Conclusion. Quantitative analysis showed a significant role of probabilistic thinking and field-independent cognitive style in the probability problem-solving skills of feminine female undergraduate mathematics education students. Qualitative analysis, through interviews based on Polya's stages, provided deeper insights. During the interview, after completing the probability test, MPI struggled to apply the combination formula before using the binomial distribution. However, in the "looking back" stage, MPI successfully wrote the final answer. These findings highlight the need to develop probabilistic thinking in higher education to support student learning outcomes

KEYWORDS

Probability problem-solving, probabilistic thinking undergraduate mathematics student female feminine, field-independent cognitive style

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INTRODUCTION

Curricula and national standards in Australia, Canada, India, Ireland, Scotland, Singapore, South Africa, Sweden, and the USA now stress the importance of competencies such as problem-solving, reasoning, and the ability to connect concepts to each other [1]. It has been shown that a problem-solving approach to teaching and learning mathematics and a certain degree of struggle are important elements in attaining this wider perspective on mathematics [1]. However, this fact is dissimilar from the quality of mathematics education in Indonesia, which is still lagging behind compared to education in many other countries in the world. This is evident from the achievements of Indonesian representatives in international events such as the IMO (International Mathematics Olympiad) in which the country is only ranked last. Besides that, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) on Education for All Global Monitoring Report (EFA-GMR) illustrates that the education for all Development Index (EDI) of Indonesia in 2014 was ranked 57 out of 115 total countries (UNESCO, 2010). PISA, O. (2012) also reported that Indonesia has been in the second lowest position from a total of 64 countries. Therefore, disciplines in mathematics and science (MS) with their focus on sustainability, innovation, and technology are often viewed as a key to the future [2]. Thus, MS higher educations are expected to prepare a skilled and knowledgeable workforce [3].

According by Rott et al. [4], mathematics education focuses on logical methods to describe the problem-solving process that follows newer patterns or variants of the model. Rott et al. [4] and Säfström et al. [5], mentioned that in the phase of solving mathematical problems, several descriptive phases models of the problem-solving process are known, namely Dewey's problem-solving phase (1910); Polya's problem-solving phase (1945); Mason, Burton & Stacey's problem-solving phase (1982); Schooenfeld's problem-solving phase (1985); Wilson et al's problem-solving phase (1993); and Yimer & Ellerton's problem-solving phase (2010). The descriptive phase model of Polya's problem-solving process is a problem-solving model/strategy that is in line with what the researcher wants, where problem-solving is very important, this is because the ability used is not only to solve non-routine problems but also requires skills that can be trained to individuals [6].

Schoenfeld states that problem-solving works on non-routine tasks with no prior learned schemes or algorithms designed to solve them [4]. To solve a modelling problem, students have to understand a given real-world situation, structure and simplify the information to set up a mathematical model, work mathematically, interpret their results at the end of the solution process, and validate their results with regard to the real-world situation [7]. Problem-solving is an important aspect of doing mathematics [8]. Therefore, it has been the focus of attention of researchers for decades. The process of solving mathematical problems in this study used Polya's steps, namely understanding the problem, devising a plan to solve the problem, carrying out the plan, and looking back [9]. From Polya's steps, it can be shown that problem-solving is a high-order thinking skill (HOTS). Not only at the school level, but HOTS is also important if applied in higher education because having HOTS skills enables students to think critically, research, solve problems, make decisions, have good character, be able to construct explanations, and make decisions in complex situations. This is in line with a study undertaken by Heong et al. [10] at Tun Hussein Onn University, Malaysia which states that students who have HOTS can learn better, develop their performance, reduce their weaknesses, and develop the ability to investigate, conduct experiments, design, and conclude.

Therefore, the importance of HOTS in probabilistic thinking for undergraduate mathematics education students as prospective teachers can have a global impact on the success of the thinking process in the nuances of probability so that: 1) can significantly act with a higher level of certainty in complex and unpredictable situations; 2) can never know the future with exact precision, but the role of probabilistic thinking is very useful to evaluate how the world is likely to look so that we can strategize effectively. Stated probabilistic thinking is the attempt to predict the probability of a situation occurring by using mathematical and logical tools [11]. In this universe, probabilistic is infinitely complex; probabilistic thinking helps determine the most likely outcomes. The importance of probabilistic thinking can also be seen in the success of students in solving probability problems. Several research findings from Sari et al. [12]; Zorzos and Avgerinos [13]; Hokor [14]; Shodiqin et al. [15]; and Rodríguez-Alveal et al. [16] have highlighted that in probabilistic thinking, students can develop their good probabilistic thinking intuitively, classically, and continuously. They can also develop conceptual and argumentative ideas in solving probability problems.

