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Determining the position of Indonesian literacy, science, and mathematics among PISA participating countries using Multidimensional Scaling Analysis

Niza Niza [1 a] *, Slamet Suyanto [1 b], Wan Zuwusni Wan Mustofa [2 c], Nurdin Nurdin [3 d]

[1] Universitas Negeri Yogyakarta Indonesia. Jl. Colombo No. 1, Yogyakarta, 55281, Indonesia
[2] Universiti Teknologi MARA. Jl. Ilmu 1/1, 40450 Shah Alam, Selangor, Malaysia
[3] Badan Pengembangan Sumberdaya Manusia Aceh. Jl. T. Panglima Nyak Makam No.8, Banda Aceh, 23127, Indonesia
[a] niza.2022@student.uny.ac.id; [b] slamet_suyanto@uny.ac.id; [d] nurdin.aceh7@gmail.com
* Corresponding Author

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Abstract: The Program for International Students Assessment (PISA) is a triennial survey of 15-year-old students worldwide. The assessment focuses on core school subjects, namely science, reading, and mathematics. The 2015 PISA survey covers 70 countries, including Indonesia. Indonesia has been participating in the PISA survey since 2000. This article aims to map Indonesia's position towards the PISA participating countries in 2015, which amounted to 72 countries. The analysis used is Multidimensional Scaling (MDS) analysis. The mapping of this position is based on the average value of science, reading, and mathematics. The analysis results show that Indonesia's position is grouped against the 70 participating countries. From this grouping, it can be seen that Indonesia has taken follow-up actions to improve the quality of education in Indonesia, especially in science, reading, and mathematics subjects.
Keywords: *PISA; MDS; Science, Literacy, Math.*

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INTRODUCTION

Science, Language (Reading), and Mathematics are the core subjects taught in schools in Indonesia. Progress in learning these three subjects is assessed regularly. Why is an assessment necessary? Because the quality of learning is determined mainly by the results of the assessment (Mardapi, 2016). Nationally, Indonesia has conducted assessments through the National Examination (UN), while internationally, assessments for the progress of learning science, language (reading), and mathematics are, among others, carried out by the Program For International Student Assessment (PISA).

Indonesia's participation in the survey conducted by PISA is very beneficial. Why? Because PISA is an ongoing program that offers insights into educational policy and practice and helps monitor trends in student knowledge and skills acquisition across countries and in different demographic subgroups within each country. PISA results reveal what is possible in education by showing what students in the highest-performing and fastest-growing education systems can do. These findings enable policymakers worldwide to measure the knowledge and skills of students in their own country versus in other countries, set policy targets against measurable goals achieved by other education systems, and learn from policies and practices implemented elsewhere. While PISA cannot identify cause-and-effect relationships between policies/practices and student outcomes, it can show educators, policymakers, and the interested public how education systems are similar and different and what this means for students (Organisation for Economic Co-Operation and Development, 2016).

Indonesia has started to participate in the PISA assessment from 2000 to 2021. The achievements of Indonesian students have not been satisfactory. In 2015 Indonesia's position was ranked sixth (sixth from the bottom) with a value of 397. This article maps Indonesia's position against the TIMSS participating countries in 2015. From the results of the TIMSS publication, it is known that the average achievement obtained by students from each country participating in the assessment. Based on these values, a mapping

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of Indonesia's position against all participating countries was carried out to show which countries have similar characteristics/characters with Indonesia and differences based on the distance (scaling) obtained.

METHODS

This study uses a descriptive method with a qualitative approach. The population in this study was students around the world aged 15 years and 29 million people. The sample in this study were all students who were 15 years old and took the test organized by PISA, as many as 540,000 people. Data was obtained from the PISA report by the OECD. The data analyzed is the average value of PISA results, namely: the average value of mathematics, reading, and science.

The analysis used is the classic Multidimensional Scaling (MDS) or Multiple Dimensional Scaling (PDG) analysis. MDS was included in the multivariate analysis. This analysis is one type of statistical analysis used to analyze data where the data used is in the form of many independent variables (Hair-Jr. et al., 2014; Hasanah et al., 2022). Multivariate data is data collected from two or more observations by measuring these observations with several characteristics.

