International Journal of Humanities and Social Science Invention (IJHSSI)
ISSN (Online): 2319 – 7722, ISSN (Print): 2319 – 7714
www.ijhssi.org ||Volume 11 Issue 4 Ser. III || April, 2022 || PP. 15-28

Dimension Reduction, Factor Analysis, Scree Plot in Educational Research and Academic Performance

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ABSTRACT:
The purpose of this paper was to demonstrate the usefulness of the Scree Plot when faced with several variable impacting on the academic performance of students. A Dimension Reduction Analysis was performed to generate Scree Plots. Those scree plot had the elbow shaped and below the line were the identified weak factors and above the line were the strong factors. The 7-point Likert scale of Diener et al., (1985) was used in the administered questionnaires. All Ethical Standards were obeyed to while collecting data, thus some limitations in sample size and freshness. Yamane (1967:886) formula was used to get the sample size and the pilot testing was according to the thumb rule proposed by Whitehead et al. ,(2016) , Machin et al. (2018) and Julious (2005). Data was input into the SPSS software of IBM to generate statistical results. When the Eigen Value was set to 2, there were 5 components extracted. The Factor analysis showed that School Leadership has a very dominant impact on the Academic Achievement of Students. The role of the educator, revision time, Policy and peer pressure should not be neglected. More recent impacts have been from Covid 19 Pandemic. From the Plots, some non impacting variables were excluded to get a better-defined Scree Plot. A leader is very often represented by the Rector, Principal and even a Senior member of the School Organization. Even though Teacher was another variable it can also be argued that a Teacher can demonstrate Leadership qualities. Ismail et al (2021) discussed in his paper that the Instructional leadership of the school leader is considered to be a key factor in school effectiveness (Adams, Mooi, & Muniandy, 2018; Alsaleh, 2018; Deniz & Erdener, 2020; Hallinger& Murphy, 1985) and educational scholars have suggested various instructional leadership models. Hallinger and Murphy (1985) Leadership model identifies three dimensions of the instructional leadership: Defines a School Mission, Manages the Instructional Program, Develops a Positive School Learning Climate.
KEYWORDS: ***Dimension Reduction , Scree plot , Factor Analysis , Education , Performance, Leadership***

Date of Submission: 14-04-2022 Date of Acceptance: 30-04-2022

I. INTRODUCTION

As described by Adegun (2005) , various educational researches are aimed at establishing interrelationships among variables and every aspect of research needs fundamental characteristics and components , and these are called variables. A variable must above all be manipulable and not necessarily something that will be measured. The researcher can also manipulate and control is the same way as obtainable in experimental research. Variables can be defined as a feature, characteristics possessed by the members of a population (Uzoagulu, 1998). It is something that varies or changes in value according to situations or how treated (Nwankwo and Emunemu, 2014).

Adegun (2005) further added that describe a variable as something that is capable of taking different values and the value of any particular variable depends on the condition it is being subjected , at that time it is being obeserved or collected. A variable can be social class, social status, level of education, sex, attitude, age, experience, teaching method among others (Aderounmu and Duyilemi, 1988) Best and Kaln (1986) stated that variables are the conditions or characteristics that the experimenter manipulates, controls or observes. They are the main elements and ingredients of research and the basis of a research work. It therefore implied that, without variables, there would be no research. Variables are the heart of the research. A variable is an object, event, idea, feeling, time period or any other category one is trying to measure. It is important to state that variables may have the following characteristics such as: a period when they start or stop, they must have a pattern such as daily, weekly, ad-hoc and monthly, they are quite detailed with an overview of in depth among others. The problem arise when there are too many variables for a same field of study. The field of education comprises many impacting variables. The solution is to put emphasis on a few variables rather than some others. In academic writing for a valid and reliable research , a researcher cannot decide by his own opinion, intuition , even experience on what variables to consider, what variables he would put forward and what to set aside. Research is not a gambling of what to consider and give importance and what to neglect and bypass. It is where

Dimension reduction , factor analysis comes into context. Costello & Osborne (2005) stated that dimensionality-reduction scientific, valid and reliable techniques such as Exploratory Factor Analysis (EFA) and Principal Component Analysis (PCA) usually require researchers to determine the number of components or factors to retain, to consider and put emphasis upon. One of the most widely used methods for this purpose is Cattell's scree test (Cattell, 1966; Horn & Engstrom, 1979).