Individual differences that need to be a concern is cognitive style. It is because cognitive style is one dimension of individual differences that are considered very relevant in teaching probability. A recent study by Kozhevnikov [17], states that cognitive style is an activity of thinking, knowing, and processing information, while individual characteristics in responding, processing, storing, thinking, and using information to respond to a task or various types of environmental situations are also considered. In addition, a person's cognitive style can affect the way perception of learning, making decisions, communicating to processing information. In addition, strategies in decision-making, especially when solving problems, are influenced by cognitive style. In the teaching and learning process, the psychological condition of students also greatly affects the success of learning. Therefore, the study attempted to discuss further about cognitive style based on psychological aspects, namely Field-Independent (FI). Field-Independent cognitive style according by Riding et al. [18], aims to measure the extent to which an individual uses an analysis that is contrary to the global/general way of experiencing the environment. This cognitive style is defined as a measure of personality, not a measure of ability. The cognitive style of FI prospective teachers can affect the personality dimensions that influence attitudes and processes in solving math problems [19]. Probabilistic thinking is thought to have a relationship and influence with the cognitive style of each individual. The relationship and influence are in line with the statement by Kozhevnikov [17] that learning involves complex thinking activities that are influenced by several factors such as individual circumstances, prior knowledge, attitudes, individual views, content, and the way of presentation. This is similar to research conducted by Wright and Phillips [20], that stated, to control probabilistic thinking, both cognitive styles can be explored. A probabilistic thinker is said to take a probabilistic view when faced with uncertainty, appreciate information that can suppress uncertainty, thus allowing an individual to develop a cognitive style that is consistent with his thinking, as well as gender. Santrcok [21] outlines that gender roles are a set of expectations that determine how women or men should think, act and feel. Furthermore, Santrcok [21] added that gender type refers to the acquisition of traditional masculine or feminine roles. As for the current research, it focused on the feminine female gender. female students were able to create new ways of being authentic math learners compared to male students [22].

THEORETICAL BACKGROUND

1. Probabilistic thinking in probability problem-solving

Weinstein and Mayer [23] suggested that thinking is a cognitive activity that occurs in a person's mental or mind, not visible but can be inferred based on observed behavior. Information processing theory is a cognitive theory of learning that describes the processing, storage, and retrieval of knowledge in the mind [24]. Cognitive strategies are considered learner activities that are intended to influence how the learner processes information [25]. It means that informations processing theory is a cognitive theory of learning that describes the processing, storage, and retrieval of knowledge from the human mind so that probabilistic thinking does not escape the existence of thinking activities as a person's mental activity in solving probability problems. Probabilistic thinking involves understanding how models are used to simulate random phenomena, how data are produced to estimate probabilities, and how symmetry and other properties of the situation enable the determination of probabilities [26]. It explains that the student correctly executed the completion step meaning that probabilistic thinking involves understanding how models are used to simulate random phenomena, how data are produced to estimate probabilities, and how symmetry and other properties of the situation enable the determination of probabilities. Thus, probabilistic thinking has no correlation between possible outcomes and what happened before [27]. However, probabilistic thinking is influenced by the nature and structure of a particular task or problem situation [28].

In solving problems related to probability, indicators are needed as a measuring tool that will be achieved in this study. Besides that, indicators are also quantitative and qualitative measures that can describe the level of achievement as designed. This is in line with the statement by Fayers and Hand [29] that the indicator emphasizes the variable being measured, and the changes that occur as a result of the variable being measured. In connection with this, in determining the solution of probability problems in the distribution of opportunities, indicators are needed that can measure student achievement, especially in binomial distribution material. Walpole et al. [30] in their book explain that in the material of probability distribution, the things that are important in solving the problem are the existence of a random experiment, determining the sample space, categorizing the event, to solving the probability of an event. This statement is by several research results in solving a probability problem through random experiments, determining the sample space to calculate the probability of an event [31]. In addition, Konold [32] considers randomness as a label used to associate many concepts such as experiment, sample space, event, and probability of an event. In this sense, the word randomness refers to a collection of mathematical concepts and procedures, that can be applied based on certain situations, so the construction of 4 probabilistic thinking from Jones adapted by researchers into 4 main constructs of probabilistic thinking in solving probability problems on discrete probability distributions, especially binomial distributions including random experiments, sample space, events, and probability of an event.

Related to the nature and structure of a particular task or problem situation, there are several strategies/ways used by students in solving probability problems. Strategies are viewed as goal-directed procedures that facilitate both problem solution and acquisition of domain-specific knowledge [33]. Furthermore, they are also seen as potentially conscious and controllable. This shows that students correctly executed the solution steps, meaning that strategies are viewed as goal-directed procedures that facilitate both problem-solving and acquisition of domain-specific knowledge. Strategies are also seen as potentially conscious and controllable. The following strategies/ways that students might use in solving probability problems are using Polya problem-solving cycle as shown in [Figure 1].

