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Study of Critical Thinking Skill Patterns in Pre-service Physics Teachers through Cluster Analysis

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Abstract.
Critical thinking skills are very important for pre-service teachers to train. Therefore, it is important to analyze their pattern for pre-service physics teachers. This empirical research uses a quantitative approach. Data collection was measured using critical thinking skills tests. The indicators studied, include elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. This instrument is in multiple-choice form with five answer options. One hundred pre-service physics teachers participated in this research. The data analysis were done using K-means clustering. The results of this research show that there are five groups of critical thinking skill mindsets for pre-service physics teachers. In addition, it was found that the pattern of critical thinking skills of pre-service physics teachers among students was in the elementary clarification (47.50) indicator in the very-low category, basic support (50.50) in the low category, inference (60.99) in the fair category, advanced clarification (43.00) with the very-low category, and strategy and tactics (52.50) with the low category. These results indicate that the pattern of critical thinking skills of pre-service physics teachers needs to receive more attention to be improved in the future.

Keywords: critical thinking skills, K-means clustering, pre-service physics teachers

1. INTRODUCTION

Critical thinking skills are a type of soft skill that involves the ability to analyze information and solve problems. This skill involves interpreting, evaluating, and analyzing information to make judgments [1, 2]. These skills also allow individuals to recognize bias, draw conclusions based on available information, conduct thorough research using credible sources, and be open-minded in problem-solving scenarios [3, 4]. Individuals with strong critical thinking skills can make the right decisions and design creative solutions to complex problems [5]. Critical thinking skills are important in personal development, career advancement, problem-solving, and decision-making processes in various fields and industries [6, 7]. This skill is very important in various aspects of life.

Critical thinking skills are very important for individuals in various fields, including education. Critical thinking skills are very important in education because they help students analyze information, solve problems, and make the right decisions [8, 9]. Improving critical thinking skills can result in better problem-solving and decision-making processes [10] and increase creativity, self-reflection, and the ability to learn from mistakes [11]. Therefore, students need to have these skills in the current era of rapid and dynamic change.

Critical thinking skills are very important for pre-service teachers because they play an important role in the teaching and learning process. These skills enable teachers to analyze and evaluate information, make decisions, and solve problems effectively [12]. Pre-service teachers with strong critical thinking skills can better understand and analyze complex educational problems, make informed decisions regarding teaching strategies and methods, and engage in reflective practice [13, 14]. In addition, critical thinking skills can help teachers develop higher-order thinking skills in their students, such as problem-solving, decision-making, and creativity [12]. In addition, teaching critical thinking skills to pre-service teachers is essential for their professional development and success in the classroom [15, 16].

Therefore, it is important to review pre-service physics teachers' critical thinking skills patterns. So, with the profile obtained, lecturers can consider further planning lectures that can train the mindset of critical thinking skills. In this research, researchers have two research questions (RQ) as follows:

RQ 1: What is pre-service physics teachers' critical thinking skills profile?

RQ 2: What is the distribution of critical thinking skills patterns of pre-service physics teachers based on class and gender in each cluster formed?

These two RQs are implicitly discussed in this research. RQ 1 is based on the descriptive analysis of the results of the measurement of critical thinking skills. Meanwhile, RQ 2 is discussed using a descriptive statistical approach based on the results of RQ 1.

2. METHOD

The research participants were 100 pre-service physics teachers at one of the state universities in South Kalimantan who participated voluntarily in this research. The participants consisted of three different classes, namely (27 students from the class of 2020, 37 students from the class of 2019, and 36 students from the class of 2018). Based on gender, there were 82 female participants and 18 male participants.

Critical thinking skills are measured using a critical thinking skills test in multiple-choice form. The test used meets the aspects of validity and reliability. This research analyzes the critical thinking skills of pre-service physics teachers at one of the universities in South Kalimantan. Data is collected and distributed using Google Forms. There are 25 questions with five answer choices (a, b, c, d, or e) referring to Ennis and Noris [17], which are listed in Table 1.

Table 1: Critical thinking skills indicator.

Critical thinking	**Sub Critical thinking**	**Explanation**
Elementary clarification	Analyze Arguments	Looking for similarities and differences
Basic support	Consider the credibility of a source	Making conclusions and hypotheses
Inference	Making deductions and considering induction	Make generalizations Membuat kesimpulan dan hipotesis
	Make and consider the value of decisions	Application of principles
Advanced clarification	Mendefinisikan istilah	Strategi definisi: aksi, tindakan, pengidentifikasian
Strategy and tactics	Decide on a course of action	Formulate possible alternatives

The data in this research are answers from pre-service physics teachers who completed the critical thinking skills test. Data from the analysis are presented in the form of images. The criteria used are presented in Table 2.

