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Exploratory Factor Analysis as a Tool for Determining Indicators of a Research Variable: Literature Review

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ABSTRACT

Background. Exploratory factor analysis can be used as a guideline for constructing instrument homogeneity.

Purpose. Factor analysis is the queen of analytical methods because of its strength, flexibility and closeness to the nature of scientific aims and objectives.

Method. Roughly speaking, an instrument whose items measure only one trait in general and can determine the indicators of a research variable. To determine the number of indicators based on eigenvalues greater than or equal to one, both in the initial factor analysis and in further analysis.

Results. A statement item is declared eligible for inclusion in a factor if the item has a factor load greater than or equal to 0.30 on only one factor. Similarly, an indicator is declared feasible if its factor load is greater than or equal to 0.30.

Conclusion. The item that has the highest factor load on a factor contributes the most to that factor, so that item is used as the basis for guidance in naming a factor as the name of the indicator.

KEYWORDS

Factor Analysis, Factor Load, Indicators

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INTRODUCTION

As is known, research instruments are very important in conducting research. Research data that is processed to answer problems, is collected using instruments. (Nida dkk., 2023). Without a good instrument, accurate data cannot be obtained, which can lead to incorrect conclusions being drawn.

A good instrument is when all items are valid and reliable. Before determining whether an item is valid or not, it is first necessary to know the indicators of a concept that we are concerned with. But sometimes determining an indicator of a concept is relatively difficult, so one way to determine an indicator is through factor analysis. For example, the instrument of how to learn math. How to learn math is a concept or a variable that can be developed according to certain rules, namely construct validity and empirical validity. This can be done when the indicators in the variable are known.(Zarnuji, 2023). Mutohir (1994: 20) states that factor analysis is a useful and appropriate analytical tool for scale preparation,(Farid, 2023). during this technique it can immediately identify the homogeneity of the items.

In the Outlines of the Mathematics Teaching Program for Public Secondary Schools (1993: 1-2) it is stated that the general objectives of mathematics education at the secondary education level emphasize the arrangement of reasoning, the basis and formation of student attitudes and also emphasize skills in the application of mathematics (Teguh dkk., 2023). Factor analysis can also identify the dimensionality of the scale and test whether hypothetical indicators can be confirmed and match the actual empirical data. (B. Beribe, 2023). The problem is what conditions must be met for an indicator to be included in a variable? This paper aims to determine the indicators of a research variable. (Makniyah & Khotimah, 2023).

RESEARCH METHODOLOGY

Factor analysis is a set of techniques for processing data that includes hypothesis testing and techniques for reducing data. (Suryaningsih, 2021). Because it covers research methods for a set of variables that are correlated with one another and not/less correlated with another set (Mutalib & Dylan, 2021a). sehingga dapat digunakan sebagai pedoman pengkontruksian homogenitas instrumen. Secara kasar homogenitas alat ukur adalah seperangkat instrumen yang butir-butirnyamengukur hanya satu sifat secara umum.(Roshayanti, Minarti, & Reca Liviviyanti, 2023). Vincent (1994: 421-422) states that factor analysis is a statistical analysis technique that aims to explain the structure of the relationship between observed variables by generating several factors that are fewer than the number of original variables.

Agung (1992: 47) states that the role of factor analysis precisely and correctly can be used to study "how many factors are needed to explain (statistically) the set of items of an instrument".(Pamungkas & Halimah, 2023). In line with Santoso and Fandy (2001: 248) that factor analysis is principally used to summarize a number of variables into fewer and name them as factors.(Fuadi & Mirsal, 2023b). Comrey (in Wrahatnolo, 1994: 2) suggests reasons for factor analysis, namely: (1) the structure that has been created can explain the correlation between variables/items,(Suryaningsih, 2021). (2) to test theories about the number and style of factor constructions to explain correlations between variables/items, (3) to determine the effects of changes in measured variables and measurement conditions on factor constructions, (4) to verify previous findings through new samples either from the same population or from different populations, and (5) to determine the impact of various factor analysis procedures on analysis results.