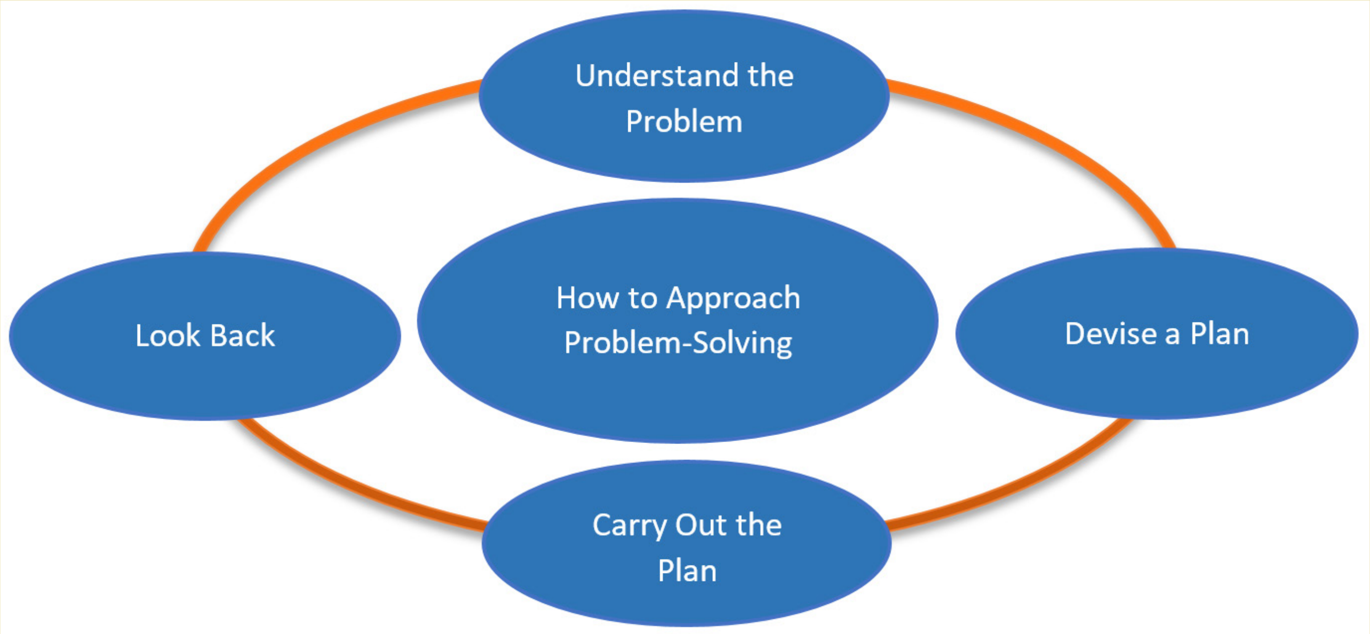


Figure 1 Polya’s problem-solving cycle

Polya's problem-solving cycle starts from 1) understanding the problem, of which Polya states that “The student should understand the problem”. This shows that the first thing a person must do in solving a problem is to understand the problem. Once the problem is understood, the problem must be analyzed. 2) Devising a plan is the next step, and Polya states that the question “do you know a related problem?” serves as a point of departure. This shows that a person should find the relationship between known and unknown data from the given problem. Furthermore, Polya in this step states “look at the unknown and try to think of a familiar problem having the same or similar unknown”. The quote shows that a person can find the relationship between known data and unknown data. 3) Carrying out the plan is next whereas in this step, Polya states that one must “check each step”. This shows that one must check each step of solving a given problem one by one. 4) The last step is looking back, whereas in this step, Polya asks “can you check the result? can you check the argument?”. The quote shows that a person needs to check the correctness of the results obtained, re-check what is asked, and use the correct reasoning in solving the problem. Furthermore, Polya in this step said “can you derive the result differently?”.