Multidimensional scaling (MDS) is a family of methods for finding multidimensional data structures. The proximity matrix, usually derived from variables measured on objects as input entities, maps these differences on low-dimensional spatial representations. A classic example concerns an asymmetric input matrix of airline distances between cities in miles. So that it can be known the position of one object with another object (Mair et al., 2016). According to Wang (2013), Multidimensional scaling (MDS) is a term that refers to a collection of approaches for reducing the dimensions of an image. Given a set of objects and the pairwise dissimilarity matrices between them (often assumed to come from distances in a high dimensional space), they generate coordinates in some low dimensional space. The distances in that space accurately represent the input differences.

Multiple Dimensional Scaling (PDG) is an analytical method that discusses mapping a set of objects into a configuration of n points in Euclidean space with a distance between points that reflects the dissimilarity/ dissimilarity between these objects. The determination of the object group is based on the distance of the object pair. If the distance of the pair of objects is getting smaller, the more similar they are and form a group. For every m-dimensional space, there are n points $x_1, \dots x_n \in R^m$. Euclidean distance squared d_{ij}^2 for every m-dimensional space, there are n points, which can be calculated using the following equation (Cox et al., 2001):

$$d_{ij}^2 = \left(X_i - X_j\right)^{\prime\left(X_i - X_j\right)} = X_i' X_i + X_j' X_j - 2X_i' X_j$$

Euclidean distance $d_{ij}^2, \ \ i,j = 1,2,3 \dots, n$ is a mapping of the dissimilarity of pairs of objects in a group in a specific Euclidean space with a squared Euclidean distance matrix written as follows can be calculated using the following equation (Cox et al., 2001):

$$\mathbf{D}_{\mathbf{nxn}}^{\mathbf{2}} = \begin{bmatrix} 0 & d_{12}^2 & . & . & d_{1n}^2 \\ d_{21}^2 & 0 & . & . & d_{2n}^2 \\ . & . & . & . & . \\ . & . & . & . & . \\ d_{n1}^2 & d_{n2}^2 & . & . & 0 \end{bmatrix}$$

Configuration matrix X_{mxn} is followings:

$$\mathbf{D}^2_{nxn} = \begin{bmatrix} 0 & d^2_{12} & . & . & d^2_{1n} \\ d^2_{21} & 0 & . & . & d^2_{2n} \\ . & . & . & . & . \\ . & . & . & . & . \\ d^2_{n1} & d^2_{n2} & . & . & 0 \end{bmatrix}$$

A matrix D is called a metric dissimilarity if:

1. d_{ij}=0, if i=j
2. $d_{ij} = d_{ji}$ for all $1 \leq i, j \leq n$
3. $d_{ij} \leq d_{ik} + d_{kj}$ for all $1 \leq i, j, k \leq n$ (triangle inequality)
4. d_{ij} positive value for all i and j

The steps determine the coordinates of each point on the double-dimensional pensecalation confectionation map as follows (Borg & Groenen, 2005).

Suppose X_{nxp} It is an observation matrix and $\hat{X}$ Is an observation matrix corrected with a matrix H, so that/with $H = \left(I - \frac{1}{n} 11'\right)$. Next $Y = \hat{X}\hat{X}'$ decomposed singularly into $Y = U\Delta V' = U \Lambda^{\frac{1}{2}} \Lambda^{\frac{1}{2}} V'$. Where U= vector eigen of $Y'Y$,Λ = diagonal matrix with diagonal value is eigen $\lambda_1, \ldots \lambda_2$, where $\lambda_1 \geq \lambda_2 \geq \ldots \lambda_r \geq 0$. It is further represented by observations expressed by G, where $G = U \Lambda^{\frac{1}{2}}$, and the variable representation is expressed by H' where $H' = \Lambda^{\frac{1}{2}} V'$.

RESULTS AND DISCUSSION

The results of the MDS analysis based on PISA data in 2015 are discussed in 4 aspects, namely: 1) Goodness of fit (GoF),2) Multidimensional scaling configuration points,3) perception maps, and 4) Grouping of Similarities and Immaturities.

Goodness of Fit (GoF)

Assessment of the classic MDS model (metric) is retired to the GoF value. The GOF value close to 1 indicates that the MDS model fits in a particular dimension. In this case, GoF values for one dimension of 0.974, two dimensions of 0.994, and 3-dimensional models of 1. In this case, two dimensions are selected to facilitate the creation of maps.