Soeprijanto (2004: 114-115) states that the objectives of factor analysis are: (1) recognize or identify the underlying indicators or factors that explain the correlation between variables, (2) recognize or identify a new set of uncorrelated variables that are less in number to replace a set of original variables that are correlated, (3) recognize or identify an important set of variables from a larger set of variables.(Mudinillah & Rizaldi, 2021). There are two kinds of factor analysis procedures that need to be distinguished, because the rationale and analysis strategies are different. First, exploratory factor analysis, used to find new ideas about factors or indicators of a number of research variables. Second, confirmatory factor analysis, used to confirm a number of factors (as hypotheses) underlying the research rationale. (Mutalib & Dylan, 2021b). Exploratory factor analysis serves to: (1) identify homogeneous items from a set of items, (2) determine valid items from a group of items, (3) determine indicators of a concept, and (4) determine the dimensional reliability of a concept. (Afifah dkk., 2023a). The analysis requirement test is first based on Barlett's test (□2) if □2 count > □2 table with $\alpha = 0.05$ then it is feasible to do factor analysis. Agung (1993: 19) states that Barlett's statistics are used to test the hypothesis that the correlation matrix is the identity matrix. Furthermore, it is stated that to determine whether the results of a factor analysis can be declared adequate or appropriate, a statistic called the KMO (Kaiser-Meyer-Olkin) accuracy measure is considered and the KMO statistic is an index to compare the sample correlation coefficient (observed) with the partial correlation coefficient. In addition, what needs to be considered is MSA (Measure of Sampling Adecuacy), namely the diagonal of the Anti-image Correlation Matrix for each basic variable. If the diagonal of the Anti-image Correlation Matrix is small, usually <0.5, the variable is discarded and then the factor analysis returns.

Factor analysis (Siswoyo, 1988: 3) has played an important role in research. Knowledge about personality, for example, has used factor analysis and it has provided additional knowledge about youth delinquency, crime, urbanism, primitive society, national characteristics, conflict, attitudes, voting behavior, and so on.

Factor analysis is a generic term for a number of different but related mathematical and statistical techniques designed to examine the nature of relationships between variables in a particular setting, as distinct from other techniques. The basic problem is to determine whether the n variables in a set exhibit patterns of relationship with each other, such that the set can be broken down into, say, m sub sets, each of which consists of a group of variables tending to be more related to each other in the sub set than to other variables in other sub sets.

The main purpose of factor analysis is to determine whether a set of variables can be described based on a smaller number of dimensions or factors than the number of variables, and determine what the factors are.

Factor analysis (Siswoyo, 1988: 8) is one of the multivariate analyses which is a scientific method for analyzing data. In factor analysis there are no restrictions on the content of the data; it can be in the form of observations about earthquakes, about the motion of gas molecules, about group behavior, attitude data obtained through questionnaires and so on.

Factor analysis (Siswoyo, 1988: 17) is known by researchers as an exploratory tool to reveal basic concepts. This method is like a translucent veil through which data can be seen its basic structure. The basic concepts found may correspond to those that already exist in a field or do not exist at all until researchers sometimes find it difficult to give names.

Agung (1992: 110) states that to measure a multivariate concept, two kinds of cases can be found. First, based on the set of items that are thought to measure a concept, for example a child's grade, a new variable is formed by summing the scores for each item. The new variable is then assumed to be interval-scale. In this case, there is a problem, namely whether each item has the same weight, in addition to the interval scale assumption for the new variable formed. In the second case, factor analysis is directly used to simplify the dimensions of the multivariate data of interest, with the expectation that a factor or indicator for the concept in question will be obtained.

Agung (1992: 111) states that to form indicators or measures of a multivariate concept, the following steps may be considered and carried out.

1. Try to make I1, I2, ..., In; or all items considered; into groups that are theoretically considered to have equal or almost equal weight.
2. Furthermore, several new variables can be defined according to the number of groups formed, each of which is the sum of the indicators in the group concerned. So that the summation is done only for indicators or items that are considered to have almost the same weight.

3. To simplify the data dimension with new variables formed based on b, factor analysis can be applied. in this case, it is expected that a factor or an indicator will be obtained to be used to explain the data. However, it is possible that we have to use two or more factors for a particular concept.

On the other hand, if the measurement scale of the concept indicator is agreed to be nominal or ordinal, data analysis is carried out using categorical data analysis methods, namely nominal categorical data analysis such as log-linear models related to Chi- squared statistics X, and Likelihood Ratio G, and linear models for ordinal categorical data analysis.

RESULT AND DISCUSSION

Varimax Rotation

In factor analysis, varimax (orthogonal) rotation or oblique rotation can be used. The use of one of these rotations is determined by the theoretical basis, in other words, varimax rotation is used when the researcher considers that the variables/dimensions/indicators are not correlated.(Arsul dkk., 2021). This can be illustrated in Figure-1 and Table-2. For example, three items (x1, x2, x3) with two factors are shown in Table-1 below.

Table 1. Factors and loading factors (Rahmah & Martin, 2022).