2. The role of probabilistic thinking female gender and field-independent cognitive style in solving math problems on probability

Furthermore, the role of cognitive style in the learning process refers to the views of experts on the dimensions of cognitive style. Skills and attitudes need to be application in learning will determine the success in a diverse and complex world [34]. Someone who has FI cognitive style has the characteristics of psychological differentiation, perceives analytically, can separate stimuli in context although perception is weak when the context changes and can improve through various situations. A person with FI cognitive style also usually uses internal factors as direction in processing information, performing tasks not sequentially, and being more efficient working alone. This type of person also generally not easily distracted and not easily confused so that it can solve complex problems. FI subjects are better able to read or identify problems than FD subjects. The ability to recognize this problem is one of the indicators of probabilistic thinking in solving probability problems, namely, students can immediately write and compile arguments regarding alternatives that must be met in solving probability problems. FI students tend to have good probabilistic thinking skills [17]. In addition to cognitive style, each person has different abilities in solving probability problems. In addition to the ability factor, it is also influenced by various other factors that cause the emergence of these differences, namely the difference in physical form between the male brain and the female brain. Some research findings explain that women are still underrepresented in the field of mathematics, due to the way mathematics is traditionally taught, but in teaching proportional thinking to grade 6 girls. It was found that the role of their preferred learning style as well as the use of integrated and authentic tasks makes the subjects enjoy the task and are enthusiastic in developing a stronger disposition to learn mathematics than boys [35]. In another study [36], females performed better than male students in collaborative problem-solving in all countries, and gender equality at the societal level played a larger role in explaining the differences in achievement between countries in areas where the gender gap favored girls such as collaborative problem solving, while another article [37] noted that there is a difference between the use of the 'guessing' strategy by female and male students when solving math problems. Female students use the 'guessing' method more often than male students, and the 'guessing' method used by male students cannot solve the problem.

RESEARCH METHODS

1. Research model

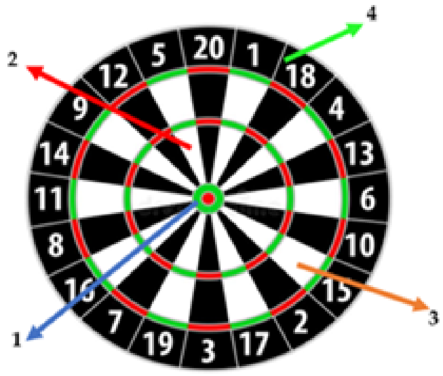
The approach used is mixed-method, which is research that combines two forms of approaches, namely quantitative and qualitative. Mixed-method combines two research methods, namely quantitative and qualitative into a research activity so that the data obtained will be more comprehensive, valid, reliable, and objective [38]. In this study, a case study research method was used. This type of research method seeks to develop understanding by describing in depth a case that is the focus of research and then focusing on a particular object that is raised as a case to be studied in depth to be able to uncover the reality behind the phenomenon of the probabilistic thinking ability of feminine and cognitive Field-Independent female students in solving probability problems.

2. Participants and data collection

The population in this study were 4th semester students consisting of 12 subjects, 11 being female students and only 1 male subject. Meanwhile, there were 15 students in the 6th semester consisting of 13 females and 2 males. According by Davison [39], the sample is part of the number and characteristics possessed by the population. The sampling technique used in this study was non-probability sampling or non-random sampling technique, which is a sampling technique that is not carried out randomly with the purposive sampling technique, namely the technique of selecting samples based on criteria determined by the researcher. In this study, the criteria that had been determined were that the subjects had taken the Mathematical Statistics I course and the GPA value needed to be above a certain number in order for them to be eligible for selection. GPA is a number that shows the achievement or progress of cumulative student learning from the first semester to the final semester. The sample selection process was tested using a mathematics ability test obtained from UTBK SBMPTN questions that were valid and reliable. UTBK SBMPTN questions are questions used in the selection process for entering state universities in Indonesia which are credible and standardized. The selection of high, medium, and low levels of math ability refers to the assessment guidelines at the Universitas Sembilanbelas November Kolaka, namely A (high ability), B (medium ability), and C (low ability). In addition, the gender questionnaire was one of the determinants in categorizing the sample before determining the selected sample. Samples in this study focused on feminine female students who had a cognitive style Field-Independent, so of the 25 feminine female students, only 20 people were included in the cognitive style Field-Independent based on the GEFT test.

Data collection techniques in this study consisted of two approaches, namely quantitatively and qualitatively. The quantitative data collection was in the form of a probability problem-solving test given to female feminine students and Field-Independent cognitive style. The form of the probability problem-solving test can be seen in [Figure 2].

A circular arrow target board has a small circular center called a bullseye, the center of the target in area 1 consists of two parts, the inner part is red (Double Bull) and the outer part is green (Bull), whereas the 20 circular areas given numbers 1 to 20 are located around the board. Each circular area is divided into three parts, namely, in area 2 it covers the target boundary line that is assumed to be part of the circle and gets a double value 3, in area 3 it includes the target border line which is presumed to enter the inside of the circles and gets the double value 2, whereas in area 4 it is the most outer area of the goal board, so that if a person throws the arrow and touches a particular number, he gets the same value as the number, twice that number, or three times those numbers, depending on which portion of the area affected in sequence on the outside, the middle part, and the portion inside which the archer is assuming that the two plates are not reached so that the target can be reached next to the target. If a person's chance of touching the center of the target is 0.01, the chance of a double value of 3 is 0.25, the probability of a duplicate value of 2 is 0.15, and the probation of an outermost area of the goal board is 0.09, as illustrated in the following figure.