Table 2: Criteria for critical thinking skills.

No	**Interval level**	**Category**
1	80-100	Very Good
2	70-79	Good
3	60-69	Fair
4	50-59	Low
5	≤49	Very Low

[18]

Apart from that, further analysis was carried out using clustering using the K-Mean Clustering method, which is a method that is based on the closeness of values in a group using the Hartigan-Wong algorithm [19].

3. RESULTS AND DISCUSSIONS

The critical thinking skills profile of pre-service physics teachers

The achievement of critical thinking skills of pre-service physics teachers per indicator and its categories is presented in Table 3.

Table 3: Achievement of critical thinking skills of pre-service physics teachers per indicator.

Indicators	Score	Category
Elementary clarification	47.50	Very Low
Basic support	50.50	Low
Inference	60.99	Fair
Advanced clarification	43.00	Very Low
Strategy and tactics	52.50	Low

Based on the results of the critical thinking skills test shown in Table 3, it was found that the achievement of critical thinking skills indicators in the aspects of elementary clarification, basic support, inference, advanced clarification, and strategy and tactics were in the very low, low, and fair categories. The results of achieving critical thinking skills indicate that the critical thinking skills of pre-service physics teachers are still lacking and really need to be optimized in the lecture process.

The lectures cause the lack of critical thinking skills of pre-service physics teachers, and the teaching materials or learning tools used do not optimally train pre-service physics teachers to think critically. Students' critical thinking skills can be improved by using learning strategies focusing on process aspects where students are active in the learning process [20, 21]. This critical thinking skill can be optimized by developing a lecture program using argumentation-driven inquiry (ADI) and its teaching materials. ADI is one of the newest learning models that equally emphasizes the role of argumentation and inquiry in science education [33]. ADI can improve students' mastery of concepts, facilitating students to understand concepts well because ADI learning activities emphasize the construction and validation of knowledge through research activities [22]. Several studies show that applying ADI in learning can optimize students' critical thinking skills [16, 23].

The distribution of critical thinking skills patterns of pre-service physics teachers based on class and gender in each cluster formed.

The next analysis is related to how group patterns are formed based on the abilities of pre-service physics teachers. Cluster analysis using the Hartigan-Wong method in K-Means Clustering shows interesting test results. The first part, cluster information from the tested model, is presented in Table 4.

TABLE 4: Cluster information.

Variable	Value
Cluster	5
N	100
R^2	0.612
AIC	241.880
BIC	307.010
Silhouette	0.230
Indeks Calinski-Harabasz	37.520

Note. All metrics are based on distance Euclidean.

Table 4 shows that the model fit based on the R2 value is at a score of 0.612, indicating that the statistical model used can explain around 61.2% of the data variability. In other words, most of the variation in the data is explained by the variables in the model.

In addition, the Silhouette value of 0.230 indicates that the clustering may have some problems. Some data points may be placed correctly within their clusters, but some data points may be placed incorrectly, or there is overlap between clusters. Finally, the index value of 37.520 that you mention in the context of the Calinski-Harabasz index shows that the clusterization used has a good spread, with high variation between and within clusters. Visually, this grouping is shown in Figure 2.

Based on Figure 1, it can be seen that the distribution of respondent groups is relatively diverse. In cluster 3, for example, there are reasons why some respondents are far from the center of the cluster, such as sample codes 90 and 43.

The next analysis is to look more closely at the distribution of clusters in each indicator in Figure 2.

Figure 2 provides information that clusters 1, 3, and 4 have a quite unique pattern where the cluster averages for the three indicators vary (sometimes positive, sometimes negative).

The results of the critical thinking skills patterns of pre-service physics teachers based on class in each cluster formed are shown in Table 5.