Multidimensional Scaling Configuration Point

MDS analysis produces configuration points. Configuration dots are used to form images or maps in two-dimensional space.

Table 1. MDS Configuration Points

Countries	[,1]	[,2]
Albania	(83.39)	9.83
Algeria	(175.11)	14.39
Argentina	8.99	(12.93)
Australia	67.46	(7.44)
Austria	50.82	6.72
Belgium	68.71	2.72
Brazil	(118.74)	(16.83)
Bulgaria	(40.50)	8.10
Canada	104.43	(10.62)
Chile	(35.77)	(23.91)
China	89.47	23.20

Countries	[,1]	[,2]
Chinese Taipei	105.68	29.23
Colombia	(92.32)	(21.18)
Costa Rica	(82.86)	(16.15)
Croatia	20.64	(17.40)
Cyprus	(44.00)	(4.46)
Czech Republic	47.77	1.86
Denmark	71.71	4.39
Dominican Republic	(214.66)	(16.60)
Estonia	105.71	(1.22)
Finland	102.48	(12.55)
France	56.25	(6.68)
Georgia	(100.04)	5.58
Germany	77.61	(4.89)
Greece	(7.86)	(10.23)
Hong Kong	121.21	8.42
Hungary	20.14	4.08
Iceland	31.39	0.98
Indonesia	(117.75)	(3.26)
Ireland	79.80	(16.19)
Israel	15.35	(8.40)
Italy	38.75	0.80
Japan	113.59	8.95
Jordan	(111.90)	(14.84)
Korea, Republic of	97.02	0.70
Kosovo	(174.47)	18.19
Latvia	40.55	(5.40)
Lebanon	(149.22)	39.96
Lithuania	20.76	2.90
Luxembourg	35.17	1.70
Macau (China)	111.98	20.73
Macedonia, Republic of	(162.81)	20.50
Malta	1.74	21.89
Mexico	(82.44)	(8.58)
Moldova, Republic of	(72.36)	5.64
Montenegro, Republic of	(76.86)	(6.16)
Netherlands	77.91	3.47
New Zealand	73.11	(11.17)
Norway	71.30	(11.75)
Peru	(119.92)	(4.13)
Poland	70.25	(4.70)
Portugal	58.41	(5.81)
Qatar	(96.81)	4.38
Romania	(43.67)	7.10
Russian Federation	50.16	(3.87)
Singapore	153.86	15.81
Slovak Republic	0.45	14.28
Slovenia	80.04	1.15
Spain	49.17	(8.86)
Sweden	56.31	(7.08)
Switzerland	75.55	17.24
Thailand	(83.25)	7.23
Trinidad and Tobago	(69.68)	(5.14)
Tunisia	(159.08)	11.24
Turkey	(67.28)	(4.09)
United Arab Emirates	(52.95)	(3.09)
United Kingdom	62.86	(4.88)
United States	41.62	(19.10)

Countries	[,1]	[,2]
Uruguay	(57.88)	(11.18)
Vietnam	67.41	7.42
United States	41.62	(19.10)
Uruguay	(57.88)	(11.18)
Vietnam	67.41	7.42

Perception Map

The configuration points derived from the MDS calculations in Table 1.1 are mapped into 2-dimensional fields based on the similarity of student achievements in OECD countries in science learning, literacy, and maths lessons. Figure 1 presented a map of similarities of OECD countries in science learning, literacy, and maths lessons.