Then determine that the odds in 12 times the arrows throw yield:
a. About the center of the target exactly 2 times
b. Get double value two maximum 4 times
c. Get a double value three more than 9 times
d. On the outermost area of the goal board as much as 2 times

Figure 2 Probability problem-solving questions

Meanwhile, the qualitative data collection was in the form of interviews and audio/video recordings. Interviews were conducted after students solve probability problem-solving problems. In this case, the researchers asked several oral questions related to the probability problem-solving questions given. Audio/video recordings were used to dig deeper into the interview results from respondents.

3. Research tools

3.1. GEFT test

GEFT cognitive style test developed by Witkin et al. [40], was used by researchers to determine the research subjects who have cognitive style field independent or field dependent by using the specified criteria. The criteria used in selecting subjects, according by Kepner and Neimark [41], were subjects who could answer correctly: 0-9 classified field dependent and 10-18 classified field independent. The time required to work on the GEFT test is divided into 3 sessions, namely session 1 with a total of 7 questions with a processing time of 3 minutes, while session 2 and session 3 each have a question of 9 numbers with a processing time of 5 minutes. The focus variable in this study is the cognitive style of independent students.

3.2. Gender questionnaire

This questionnaire is used to obtain data about students who have characteristics as Masculine and Feminine, Androgynous, and Undifferentiated. Gender questionnaire adapted from The Bem Sex Role Inventory (BSRI) developed by Monto [42]. The BSRI questionnaire has 60 items consisting of 20 masculine items, 20 feminine items, and 20 neutral items regarding the characteristics of a person. Students are asked to assess the 60 items by writing a number in the form of a scale of 1 to 7 based on the suitability of the trait with their personality. In this case, there is no good or bad, right or wrong answer. Each number on the scale has its own meaning, the focus variable in this study is female students with feminine personalities.

3.3. Probability problem-solving tasks

Probability problem-solving tasks used in this study are non-routine mathematical problems designed to obtain data on the probabilistic thinking of undergraduate mathematics education students with feminine personalities and have a field-independent cognitive style. This problem is in the form of a description problem that was prepared by the researcher and consulted with promoters and co-promoters. In this task, the selected sample was asked to complete the description question for approximately 60 minutes. The description question was chosen to determine the ability of undergraduate mathematics education students to solve probability problems, because with the description form, the process of solving the problem is more visible, then content and language validation was held by 3 experts in the field of mathematics education. Content validation is carried out to determine the suitability of the problem with probability material that matches the level of students who are the sample of this study, In addition, the question has also gone through a readability test process at two universitas, namely undergraduate students of mathematics education at Universitas Halu Oleo and undergraduate students of mathematics education at the Universitas Sembilanbelas November Kolaka.

4. Data analysis

The data analysis technique in this study uses Sequential Explanatory Mixed Methods. Details are presented in [Figure 3].

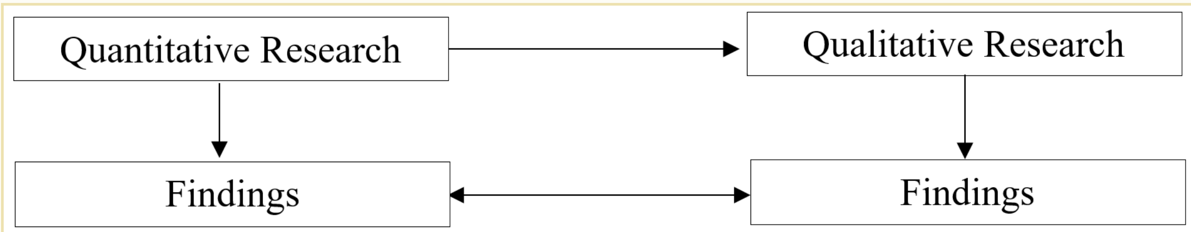


Figure 3 Sequential Explanatory Design

Sequential Explanatory is a technique of processing and analyzing the data that has been collected. To analyze two types of quantitative and qualitative data, a mixed-method was used. In this method, the first step of analysis was to analyze the quantitative data, using SPSS 20.0. With the conclusion of the quantitative analysis, the qualitative data analysis served to explain more about the results of the quantitative data analysis [43].