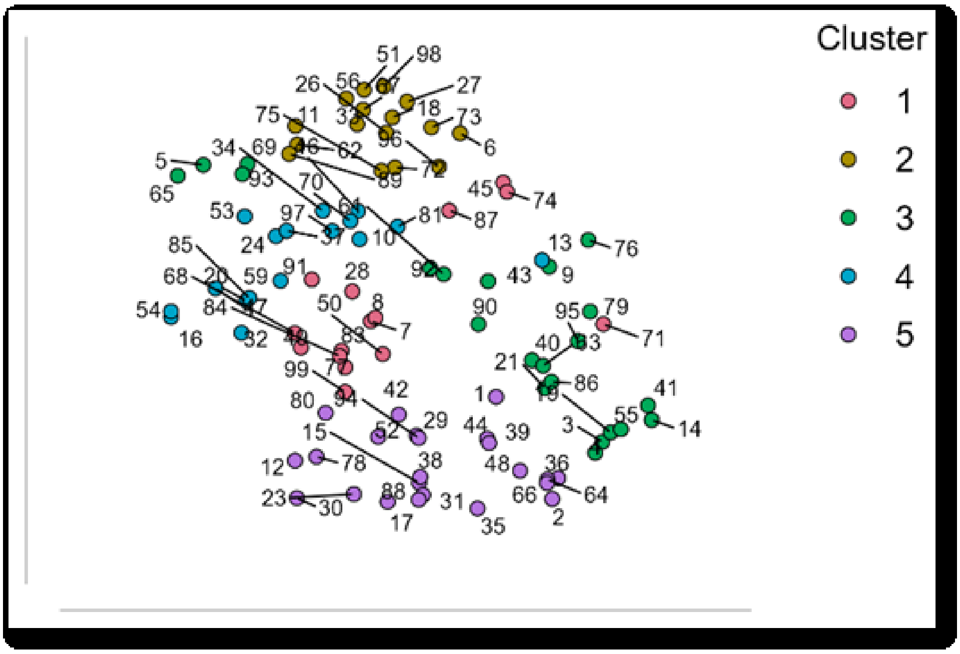

Figure 1: T-SNE grouping.

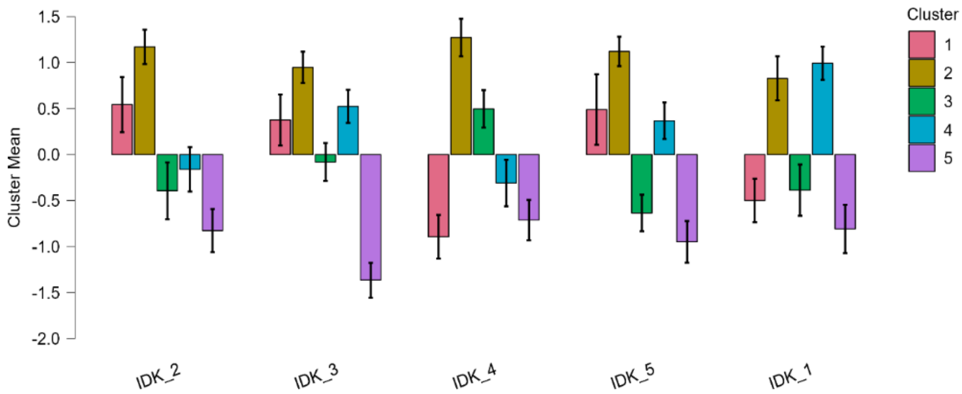

Figure 2: The distribution of the clock in each indicator.

Table 5 shows that Cluster 1, class of 2018 students, has the highest frequency in this cluster, with nine students (60% of the total cluster). Followed by students from the class of 2019 with four students (26.67%) and followed again by students from the class of 2020 with two students (13.33%). This cluster is mostly inhabited by students from the class of 2018, with the majority being 2018 students.

Cluster 2, students from the class of 2018 also dominate this cluster, with eight students (40% of the total cluster). This was followed by students from the class of 2019, with seven students (35%), and students from the class of 2020, with five students (25%). This cluster is also dominated by students from the class of 2018, although there is more variation in other classes compared to Cluster 1.

Table 5: Patterns of critical thinking skills of pre-service physics teachers by class.

Cluster	Class	Frequency	Percent	Valid Percent	Cumulative Percent
1	2018	9	60.000	60.000	60.000
	2019	4	26.667	26.667	86.667
	2020	2	13.333	13.333	100.000
2	2018	8	40.000	40.000	40.000
	2019	7	35.000	35.000	75.000
	2020	5	25.000	25.000	100.000
3	2018	9	40.909	40.909	40.909
	2019	6	27.273	27.273	68.182
	2020	7	31.818	31.818	100.000
4	2018	5	26.316	26.316	26.316
	2019	8	42.105	42.105	68.421
	2020	6	31.579	31.579	100.000
5	2018	5	20.833	20.833	20.833
	2019	12	50.000	50.000	70.833
	2020	7	29.167	29.167	100.000

Cluster 3: There is a more even distribution between the forces in this cluster. Students from the class of 2018 had the highest frequency, with nine students (40.91%), followed by students from the class of 2020, with seven students (31.82%). Then, this was followed by students from the class of 2019, with six students (27.27%). This cluster shows more even variation between groups compared to Clusters 1 and 2.