	F1	F2
x_1	β11	β12
x_2	β21	β22
x_3	β21	β32

Description:

Fi : factor

βij : loading factor

xi : variable/dimension/indicator/item

To determine the coordinates of the points resulting from varimax rotation, a linear transformation is used (Rummel, 1979: 120) as follows.

Linear transformation for x1:

Ω11 = Cos μ. β11 + Sin μ. β12

Ω12 = -Sin μ. β11 + Cos μ. β12

Linear transformation for x2:

Ω21 = Cos μ. β21 + Sin μ. β22

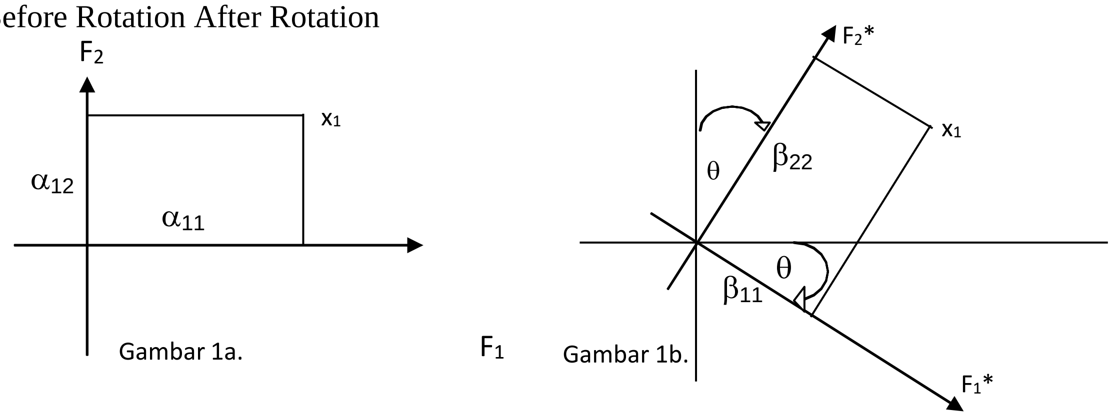
Ω22 = -Sin μ. β21 + Cos μ. β22

Linear transformation for x3:

Ω31 = Cos μ. β31 + Sin μ. β32

Ω32 = -Sin μ. β31 + Cos μ. β32

Before Rotation After Rotation



Gambar 1a. Gambar 1b.

Table 2. Illustration of factor loading before and after rotation

F_1 (sebelum rotasi)	F_2	F_3	F_1^* (sesudah rotasi)	F_2^*	F_3^*
x	x	.	x	.	.
x	x	x	x	.	.
x	x	x	x	x	.
x	.	x	.	x	.
x	x	x	.	x	.
x	x	.	.	x	x
x	.	x	.	.	x
.	x	x	.	.	x

In Table-2 we can see that after rotation it is easier to identify items that measure more of a dimension/indicator than before rotation.

Trial Sample

The sample size is based on the sample size for factor analysis. Factor analysis presupposes a large sample. Nunnally (in Kaluge, 1988: 21) formulated a sample size equal to 10 times the number of items or dependent variables, but still gave the possibility of bargaining.(Yennizar dkk., 2022). In reasonable conditions, the number 10 in the formula can decrease to 5. In line with Gable's opinion (1986: 39) that the number of samples or respondents for factor analysis ranges from 6 to 10 times the number of items. Comrey (in Kaluge, 1988: 21) made a benchmark sample size for factor analysis as follows.

Table 3. Quality of Sample Size (Afifah dkk., 2023b).

Sample size	Quality
50	Very poor
100	Poor
200	Fair
300	Good
500	Very good
1000	Excellent

Indicators of a Variable

Based on the objective, namely determining the indicators of a research variable, the factor analysis used is exploratory factor analysis, namely factor analysis from the beginning of the items collected (Andra dkk., 2023), In this case, the correlation between items or it can be seen that the number of items is the number of dimensions of a concept to be measured.

Agung (1993: 17) states that among all the preliminary statistics in each factor, the most important to note are the eigenvalues and the percentage of variation (Pct of var) including the cumulative (Pathurohman dkk., 2023). It further states that in general, the number of factors to be used is associated with eigenvalues greater than or equal to one (Muhammadong dkk., 2023). From the selected factors, further determination of homogeneous items by paying attention to the factor loading or factor loading which is quite large (□ 0.30) on one particular factor and has a small factor loading on other factors. (Lasmi dkk., 2023), Factor loading (in Wrahatnolo, 1994: 3) is the relationship between indicators or factors and items.