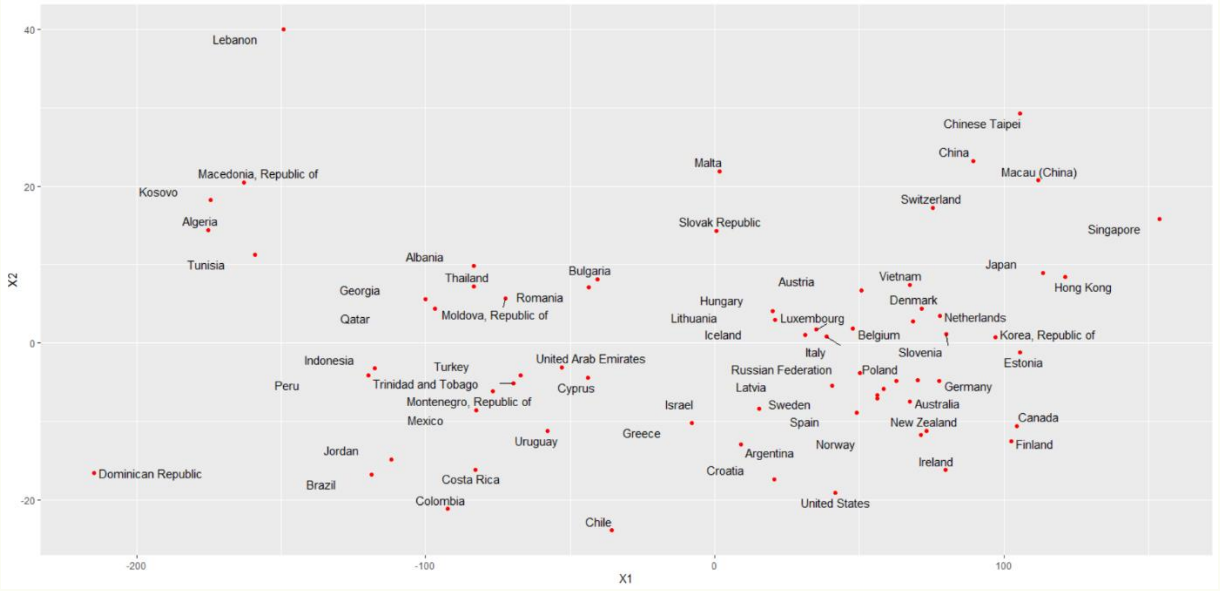

Figure 1. Map of Similarities and Immaturity of students in OECD Countries in science, literacy and maths learning.

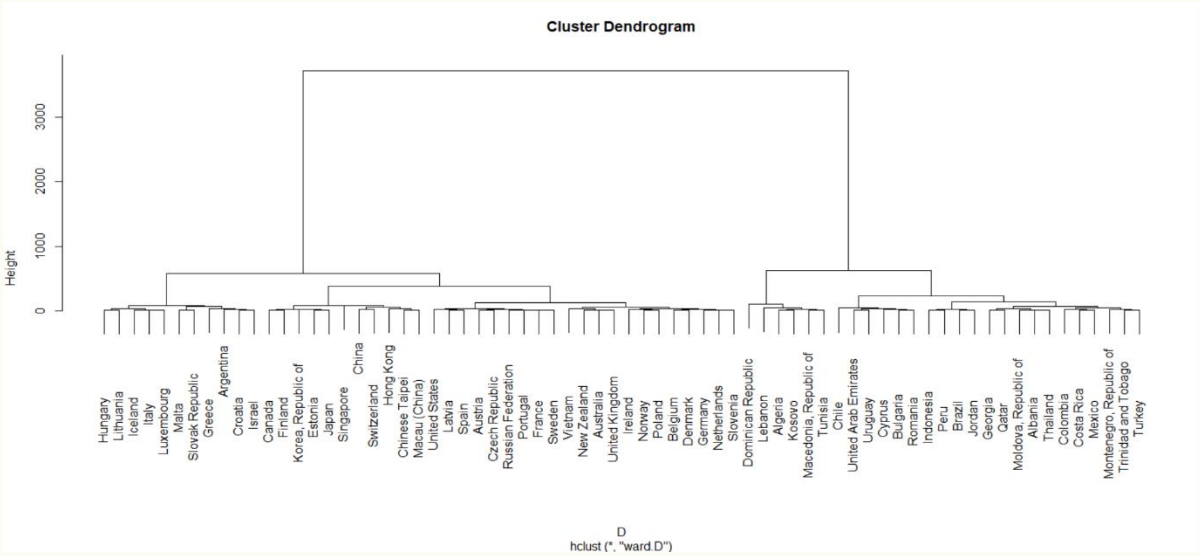

Figure 2. Grouping of student similarities in OECD Countries in science, reading and maths learning

Figure 1 shows that countries in quadrant 1 (bottom left) are the countries that have the lowest average of science, literacy and math learning achievements, while countries in quadrant 4 (top right) are a group of countries that have a high average of science, literacy and math learning achievements. The Dominican Republic is a country that has the lowest average of science, literacy and math learning achievements,

while China Taipei is the country that has the highest achieve-ments of science, literacy and mathematics learning.

