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PROGRAM FOR INTERNATIONAL STUDENT ASSESSMENT (PISA) ANALYSIS OF ASIAN COUNTRIES USING K-MEAN CLUSTERING ALGORITHMS

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ABSTRACT
The Organization for Economic Co-operation and Development (OECD) report shows that there are still some Asian countries at the lowest level in terms of achieving the Program for International Student Assessment (PISA), such as the Philippines, Lebanon, Indonesia, Kazakhstan, Azerbaijan, and Saudi Arabia. Based on these problems, it is necessary to group countries in Asia based on PISA indicators so that the characteristics of each country can be known through the k-mean clustering algorithm method. The data in this study are secondary data from the 2018 PISA results, which include variables in reading, mathematics, and science. The sample in this study were Asian countries that participated in PISA in 2018, totaling 17 countries. Based on the clustering results, three clusters are 3 clusters formed: cluster 1 is China and Singapore, which are countries with PISA capabilities above average. Cluster 2 consists of Malaysia, Brunei Darussalam, Qatar, Saudi Arabia, Thailand, Azerbaijan, Kazakhstan, Indonesia, Lebanon, and the Philippines with below-average PISA acquisition. Whereas cluster 3 consists of countries with medium capabilities in PISA acquisition, such as Macau, Hong Kong, Korea, Japan, and China-Taipei.

Keywords: Clustering Analysis, Program for International Student Assessment.

INTRODUCTION

Quality human resources are one of the determining factors in the quality of a country's education. Some developing country experiences show that human resources prioritize the availability of natural resources (Tjalla, 2010). Even if there is a country with abundant natural resource availability, it should be able to have an impact on human resources. In this context, some countries in Asia that have abundant natural resource reserves do not impact increasing human resources. Countries that do not have natural resources, such as China, Singapore, Korea, and Taiwan, have far better human resources (Sholikin, 2019). One indicator measuring a country's education quality is the Program for International Student Assessment (PISA). PISA is a collaborative program between countries that are members of the Organization for Economic Co-operation and Development (OECD), which is carried out three times a year to assess the reading, math, and science skills of 15-year-old students. (Organisation for Economic Co-operation and Development, 2003).

PISA assessment not only measures theoretical abilities but rather the ability to solve problems in everyday life. PISA questions emphasize higher-order thinking skills. This ability domain requires students to master concepts that can be implemented to solve problems (Ernawati et al., 2019). In addition, the results of PISA have been widely used by several

developed countries in formulating essential policies to improve the quality of their education (Schleicher, 2019). If you look at the results of the PISA, the achievement of the Asian trading countries is quite reasonable compared to countries in Europe and America. PISA 2018 results reported by the OECD(OECD, 2020b) show China, Singapore, Macao, Hong Kong, Korea, and Japan ranked at the top for the achievement of reading, math, and science skills. Even these countries are pretty stable in achieving PISA 3 times. However, the success of these countries has not yet been followed by other Asian countries. Of course, several factors can influence this, such as the high and low values of a country's Gross Domestic Product (GDP). Studies (Barclay et al., 2017) prove that GDP contributed to improving education in China. In addition, the human development index (HDI) can also affect the improvement of the quality of education and human resources of a country. (Alitasari, 2014)

Based on OECD data (Schleicher, 2019), some countries are still at the lowest level regarding PISA achievements, such as the Philippines, Lebanon, Indonesia, Kazakhstan, Azerbaijan, and Saudi Arabia. Efforts to increase PISA achievement are undoubtedly essential to be done so that they can continue to compete with other Asian countries. In this case, each country certainly has a different policy to increase these achievements. It is not enough to formulate policies related to PISA results by looking at the average acquisition of PISA scores in each area of ability. However, there is a need for further analysis by knowing the characteristics of each country through the k-mean clustering algorithm or cluster analysis.

Cluster analysis is a method of grouping objects into groups called clusters. Data or objects with similar characteristics will be grouped in one cluster with specific characteristics (Bansal et al., 2017). In this case, the grouping is done on objects or countries in the Asian region based on the acquisition of PISA scores in each area of ability. In addition, this cluster analysis will also consider the country's GDP and HDI factors. This method will be known how many clusters are formed and what characteristics appear in each of these clusters.