II. METHODOLOGY

Research methodology is a systematic way to solve a problem. It is a science of studying how research is to be carried out. Essentially, the procedures by which researchers go about their work of describing, explaining and predicting phenomena are called research methodology. It is also defined as the study of methods by which knowledge is gained. Its aim is to give the work plan of research (Rajasekar et. al.,2006).

Rajsekar, et. al. (2006) stated that there are basically two types of research and applied research. This paper is a basic research. Basic research is described as an investigation on basic principles and reasons for occurrence of a particular event or process or phenomenon. It is also called theoretical research. Study or investigations of some natural phenomenon or relating to pure science are termed as basic research. Basic research sometimes may not lead to immediate use or application. It is not concerned with solving any practical problems of immediate interest. But it is original or basic in character. It provides a systematic and deep insight into a problem and facilitates extraction of scientific and logical explanation and conclusion on it. It helps build new frontiers of knowledge. The outcomes of basic research form the basis for many applied research. The knowledge from this papers cane be used in other higher studies papers and research. Researchers working on applied research have to make use of the outcomes of basic research and explore the utility of them.

Babbie (1989) identifies three purposes of social science research. The purposes are exploratory, descriptive and explanatory. Exploratory research is used when problems are in a preliminary stage. Exploratory research is used when the topic or issue is new and when data is difficult to collect. Exploratory research is flexible and can address research questions of all types (what, why, how). Exploratory research is often used to generate formal hypotheses. Shields & Tajalli (2006) link exploratory research with the conceptual framework working hypothesis. In this paper several academic papers and research in the field were reviewed and adapted to the contextualized problem of a lack of understanding of the importance of Dimension reduction and factor analysis. After exploring the various literature on the topic the information was scrutinized, analyzed and processed in a comprehensible logical way to put forward the argument of the importance of Factor analysis in Educational research.

a) Research Gap

The research gap identified in this papers is as follows :

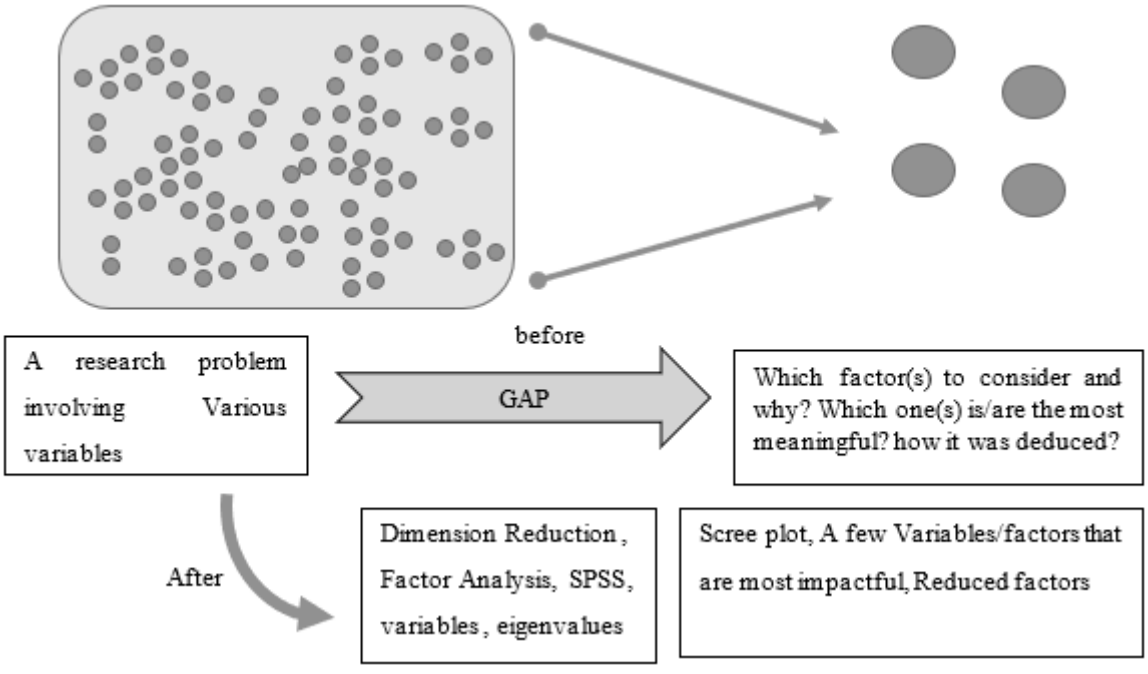


Figure 1 showing The research Gap before and after . SPSS Software is used to perform this operation

b) Research Problem, Objectives and Aim

The research problems identified by this research paper are ;

(i) The lack of understand of the involvement of several variables into research, such as over 20 variables into a research problem and possibility to exclude variables on the Scree Plot, within SPSS itself

(ii) Criticism of how several variables can be reduced to a few

(iii) The importance and use of the Dimension Reduction , factor Analysis operation which can be performed by the SPSS software.