Grouping of Similarities and Immaturity

Any similar countries are grouped using the dendrogram cluster method to facilitate interpretation. The following Dendrogram Cluster presents the similarity grouping of students in OECD Countries in science, literacy and mathematics learning (Figure 2).

Based on Figure 2, it can be visually known which countries are least similar and the countries that most resemble their students' ability in math, literacy, and science lessons. The farther the distance the country in the Dendrogram Cluster shows, the less similar, instead of the closer the distance of the country in the Dendrogram Cluster shows the country has similarities in terms of mathematical, literacy and science skills. Figure 1.2 shows that students in OECD member countries can be grouped into five major groups to achieve science, literacy, and maths learning.

The first group is represented by eleven countries: Hungary, Lithuania, Iceland, Italy, Luxembourg, Malta, Slovak Republic, Greece, Argentina, Croatia, and Israel. The second group is organized by eleven countries: Canada, Finland, the Republic of Korea, Estonia, Japan, Singapore, China, Switzerland, Hong Kong, Chinese Taipei, and Macau. The third group is represented by 21 countries, namely, the United States, Latvia, Spain, Austria, Cehnya Republic, Russian Federation, Portugal, Francis Sweden, Vietnam, New Zealand, Australia, United Kingdom, Ireland, Norway, Poland, Belgium, Denmark, Germany, Netherlands, and Slovenia. Six countries represent the fourth group: the Dominican Republic, Lebanon, Al-Jazeera, Kosovo, Macedonia, and Tunisia. The fifth group is represented by 22 countries, namely, Chile, United Arab Emirates, Uruguay, Cyprus, Bulgaria, Romania, Indonesia, Peru, Brazil, Jordan, Georgia, Qatar, Republic of Moldova, Albania, Thailand, Colombia, Costa Rica, Mexico, Republic of Montenegro, Trinidad and Tobago, and Turkey.

CONCLUSION

Schelling's Multidimensional Analysis can be used to illustrate Indonesia's position among PISA-participating countries. The results of the analysis showed that there were four (5) large groups, and The Indonesian Poisisi was in the fifth group, which is equivalent to 22 countries, namely, Chile, United Arab Emirates, Uruguay, Cyprus, Bulgaria, Romania, Indonesia, Peru, Brazil, Jordan, Georgia, Qatar, Republic of Moldova, Albania, Thailand, Colombia, Costa Rica, Mexico, Republic of Montenegro, Trinidad and Tobago, and Turkey.

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SINTAX ANALISIS

Syntac R Appendix for Classical MDS

Sintax R Multidimensional Scaling Metrik

```
#PANGGIL DATA
rm(list=ls())
babeh<-read.csv("babeh.csv", header=T)
head(babeh)
row.names(babeh) <- babeh$Negara
babeh <- babeh[,-1]
# HITUNG MDS
D <- dist(babeh, method="euclidean")
D.fit <- cmdscale(D, eig=TRUE, k=2)
#BULATKAN HASIL PERHITUNGAN
signif(D,2)
plot (D.fit$points)
text(D.fit$points, labels=row.names(babeh), pos=3, cex=0.7)
library (ggrepel)
D.fit2<- data.frame (D.fit$points)
ggplot(D.fit2, aes(X1, X2, label=row.names(D.fit2)))+geom_point(colour="red")+geom_text_repel()
#KELOMPOKKAN KEMIRIPAN
D.3 <- hclust(D, method = "ward.D")
plot(D.3)
#manual computation
A <- as.matrix(-D*D/2)
n <- nrow(A)
```

```
H <- diag (n)-(array(1,c(n,n))/n)
B <- H %*% A %*% H
eig_B <- eigen(B)
head(eig_B$vectors %*% sqrt(diag(eig_B$values))[,1:2])
head(D.fit$points)
#Goodness of fit
gof1<- eig_B$values / sum(abs(diag(eig_B$values)))
gof2<- eig_B$values / sum(diag(eig_B$values > 0))
#sum(eig_B$values >0) : su up all number in a cell, greater than 0
gof1[1]+gof1[2]
gof2[2]+gof2[2]
        D.fit$GOF
```