4.1. Quantitative Data Analysis

a. Assumption test

1) Normality test, carried out using the Komogrov-Smirnov Test. If Sig > $\alpha = 0.05$ then the residuals were normally distributed and vice versa.

2) Linearity Test, using test from linearity testing. If the sig. value on Deviation from linearity was greater than 0.05 between the independent variable and the dependent variable, there was a linear relationship.

3) F Test (Simultaneous Test), if the sig value of $F_{count} \leq \alpha = 0.05$, then the independent variables together had a significant effect on the dependent variable.

b. T-test (Partial Test), if sig $t_{count} \leq \alpha = 0.05$, then the independent variable had no significant effect partially on the dependent variable and vice versa, as well as analyzing linear regression equations with formulas: $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$.

c. Correlation Coefficient (R) and Determination (R^2), the value of the correlation coefficient and the coefficient of determination was between zero (0) and one (1). If R = zero (0) means there was no correlation relationship. The independent variable could have a strong influence on the dependent variable if the R^2 value was close to one.

4.2. Qualitative Data Analysis

Qualitative data analysis activities were divided into three [44], namely:

a. Data reduction, means summarizing, choosing the main thing, and looking for themes and patterns.

b. Presentation of data, done in the form of brief descriptions, charts, relationships between categories, and flowcharts.

c. Conclusion drawing/verification. Conclusions were drawn based on the results of the data that has been obtained during the research.

STUDY RESULTS

In this section, the findings are presented. The results were analyzed using a mixed-method approach, specifically the Sequential Explanatory Design. As explained earlier, there were 20 participants involved in this study, who were grouped based on the feminine gender and field-independent cognitive style, and then analyzed using quantitative analysis to find out the probabilistic thinking of undergraduate mathematics education students towards problem-solving probability. Furthermore, one student was selected as a representative to do the interview process then analyzed qualitatively. The full results are presented in quantitative and qualitative form below.

1. Quantitative result

a) Normality test

Table 1

Normality Test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Probabilistic Thinking Feminine Female	.134	20	.200*	.945	20	.291
Field-Independent Cognitive Style	.175	20	.110	.934	20	.184
Problem-solving probability	.151	20	.200*	.930	20	.152

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on the results of the normality test above, several results were obtained: 1) The significance value of probabilistic thinking of feminine female students was 0.200 > 0.05, so it can be concluded that the data were normally distributed; 2) The significance value of cognitive style field-independent was 0.110 > = 0.05, so it can be concluded that the data cognitive style field-independent normally distributed; 3) The significance value of problem-solving probability was 0.200 > = 0.05, so it can be concluded that the data probability problem solving normally distributed.

b) Linearity test

Table 2

Linearity Test of the Probabilistic Thinking of Feminine Female Students to Problem-Solving Probability

ANOVA Table							
			Sum of Squares	df	Mean Square	F	Sig.
Problem-solving probability* Probabilistic thinking feminine Female	Between Groups	(Combined)	1233.967	12	102.831	6.801	.009
		Linearity	881.993	1	881.993	58.337	.000
		Deviation from Linearity	351.974	11	31.998	2.116	.165
	Within Groups		105.833	7	15.119		
	Total		1339.800	19			

Based on the linearity test results shown in <Table 2> above, the F value in the deviation from the linearity row was 2.116 with a significance of 0.165 > α = 0.05. This shows that probabilistic thinking feminine female and probability problem solving had a linear relationship pattern.

Table 3

Linearity Test of Field-Independent Cognitive Style to problem-solving probability

ANOVA Table							
			Sum of Squares	df	Mean Square	F	Sig.
Problem-solving probability* Field-Independent Cognitive Style	Between Groups	(Combined)	586.383	6	97.731	1.686	.202
		Linearity	45.952	1	45.952	.793	.389
		Deviation from Linearity	540.432	5	108.086	1.865	.169
	Within Groups		753.417	13	57.955		
	Total		1339.800	19			

Based on the results of the linearity test shown <Table 3> above, the obtained F value in the deviation from the Linearity line was 1.865 with a significance of 0.169 > α = 0.05. This indicates that the cognitive style field-independent of probability problem-solving had a linear relationship pattern.

c) Multiple linear regression test

Table 4

Multiple Linear Regression Test of Probabilistic Thinking of Feminine Female and Field-Independent Cognitive Style Students on Problem-Solving Probability

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	983.123	2	491.562	23.429	.000b
	Residual	356.677	17	20.981		
	Total	1339.800	19			

a. Dependent Variable: Problem-solving probability

b. Predictors: (Constant), Field-Independent cognitive style, probabilistic thinking feminine female.