(iv) Ignorance of the meaning of Eigenvalues and interpretation of the Scree Plot

The aim of the research is to provide a concise meaningful understanding of Dimension Reduction, the importance of Eigen Values , factor analysis and the Scree Plot interpretation in Research. This paper can be a contribution to other research that involves several variables such as In Education. Due to Prevailing Covid 19 Pandemic that struck the world like a Meteorite from outer space, till date, that severely affected Education throughout the world. Sc Cambridge examination were cancelled and in some cases postponed for later dates. Schools were locked and student had to stay at home. Online teaching and hybrid teaching learning became a new normal. In Mauritius Universities, ethical clearance from an Ethical Clearance Committee of the Open University of Mauritius was required for any Data Collected as from October 2022. In a study from data collected before the Covid 19 Pandemic, before the cutoff date October 2022, the sample population , that is number of students who attempted Sc exam in 2019, was as follows ;

	Number of students 2019
Boys	6363
Girls	8191
Total	14554

Table 1 showing sample of study. (Source MES ,2022)

Yamane (1967:886) provides a simplified formula to calculate sample sizes. 95% confidence level and P = .5 are assumed for Equation $n = \frac{N}{1+N\,(e)^2}$

Where n is the sample size, N is the population size,
and e is the level of precision

For a homogeneous and valid result the sampling for boys and girls are performed separately. Otherwise , at the end there can be a sample size with an disproportionate number of boys and girls.

$Boys_{\,Sample\ size} = \frac{6363}{1+(6363\,)(0.05)(0.05)} \approx 377$ $\qquad$ $Girls_{\,Sample\ size} = \frac{8191}{1+(8191\,)(0.05)(0.05)} = 400$

Note:

(a) Affected their Performance of SC: 377 boys and 400 Girls , corresponds to students of Grade 12 . These sample population value corresponds to students who have already attempted Sc Examination Grade 11 the previous years. The year the data was collected they had already been through the Experience of SC Exam. These samples also include some who are repeating their Grade 11. Covid 19 Pandemic Factor was not included in the Questionnaires

(b) Affecting their Performance at SC: A similar number of sample population of boys and girls was administered the Questionnaire with nit an added factor Pandemic Covid 19 in 2020. These samples have not yet been through their final examination of SC.

Whitehead et al. (2016) and Machin et al. (2018) described the rule of thumb technique to determine the sample size for a pilot study. Julious (2005) proposed a Sample size of 12 per group rule of thumb for a pilot study.

For the collection of Quantitative data, online Questionnaires were used and administered to the sample population. The HUN School of Princeton (2019) argued that Classroom sizes across the U.S. have generally been on a declining trajectory, from an average student-teacher ratio of 22:1 in 1970 to 15:1 in 2008. This trend is a positive one indicating that educational systems recognize the importance of reducing the ratio as much as possible. The Indian education system lacks teachers with a reported pupil-teacher ratio (PTR) at senior secondary schools is 47:1 as against 26:1 of the overall school system. OECD states that On average across OECD countries, there are 15 students for every teacher in primary education and 13 students per teacher in lower secondary education. The average school class has 21 students in primary education and 23 students in lower secondary education (OECD iLibrary,2022).

Educator $_{Sample\ size} \approx Boys_{Sample\ size}$ / 13 = 29 . For a homogeneous and reliable sample, 29 Women Educators and 29 Men educators are the sample size.