Cluster analysis via the k-mean algorithm method is relatively easy to apply because it does not have a complicated equation like any other statistical method (Jamesmanoharan et al., 2014). The k-mean algorithm in its analysis consists of two separate phases: first, choose the cluster center randomly by selecting the number of clusters at the beginning. Second, determine each data object to the nearest cluster center (Na et al., 2010). The clustering process begins by identifying the data clustered through the following steps: first, randomly determining the cluster's center. Second, choose the data object to the nearest cluster center. Third, update the cluster center. Fourth, after placement for all objects, recalculate the cluster center position (k-centroid) (Shankar et al., 2016). Next, repeat the second and fourth stages until no more data is switched to another cluster (Nugraha & Hairani, 2018). The k-mean formula can be written as follows (Shankar et al., 2016), $=.\sum_{m=1}^{k}\sum_{tm=1} eKm\,(C_m - t_{mt})^2\, S(x)\,\frac{\{b(x)-a(x)\}}{\max\{a(x),b(x)\}}$ Studies on cluster analysis have been carried out because this method is indeed quite easily applied in various scientific fields. Cluster analysis applied to the statistical field is carried out by (Kalra et al., 2018) to group heterogeneous data types. This research proves that cluster analysis is not only done on homogeneous data types. The results of other studies in business (Ahmed et al., 2019) show that k-mean algorithm cluster analysis can be done with multidimensional data applied to game sales. The application of other cluster analyzes can also be found in various scientific fields such as geology to classify types of groundwater (Javadi et al., 2017) and information technology (Raval & Jani, 2016).

The application of cluster analysis in education itself is carried out by (Singh et al., 2016) to group elementary school students' abilities by place of residence. In terms of grouping students 'abilities, cluster analysis can be done to group students' cognitive abilities (Chiu et al., 2009). Research (Mansur & Yusof, 2018) also applies cluster analysis to classify student behavior. In Indonesia, the application of cluster analysis, especially in education, is carried out

(Lase & Panggabean, 2019) in terms of choosing majors for vocational students. To find out student learning styles can also be done through cluster analysis as research conducted (Palupi et al., n.d.) The results showed that student learning styles can be grouped into four categories: audio-visual, visual-audio, visual, and kinesthetic audio.

So far, based on literature studies, no studies have been found relating to the application of cluster analysis to analyze the ability of students in PISA, especially in Asian countries. This study is essential because, based on the previous description, PISA scores of students in Asian countries are, on average, relatively low. Cluster analysis in this study will focus on applying the k-mean algorithm cluster analysis to determine the characteristics of countries in the Asian region based on mastery of reading, mathematics, and science skills.

METHOD

This research is quantitative. This study aims to explain the phenomenon through data collection in the form of numbers that are analyzed using statistical methods (Sukamolson, 2007). The statistical method used in this study is multivariate analysis. The use of multivariate analysis is used to estimate enormous numbers of variables and samples. One classified as multivariate analysis is the cluster analysis-mean algorithm (Alvin, 2002). The data in this study are secondary data from the 2018 PISA results, which include variables in reading, mathematics, and science (OECD, 2020a). The sampling technique is done intentionally (purposive sampling) based on the objectives and research needs (Guarte & Barrios, 2006). The sample in this study were Asian countries that participated in PISA in 2018, totaling 17 countries. Data analysis techniques using cluster analysis-mean algorithm with the help of SPSS software. The data structure in this study can be seen in the table below.

Table 1. Research Data Structure

No	Country	Variable		
		Reading (X1)	Mathematics (X2)	Science (X3)
1	China	555	591	590
2	Singapore	549	569	551
3	Macau	525	558	544
4	Hongkong	524	551	517
5	Korea	514	526	519
6	Japan	504	527	529
7	China-Taipei	503	531	516
8	Malaysia	415	440	438
9	Brunei Darusalam	408	430	431
10	Qatar	407	414	419
11	Saudi Arabia	399	373	386
12	Thailand	393	419	426
13	Azerbaijan	389	420	398
14	Kazakhstan	387	423	397
15	Indonesia	371	379	396
16	Lebanon	353	393	384
17	Philippines	340	353	357

Source: OECD data, 2020

RESULTS AND DISCUSSION

In cluster analysis, the first step that needs to be done is to transform the variable to the z-score (standard value). The transformed data is based on descriptive analysis, as shown in the following table.

Table 2. Descriptive Statistics

	N	Min	Max	Mean	Std. Deviation
Reading Ability	17	340	555	443.29	73,787
Mathematical Ability	17	353	591	464.53	78.501
Science Ability	17	357	590	458.71	72,787
Valid N (listwise)	17				

Based on the variable data in table 2, using SPSS software, the following data transformation results are obtained.