Siswoyo (1988: 33) states that the proportion of the total variance contributed by each factor is called factor loading and the sum of the factor loadings in a common factor is called common factor loading and is given the symbol h, and the square of h (h2) is the common factor variance and is often called communality (Saputra dkk., 2023). Factors that have loading on two or more variables are joint factors or common factors, while factors that only have loading on one variable are called specific factors. (Kurniawan dkk., 2023). In addition to the common and specific factors, there is another component, namely the error or residual factor.

The sources of variance of a measure (Kerlinger, 1992: 1007) are as follows.

Vt = Vco + Vsp + Ve, h2 = Vco with

Vt = total variance of a measure

Vco = shared factor variance = communality

Vsp = specific variance Ve = error variance.

h2 = V = a 2 + b 2 + ...+ k 2 with

a 2 , b 2 , ..., k 2 is the square of the factor load.

These factors can be known by extracting them. The extraction is done one by one until there is no more correlation between variables/items. The process of extracting factors will obtain a factor loading matrix. Factors with each other are not correlated (orthogonal).(Susanti dkk., 2023). Mutohir (1994: 11) states that a good item or variable must actually have clear discrimination power in the sense that the item or variable clearly measures one particular factor (indicated by the magnitude of the factor load) and has no significant (small) factor load on other factors. Any item that loads significantly on more than one factor or does not load significantly on a particular factor is expected to be discarded (N. A. Putri dkk., 2023). Furthermore, Mutohir (1994: 11) states that if some items have to be discarded as a result of this process, then further factor analysis is carried out again to determine whether the factor pattern that has resulted from the previous factor analysis has not changed. (Johanna dkk., 2023), The factors obtained, formed a factor (in Kaluge, 1988: 23) if a factor is at least 3 (three) items or variables that have factor loading greater than 0.30. With the last factor obtained, a name for the selected factor is needed. Kaluge (1988: 23) states that the item with the highest loading means that it contributes the most to the factor, therefore it is used as a basis for guidance in naming.

Santosa and Fandy (2001: 250) state that broadly speaking, the stages in factor analysis up to factor naming are (1) selecting variables that are worthy of inclusion in factor analysis, (Sari dkk., 2023) (2) after a number of variables are selected, the variables are 'extracted' into one or more factors, and (3) after the factors are formed, the process continues by naming the factors.

Example of Determining Indicators of Variable Learning Methods in Mathematics (fictitious data)

As for a more concrete example, the instrument of how to learn mathematics consists of 68 statement items (P1, P2, P3, ..., P68) (Maulida dkk., 2023). The instrument for how to learn mathematics refers to the boundaries of Oemar Hamalik's way of learning which includes aspects of learning plans, following lessons, workbooks, studying books, discussing, asking questions, memorizing lessons. From these aspects, 68 statement items were compiled (L. R. Putri dkk., 2023). The following are the characteristics of how to learn mathematics (Kamaluddin dkk., 2023).

Determination of indicators of variable ways of learning mathematics

With a trial sample size of 206 respondents and sixty-eight statement items (C1, C2, ..., C68) on how to learn mathematics, 14008 item scores were obtained (Qureshi dkk., 2022). From these scores, factor analysis using varimax rotation obtained the results of factor analysis-1 and resulted in 21 (twenty-one) factors that have an eigen value greater than or equal to one with a cumulative proportion of 84.1% shown in Table 5 and Table 6 below.

Table 4. Eigenvalues of the Correlation Matrix: Total = 68 Average=1

	1	2	3	4	5	6
Eigenvalue	11.751369	5.218811	4.270508	3.650556	3.294340	3.120746
Cumulative	0.1728	0.2496	0.3124	0.3660	0.4145	0.4604
	7	8	9	10	11	12
Eigenvalue	2.733455	2.492512	2.373866	2.264960	1.981678	1.931775
Cumulative	0.5006	0.5372	0.5721	0.6055	0.6346	0.6630

	13	14	15	16	17	18
Eigenvalue	1.716992	1.586425	1.553252	1.405597	1.373018	1.229325
Cumulative	0.6883	0.7116	0.7344	0.7551	0.7753	0.7934

	19	20	21	22	23	24
Eigenvalue	1.132229	1.096121	1.036752	0.915516	0.830713	0.818926
Cumulative	0.8100	0.8261	0.8414	0.8549	0.8671	0.8791

	63	64	65	66	67	68
Eigenvalue	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Cumulative	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

21 factors will be retained by the NFACTOR criterion.