Cluster 4: This cluster has a different pattern, with the majority of students from the class of 2019, namely eight students (42.11% of the total cluster). Followed by students from the class of 2020 with six students (31.58%) and followed by students from the class of 2018 with five students (26.32%). Students from the class of 2019 mostly inhabit this cluster.

Cluster 5: This cluster has a quite different distribution, with the majority of students from the class of 2019, namely 12 students (50% of the total cluster). Followed by students from the class of 2020 with seven students (29.17%) and followed by students from the class of 2018 with five students (20.83%). This cluster is mostly inhabited by students from the class of 2019, with the majority of all clusters.

The results obtained show that the classes of 2018 and 2019 dominate in several clusters. This is because pre-service physics teachers in this class took more courses than the class of 2020.

The results of the critical thinking skills patterns of pre-service physics teachers based on gender in each cluster formed are shown in Table 6.

TABLE 6: Pattern of critical thinking skills of pre-service physics teachers based on gender in each cluster.

Analysis_results	Gender	Frequency	Percent	Valid Percent	Cumulative Percent
1	L	1	6.667	7.143	7.143
	P	13	86.667	92.857	100.000
2	L	7	35.000	35.000	35.000
	P	13	65.000	65.000	100.000
3	L	3	13.636	13.636	13.636
	P	19	86.364	86.364	100.000
4	L	4	21.053	21.053	21.053
	P	15	78.947	78.947	100.000
5	L	3	12.500	12.500	12.500
	P	21	87.500	87.500	100.000

Table 6 shows that in cluster 1, there is one observation with gender L (Male), which accounts for 6.67% of the total observations in that cluster. Meanwhile, there are 13 observations with gender P (Female), which accounts for 86.67% of the total observations in this cluster. This cluster is dominated by observations with gender P (Female), with a significant majority.

In cluster 2, there are seven observations with gender L (Male), which accounts for 35% of the total observations in this cluster. Meanwhile, there are 13 observations with gender P (Female), which accounts for 65% of the total observations in this cluster. Even though there are observations with gender L (Male), this cluster is still dominated by observations with gender P (Female).

In cluster 3, there are three observations with gender L (Male), which accounts for 13.64% of the total observations in this cluster. Meanwhile, there were 19 observations with gender P (Female), which accounted for 86.36% of the total observations in this cluster. This cluster is very dominated by observations with gender P (Female), with a significant proportion.

In cluster 4, there are four observations with gender L (Male), which accounts for 21.05% of the total observations in this cluster. Meanwhile, there are 15 observations with gender P (Female), which accounts for 78.95% of the total observations in this cluster. This cluster is also dominated by observations with gender P (Female), although the proportion is slightly more balanced compared to the previous cluster.

In cluster 5, there are three observations with gender L (Male), which accounts for 12.5% of the total observations in this cluster. Meanwhile, there are 21 observations with gender P (Female), which accounts for 87.5% of the total observations in this cluster. As with the previous cluster, this cluster is also very dominated by observations with gender P (Female).

Relevant research results state that female students are better at critical thinking than male students [24]. This research results indirectly follow the statement that female students have better learning achievements than male students [25]. The achievement of critical thinking skills of pre-service physics teachers is based on gender; there is a difference between the critical thinking skills scores of female and male students, so this can be a consideration when group division in lectures is carried out heterogeneously.

4. CONCLUSION

The research results show five groups of critical thinking skill mindsets in pre-service physics teachers. Based on the cluster analysis results, it was found that the classes of 2019 and 2018 dominated in several clusters compared to the class of 2020. In addition, female physics teacher candidates dominated in each cluster compared to males. Apart from that, it was found that the pattern of critical thinking abilities of pre-service physics teachers among pre-service physics teachers in the indicators of basic clarification, basic support, inference, advanced clarification, and strategies and tactics, were in the very low-fair category. These results indicate that pre-service physics teachers' critical thinking ability patterns need to be optimized in the lecture process, both through developing lecture programs and the teaching materials used.

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