Table 3. Data Transform

No	Country	Variable		
		Z-Reading (X_1)	Z-Mathematics (X_2)	Z-Science (X_3)
1	China	1.51390	1.61107	1,80380
2	Singapore	1.43258	1.33082	1,26799
3	Macao	1.10732	1.19069	1.17182
4	Hongkong	1.09377	1.10152	0880088
5	Korea	0.95824	0.78305	0.82836
6	Japan	0.82272	0.79579	0.96574
7	China-Taipei	0.80916	0.84674	0.78714
8	Malaysia	-0.38345	-0.31247	-0.28447
9	Brunei Darusalam	-0.47832	-0.43986	-0.38064
10	Qatar	-0.49187	-0.64367	-0.54550
11	Saudi Arabia	-0,60029	-1.16596	-0.99888
12	Thailand	-0.68161	-0.57998	-0.44933
13	Azerbaijan	-0.73582	-0,56724	-0.83401
14	Kazakhstan	-0.76293	-0.52903	-0.84775
15	Indonesia	-0.97977	-1.08953	-0.86149
16	Lebanon	-1.22371	-0.91119	-1,02636
17	Philippines	-1.39990	-1.42074	-1.39730

After the variable data has been transformed, as shown in table 3 above, cluster analysis is performed. As stipulated in the cluster analysis of the K-Mean method, the cluster formation was determined in advance. In this case, the cluster is determined by 3 clusters. The first cluster analysis output using SPSS software is the initial cluster table below.

TABLE 4. Initial Cluster Centers

	Cluster		
	1	2	3
Zscore: Reading Ability	1.51390	-1.39990	.80917
Zscore: Mathematical Ability	1.61107	-1.42074	.84675
Zscore: Science Ability	1.80381	-1.39731	.78715

In the initial cluster table above, it can be seen that 4 clusters have been formed. Then, proceed with iteration to test and relocate each cluster (Rivani, 2010) as stated in the following table.

Table 5. Iteration History

Iteration	Change in Cluster Centers		
	1	2	3
1	.305	1,106	.217
2	.000	.000	.000

The minimum distance between initial centers is 1,454.

From the iteration results in table 5, it can be seen that the iteration process is carried out two times. Iteration is done to get the right cluster. The minimum distance between cluster centers after iteration is 1,454. The final cluster analysis results after iteration are explained in the Final Cluster Centers table below.

Table 6. Final Cluster Centers

	Cluster		
	1	**2**	**3**
Zscore: Reading Ability	1.47325	-.77377	.95825
Zscore: Mathematical Ability	1.47095	-.76597	.94356
Zscore: Science Ability	1.53590	-.76258	.91079

Noting the Final Cluster Centers table above basically still refers to the transformation process of the previous z-score data. Values on positive clusters (+) indicate that the data is above the total average. At the same time, the cluster values that are negative (-) indicate that the data is below the total average. To determine how much the average variable in each cluster can be calculated using the formula $X = \mu + Z .\sigma$. Calculating the average variable can be seen in the following table.

Table 7. Variable averages

	Cluster		
	1	**2**	**3**
Zscore: Reading Ability	552.0	-353.3	213.4
Zscore: Mathematical Ability	580.0	-365.8	234.9
Zscore: Science Ability	570.5	-362.3	240.6

Table 7 above shows that states in cluster 1 are superior in mastering mathematical abilities. In cluster 2, most of them excel at mastering mathematical abilities. Whereas in cluster 3, most of them excel at mastering scientific ability. Furthermore, to determine whether the three clusters have significant differences, it is necessary to test, which can be identified through the Anova table below.

Table 8. Test the Significance of Cluster Differences

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
Zscore: Reading Ability	7,460	2	.077	14	96,641	.000
Zscore: Mathematical Ability	7,323	2	.977	14	75,721	.000
Zscore: Science Ability	7,340	2	.94	14	77,912	.000

Significance test results for differences between clusters based on table 8 variables of reading, mathematics, and science showed a significance value smaller (<) than 0.05. The greater the value of F, the more significant the difference between clusters on each ability variable. Then, there are significant differences between clusters 1, 2, and 3 relating to the variable ability to read, mathematics, and science. Based on the information in table 8, it can be seen that the most considerable F value on the reading ability variable is 96,641. This shows that students' reading ability in countries in cluster 1 is very different from students in countries in cluster 2. The ability to read students in countries in cluster 1 is also very different compared to students in countries in cluster 1 3, and the reading ability of students in countries in cluster 2 is very different compared to students in countries in the cluster. To find out which countries are grouped in each cluster can be seen in the following table.

Table 9. Number of Cases in each Cluster

Cluster		
1	**2**	**3**
China Singapore	Malaysia Brunei Darussalam Qatar Saudi Arabia Thailand Azerbaijan Kazakhstan Indonesia Lebanon Philippines	Macao Hongkong Korea Japan China-Taipei

Based on the results of data analysis using cluster analysis, it can be seen that the cluster formed consists of 3 clusters. As table 6, cluster 1 is a cluster consisting of countries in Asia (China and Singapore) with the highest PISA score or 11.8 percent. Cluster 2 consists of countries in Asia (Macau, Hong Kong, Korea, Japan, China-Taipei) with a medium PISA score of 29.4 percent. In cluster 3, those were the countries with the lowest PISA scores, such as Malaysia, Brunei Darussalam, Qatar, Saudi Arabia, Thailand, Azerbaijan, Kazakhstan, Indonesia, Lebanon, the Philippines or 58.8 percent.