Sample	Year	Variables difference	Sample size	
			Boys	Girls
Sample A, Factors that Affected their Performance	They have been through SC exam of Oct/Nov 2019	SC Aggregate available	377 **One Scree Plot**	400 **One Scree Plot**
Sample B, Factors that are Affecting their Performance	They have NOT yet been through SC exam Before September 2020	SC Aggregate not available New factor Pandemic	A similar sample size 377 Boys. **One Scree Plot**	A similar sample size 400 Girls. **One Scree Plot**
Sample C		Before September 2022	29 Men **One Scree Plot**	29 Women **One Scree Plot**

Table 2 Showing 3 sample population, Affected, affecting and educators

III. DISCUSSION

a) Ethics importance

CUoL (2022) emphasized on the importance of ethics. This paper has abided to all ethical standards. Ethical standards imply namely informed consent to any participants. Purpose and aim of the research informed to all participants. In case of minor participants, permission asked from their responsible parties. Assurance given to responsible parties that in no way the research will cause prejudice to any of their ward. The whole research process was confidential. Participants, the sample take part voluntarily, free from any coercion or undue influence,

respect of rights, dignity and autonomy of any participant. Any risks involved was notified to participants as well as the benefits. Equal treatment to every category of people of the society and the field. No discrimination and no community set aside, unless voluntarily demanded to be excluded from the research. No conflictual interested was entertained. In researchers involving human and animal testing, some further ethical standards need to be obeyed. As Civil Servant of the Government, there are also some Ethical code of conduct to abide to , even as a researcher.

b) Factor Analysis and Dimension Reduction

Child (2006) stated that Factor analysis uses mathematical procedures for the simplification of interrelated measures to discover patterns in a set of variables (Child, 2006). According to Harman (1976), parsimony is the attempt to discover the simplest method of interpretation of observed data is known as parsimony, and this is infact factor analysis and dimension reduction. Costello & Osborne (2005) argued that dimensionality-reduction techniques such as Exploratory Factor Analysis (EFA) and Principal Component Analysis (PCA) usually require researchers to determine the number of components or factors to retain . One of the most widely used methods for this purpose is Cattell's scree test

(Cattell, 1966; Horn & Engstrom, 1979). The scree test is a heuristic graphic method that consists of:

a. plotting the eigenvalues (y-axis) against the components (x-axis), and
b. inspecting the shape of the resulting curve in order to detect the point at which the curve changes drastically (and the "scree on the hill slope" begins).
c. This point on the curve indicates the maximum number of components to retain. While the approach is simple and generally useful, such an intuitive but also fuzzy procedure has been criticized as subjective (Zwick & Velicer, 1982).

It should also be precised that Technological advancement in both field of computational analysis and research has led to advanced software like the SPSS that were not present in those years of research of Zwick & Velicer (1982). Dimension reduction can now be performed scientifically with high precision.

c) Mathematical Interpretation of Factor Analysis

In the 'classical factor analysis' mathematical model, p denotes the number of variables $(X_1, X_2, X_3, \dots \dots X_p)$ and

m denotes the number of underlying factors $(F_1, F_2, F_3, \dots . F_m)$. Xj is the variable represented in latent factors. Hence, this model assumes that there are m underlying factors whereby each observed variables is a linear function of these factors together with a residual variate.

This model intends to reproduce the maximum correlations.

$$X_{j=}\ a_{j1}F_1 + a_{j2}F_2 + \cdots \dots \dots \dots . a_{jm}F_m + e_j$$

where *j* = 1,2.3...p

where, the factor loadings are $a_{j1} + a_{j2} + \cdots \ldots \ldots a_{jm}$
which denotes that a_{j1} is the factor loading of j the variable on the 1st factor.
The specific or unique factor is denoted by e_j
The factor loadings give us an idea about how much the variable has contributed to the factor; the larger the factor loading the more the variable has contributed to that factor (Harman,1976). Factor loadings are very similar to weights in multiple regression analysis, and they represent the strength of the correlation between the variable and the factor (Kline, 1994).
The fundamental theorem of factor analysis, which is used in the common factor analysis model, is illustrated in the equation , $R_{m \times m} - U^2{}_{m \times m} = F_{m \times p} F'_{p \times m}$
where $R_{m\ x\ m}$ denotes the correlation matrix, $U^2{}_{m\ x\ m}$ is the diagonal matrix of unique variances of each variable, and $F_{m\ x\ p}$ represents the common factor loadings (Rummel, 1970).
Factors are rotated (Rotation Methods) for better interpretation since unrotated factors are ambiguous. The goal of rotation is to attain an optimal simple structure which attempts to have each variable load on as few factors as possible but maximizes the number of high loadings on each variable (Rummel, 1970).