Based on the results of the multiple linear regression test demonstrated in <Table 4> above, the F value obtained in the regression row was 23.429 with a significance of $0.000 < \alpha = 0.05$. This shows that in probabilistic thinking, both variables possessed a significant role in solving probability problems.

d) Partial t-test

Table 5

Partial T-Test on Problem-Solving Probability

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	40.946	10.382		3.944	.001
	Probabilistic thinking feminine female	.738	.110	.841	6.683	.000
	Field-Independent Cognitive Style	-1.240	.565	-.276	-2.195	.042

a. Dependent Variable: Problem-solving probability

Based on the results of the partial t-test in <Table 5> above, the obtained t-value on the probabilistic thinking of the subjects based on the feminine female gender was 6.683 with a significance of 0.000 <0.05. This shows that the probabilistic thinking of the subjects with regards to gender had a significant role in solving probability problems. At the same time, the t-value in the row of field-independent cognitive style was -2.195 with a significance of $0.042 < \alpha = 0.05$. This indicates that the field-independent cognitive style had a significant role in solving probability problems. Based on the Coefficients multiple linear regression, the equation is: $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$. Therefore, based on the coefficients in Table 5 above, the equation was Y = 40,946 + 0,738 – 1240 + ε. From the regression equation, the findings are:

1) Constanta value ( ) of 40, 946 means that both variables of gender and cognitive style played a significant role in the subjects' probabilistic thinking.

2) The coefficient value of 0.738 means that if the feminine female gender increased by 1% then the probabilistic thinking of the subjects in solving probability problems would increase by 0.738.

3) The coefficient value of -1.240 means that if the field-independent cognitive style increased by 1% then solving probability problems would decrease by 1.240.

e) Coefficient of determination (R^2)

Table 6

Coefficient of Determination (R^2) on Probability Problem-Solving

Model Summary[b]							
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					df1	df2	Sig. F Change
1	.857a	.734	.702	4.58050	2	17	.000

a. Predictors: (Constant), Field-Independent cognitive style, Probablistic thinking feminine female

b. Dependent Variable: Problem-solving probability

Based on the results of the coefficient of determination (R^2) in Table 6 above, the R Square value was 0.734 or 73.40%. This figure means that the probabilistic thinking of undergraduate mathematics education students in regard to the feminine female gender and Field-Independent cognitive style simultaneously had a role in solving probability problems by 73.40%. Meanwhile, the remaining 26.60% was influenced by other variables.

2. Qualitative result Based on the Interviews

In this study, a direct explanation/interview was conducted with one selected subject who was one of the 6th semester students of the 2020 batch of the S1 Mathematics Education study program, Faculty of Teacher Training and Education. The purpose of holding the interview was to find out the role of probabilistic thinking of a feminine female student with an FI cognitive style in solving probability problems. As stated earlier, a student representative was recruited who was randomly selected based on the categories of feminine female and field-independent cognitive style. The selected subject was then given the code MPI for the in-depth interview. This interview consisted of questions and answers relevant to the problem, and was conducted in April 2023 located in room B2 1st floor, Faculty of Teacher Training and Education Universitas Sembilanbelas November Kolaka building.

The questions were constructed based on Polya's steps in solving probability problems. For point number 1, the question was related to how to understand the problem on random experiments, sample space, and events. In this stage, it was found that the selected subject was able to understand the problem. For example, in the aspect of writing down things that are known and asked in probability problem-solving problems, MPI was able to write down the number of events, random variables, the chance value of hitting the center of the target, the chance for double 3 and double 2 and the outermost area of the target board. Furthermore, the subject was also able to write down the things that were asked in the probability problem-solving problem such as what was the chance of hitting the center of the target exactly 2 times, getting a double 3 score more than 9 times, getting a double 2 score at most 4 times, and hitting the outermost area of the target board 2 times. The second point was related to how to design a problem-solving plan on randomized trials, sample space, events, and the probability of an event. The findings showed that the subject could design a problem-solving plan using the binomial distribution formula based on things known and asked in the probability problem-solving problem. Furthermore, she was also able to write the formula directly and did not use a formula combination. For point 3, it was related to how to complete the problem-solving plan on randomized trials, sample space, events, and the probability of an event. The results of the interview showed that the subject was able to complete the problem-solving plan using the binomial distribution formula. However, the subject could not use the combination formula first before substituting the results into the binomial distribution formula. Point 4 related to how to look back at the results of solutions to random experiments, sample space, events, and opportunities of an event. The results suggested that the subject could not rewrite the final answer of the problem given, but by using interviews, MPI had done a re-examination of the results of his work ranging from known things to the results of the probability value of an event accurately. Therefore, the role of probabilistic thinking of the subject with feminine gender and an FI cognitive style is very important to use in processing and solving probability problems.