The inclusion of China and Singapore in the group with the highest PISA achievement did occur in 2018. However, the results of PISA 2012 China were ranked top for the achievement of mathematical ability with an average score of 613. Singapore also filled the second rank with an average score of 573. The acquisition of the scores of these two countries

also exceeded the average of the OECD countries (OECD, 2013). In 2015, China and Singapore also dominated the PISA score. This year, the two countries received the highest reading ability scores. Even Singapore's score of 535 exceeded the average score of OECD 493 countries, followed by China, Canada, and Finland (OECD, 2016). Singapore also achieved the score of science ability with 556, followed by Japan 538 and China 532.

Many things certainly influence Singapore and Hong Kong's achievements in international competition. Research conducted by Robinson (2008) in Harris et al. (2014) proves that school leadership significantly impacts academic ability. This aspect of school leadership is at least an essential aspect of the education system in Singapore. For example, teachers in Singapore who have leadership potential are detected from the beginning and continue to be maintained by their leadership potential by occupying certain positions such as school principals. Even teachers who have leadership talent undergo training in the National Institute of Education (NIE) in Singapore for six months (Harris et al., 2014). In addition, China started in 2009, becoming a global concern. His participation in PISA 2009 amazed the world, as Sellar & Lingard (2013) termed it "PISA-shock". Even at that time, China was also used as an essential reference in several Asian countries and the world.

The achievement of PISA in countries in our cluster 3 are countries with a middle category or slightly lower than cluster 1. In PISA 2018, Macau, Hong Kong, Korea, Japan, and China-Taipei, are still in the level 3 category or above the average OECD country (Schleicher, 2019). This shows that countries in cluster 3 have many of the same characteristics. The achievement of PISA scores in the last three times also showed satisfying results. PISA 2012 data shows that Macau, Hong Kong, Korea, Japan, and China-Taipei also score math abilities above the OECD country average (OECD, 2013). Another optimal factor achievement of PISA, especially in countries in East Asia contained in clusters 1 and 3, is parents' attitudes and beliefs in their children (Jerrim, 2015). If you look at countries in East Asia, indeed, most people obey the preservation of local traditions to shape the mentality of their generation. In this case, the mental reinforcement is carried out by parents at home, which has a positive impact on the development of their children's achievements.

The human development index of countries belonging to clusters 1 and 3 is also relatively high. Based on data from the United Nations Development Program (UNDP), Hong Kong-China (SAR) ranks 6th with an index of 0.939. Singapore ranked 9th with an index of 0.935, Japan ranked 19th with an index of 0.915, and Korea ranked 22nd with 0.906 (Pedro Conceição, 2019). In addition, the countries in clusters 1 and 3 also have an average Gross Domestic Product (GDP) high (The World Bank, 2019). This shows that GDP contributes to the human development index. The high human development index also impacts increasing human resources, which contributes to the achievement of the country's PISA. In contrast, countries in cluster 2 generally have low human development indexes and GDP.

In addition to these factors, the still low achievement of PISA 2018 in countries in cluster 2 can be seen from the low reading ability, as shown in table 7. In table 7, it is known that reading ability is the lowest ability in cluster 2. This is consistent with the study conducted (Akbasli et al., 2016) that reading ability is correlated with math and science skills. A study conducted (by Imam, 2016) also proved that reading, especially in terms of discovering the main ideas and drawing conclusions, contributes to the improvement of mathematical and scientific abilities. Especially for science, studies Jufrida et al. (2019) prove that students' level of science literacy affects science achievement.

CONCLUSION

The cluster analysis results on the field of PISA capability based on countries in Asia consist of 3 clusters. Cluster 1 consists of China and Singapore, countries with above-average PISA capabilities. These two countries generally excel in mastering mathematics. Cluster 2 consists of Malaysia, Brunei Darussalam, Qatar, Saudi Arabia, Thailand, Azerbaijan, Kazakhstan, Indonesia, Lebanon, and the Philippines, with the acquisition of PISA below the average of other countries in clusters 1 and 3. The most capable area low on cluster 2 is reading ability. Whereas cluster 3 is a cluster consisting of countries with medium ability to obtain PISA. Countries in cluster 3 such as Macau, Hong Kong, Korea, Japan, and China-Taipei are superior in science capabilities.

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