Tabel 5. Rotated Factor Pattern

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
C1	**0.40**	0.13	-0.05	0.23	0.03	-0.09	**0.58**	0.03	-0.13	0.03	-0.16	0.02	-0.03	0.21	-0.17	-0.10	0.06	0.13	-0.23	0.09	0.24
C2	0.08	0.04	-0.01	-0.16	0.03	-0.02	**0.87**	0.10	0.12	-0.06	0.04	-0.01	0.02	0.03	0.09	0.05	0.01	-0.06	0.04	-0.08	0.02
C3	-0.04	-0.06	0.39	-0.20	0.06	0.03	**0.53**	0.07	-0.32	-0.03	-0.04	0.27	0.18	-0.23	0.14	-0.07	-0.00	0.04	0.15	0.09	-0.08

From these 21 factors as an initial source of determining the items that have a factor loading (loading factor) greater than 0.40 on a particular factor and have a small factor loading (□ 0.40) on another factor. With these conditions, 51 items were produced. The factor analysis process can be seen in Table 6 below.

Table 6. Results of the Factor Analysis Process

Factor Analysis	Many Items	Many Factors (eigenvalue >= 1)	Proportion Cumulative (%)	Many Invalid Items	Many Valid Items
1.	68	21	84,1	17	51
2.	51	17	80,3	12	39
3.	39	13	75,4	6	33
4.	33	13	77,7	5	28
5.	28	10	70,8	4	24
6.	24	10	69,4	5	19
7.	19	8	68,9	3	16
8.	16	8	73,8	1	15
9.	15	7	70,1	2	13
10.	13	6	68,4	1	12
11.	12	5	64,1	1	11
12.	11	5	67,4	0	11

Based on Table 5 row 12 column 5, there are no invalid items and there are 5 factors that have eigenvalues >= 1 with a cumulative proportion of 67.4%. For more details, see Table 8 about the items that represent a factor.

Table 7. Rotated Factor Pattern

	F1	**F2**	**F3**	**F4**	**F5**
C2	0.05793	0.30155	**0.77988**	-0.01342	0.10189
C3	0.06537	-0.13593	**0.83347**	0.08044	-0.11182

C6	-0.02319	**0.85307**	0.06926	0.12236	0.20748
C19	0.06091	-0.15076	0.12064	0.23678	**0.79346**
C25	0.20801	**-0.80062**	-0.02151	-0.05883	0.32695
C29	0.01434	0.06633	0.17872	**0.65097**	-0.02496
C37	0.19014	0.01182	-0.26196	**0.69479**	-0.06720
C38	-0.00877	-0.19543	0.28237	0.31463	**-0.58203**
C43	-0.24281	0.11605	0.09905	**0.57235**	0.20616
C65	**0.89083**	-0.01912	-0.00047	0.00789	0.09124
C66	**0.86644**	-0.15609	0.12217	0.00633	-0.02216

Based on Table 7, the items representing factor-1 are C65 and C66; the items representing factor-2 are C6 and C25; the items representing factor-3 are C2 and C3; the items representing factor-4 are C29, C37 and C43; and the items representing factor-5 are C19 and C38.

Factor naming

Santosa and Fandy (2001: 250) state that broadly speaking, the stages in factor analysis up to factor naming are (1) selecting variables that are suitable for inclusion in factor analysis, (2) after a number of variables are selected, the variables are 'extracted' to become one or several factors, and (3) after the factors are formed, the process continues by naming the existing factors. Furthermore, Kaluge (1988: 23) states that the item with the highest factor load means that it contributes the most to that factor, therefore it is used as the basis for guidance in naming. On this basis, factor-1, factor-2, factor-3, factor-4, and factor-5 were named C65 (memorizing lessons), C6 (preparing workbooks), C3 (study plan), C37 (studying books), and C19 (following lessons), respectively.

CONCLUSION

1. Exploratory factor analysis is one of the tools to determine: the number of indicators of a research variable.
2. To determine the number of indicators based on eigenvalues greater than or equal to one, both in the initial factor analysis and in the further analysis.
3. Items are declared worthy of being included in a factor (valid) if the item has a factor load greater than or equal to 0.40 on only one factor.
4. The item that has the highest factor load on a factor contributes the most to that factor, so that item is used as the basis for guidance in naming a factor or indicator.
5. The variable of how to learn math which consists of 68 statement items, obtained 11 valid items with 5 indicators. These indicators are memorizing lessons, preparing workbooks, lesson plans, studying books, and following lessons.

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AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

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