DISCUSSION

Based on the results of the quantitative analysis, the obtained data assumption test for the problem-solving probability can be seen from the significance value of probabilistic thinking data which had a significance value of $0.200 > \alpha = 0.05$. The cognitive style of field-independent had a significance value of $0{,}110 > \alpha = 0{,}05$. Lastly, the problem-solving probability had a significance value of $0.200 > \alpha = 0.05$. At the same time, the linearity test of deviation from the linearity line obtained a significance value of $0.169 > 0.05$. This indicates that the probabilistic thinking of the subjects with problem-solving probability had a linear relationship pattern. Furthermore, the results of the multiple regression analysis obtained $F_{count} = 23.429$ with a significance of $0.000 < = 0.05$. This indicates that the cognitive style field-independent with problems-solving probability had a linear relationship pattern, as well as the feminine female had a significance value of $0.165 > \alpha = 0.05$.

This indicates that the probabilistic thinking had a significant role in problem-solving probability. Based on the results of the partial t-test, each partial t-value had a significance of 0.042 and 0.000 respectively which was smaller than 0.05. It can be interpreted that both variables had significant roles on problem-solving probability. The regression equation also showed a unidirectional role of probabilistic thinking. Meanwhile, the results of the coefficient of determination (R^2) showed a value of 0.734 or 73.40%. This figure means that the probabilistic thinking with regard of both variables, feminine female and cognitive style field-independent, simultaneously had a role in the problem-solving probability by 73.40%. Meanwhile, the remaining 26.60% was influenced by other variables besides the previous two variables. This is in line with research by [45], that cognitive style influences the basic mathematics skills of prospective mathematics teacher students but has no effect on advanced mathematics skills, Working memory capacity was seen to positively affect math performance (basic and advanced math skills, problem-solving skills), while mathematics anxiety demonstrated negative effects on advanced math skills and problem-solving skills.

The qualitative results were shown through in-depth interviews with a student representative selected based on the criteria that had been set prior to the research. Based on the results of the probabilistic problem-solving test, the subject was able to write the chance of not hitting the double value of 3 more than 9 times and the number of random trials, write the number of events, random variables, the chance value of hitting the target center, the chance for double 3 and double 2, and the outermost area of the target board, and be able to write down the things asked in the probability problem-solving problem such as what was the chance of hitting the target center exactly 2 times, getting double value 3 more than 9 times, getting double value 2 at most 4 times, and hitting the outermost area of the target board 2 times. For the designing a solution plan stage, the subject was able to design a problem-solving plan using the binomial distribution formula based on what was known and asked in the probability problem-solving problem. Furthermore, she could write the formula directly and did not use the combination formula. For the stage of implementing the solution plan, the subject was able to complete the problem-solving plan using the binomial distribution formula but did not succeed in using the combination formula first before substituting the results into the binomial distribution formula. Furthermore, at the rechecking stage, the results of the MPI subject's work showed that the subject could not rewrite the final answer given, but by using interviews, it was found that the MPI subject had re-examined the results of his work starting from the known things to the results of the probability value of an event accurately. This is in line with the finding from a previous study by Juniati and Budayasa [46], which states that the Field-Independent cognitive style of feminine female is lower than masculine male. This was obtained from 170 participants who were tested, and most of them produced lower performance on Field-Independent tests, especially among feminine female students. Other than that, according by Batanero and Arroyo [47], Importance of enhancing teachers' mathematical knowledge of various probability concepts and their didactic knowledge, so as to solve problems of conditional probability, probability distributions, and probability modeling.

CONCLUSION

Quantitatively, there was a significant role of probabilistic thinking in problem-solving probability, which can be seen from the quantitative data obtained. In addition, the qualitative analysis carried out in order to find out more about the role of a student’s probabilistic thinking, with regard to the feminine female gender and an FI cognitive style, yielded positive results aside from the stage of carrying out the solution plan. The subject was not able to use the combination formula first before substituting the results into the binomial distribution formula. Besides that, in the aspect of looking back, the subject did a rewriting of the final answer to the problem given. Therefore, it should be noted that it is important for probabilistic thinking to be developed especially in the higher education context to support the achievement of learning for undergraduate students. As a result, the graduates as prospective teachers would be able to apply their field of expertise and utilize science and technology in solving problems and being able to adapt to the situation. Moreover, it is also expected that they could face and master the theoretical concepts of certain fields of science in general and the theoretical concepts of special parts of the field of science in depth, and be able to formulate procedural problem-solving contained in the learning outcomes of the mathematics education study program specifically, namely statistics and probability concepts.

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