c) Eigen values and Number of Factors to Retain

Extracting too many factors may present undesirable error variance but extracting too few factors might leave out valuable common variance. So it is important to select which criterion is most suitable to your study when deciding on the number of factors to extract. The eigenvalues and scree test (i.e., scree plot) are used to determine how many factors to retain. One criterion that can be used to determine the number of factors to retain is Kaiser's criterion which is a rule of thumb. This criterion suggests retaining all factors that are above the eigenvalue of 1 (Kaiser, 1960). Another criterion is based on Jolliffe's criterion which recommends retaining factors above .70 (Jolliffe, 1986). It has been argued that both criteria may result in overestimation in the number of factors extracted (Costello & Osborne, 2005; Field, 2009); therefore, it is suggested to use the scree test in conjunction with the eigenvalues to determine the number of factors to retain.

d) SPSS steps to Dimension Reduction

Step 1. The first step in Dimension reduction is to identify the variables in the research context. In the field of education, the variables that come into play in research involving the academic performance of students are tabulated in table2 . These variables were identified and extracted from literature and past research in the field of education.

1. policy and reforms	9. peer pressure	17. School Environment, culture and school climate
2. gender	10. school leadership	18. Punctuality
3. technology	11. teacher affects	19. Student-teacher ratio
4. involvement of parents	12. revision time	20. Resources available
5. occupation of the parents (socio economic status)	13. private tuition	21. Language of learning and teaching LOTL
6. Syllabus, content and curriculum	14. sleeping pattern	22. Intellectual abilities
7. basic needs.	15. discipline problems	23. Quality Assurance and Inspection Division
8. psychosocial problems	16. motivation impact	24. Performance Management System
		25. Schooling Costs and examination fees
		26. Pandemic (added Variable in March 2020)
		27. Climatic Conditions

Table 2 Showing List of Identified variables (Source : From various literature)

Step 2 A Questionnaire was designed , sample sizes identified (Yamane ,1967:886) and pilot tested (Whitehead et al. ,(2016) , Machin et al. (2018) and Julious (2005))
Step 3 All Ethical standards were observed and the local cutoff date September 2020.
Step 4 Administering the Questionnaire to Sample Boys , Sample Girls and Sample Educators. The likert Scale was used in the questionnaire. This type of scale was developed by a researcher, named Likert (1931), who described and then developed this technique for the assessment of attitudes in psychology. Jamieson (2004) stated that usually, there are 5 categories of response ranging from 5 = strongly agree to 1 = strongly disagree with a 3 = neutral type of response. For this research , the seven-point Likert scale (1 = strongly disagree, 7 = strongly agree) of Diener et al., (1985) was used.

IV. FINDINGS

Step 5. A Cronbach Alpha Reliability test was performed for each questionnaire and was found to be acceptable.
Step 6. The questionnaires Administered to the 3 sample population.
Step 7. Data was input into SPSS Software (IBM)
Step 8. The 6 plots of Scree diagram were generated

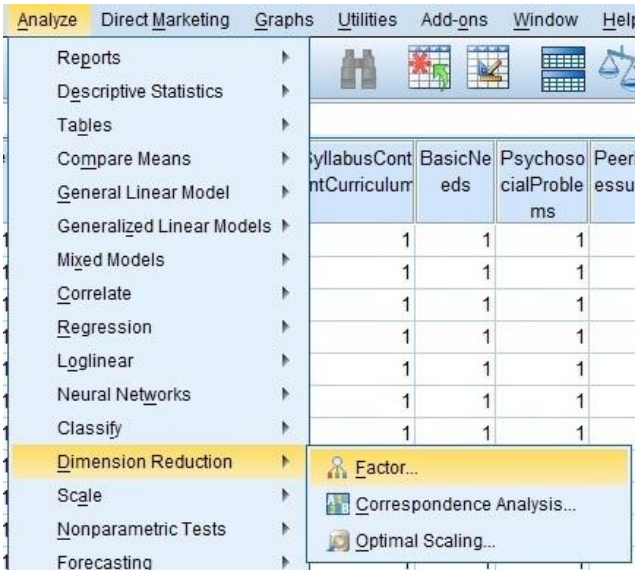


Figure 2 showing Statistics

Analyze > Factor

Figure 3 showing Statistics

Input of variables to the right side

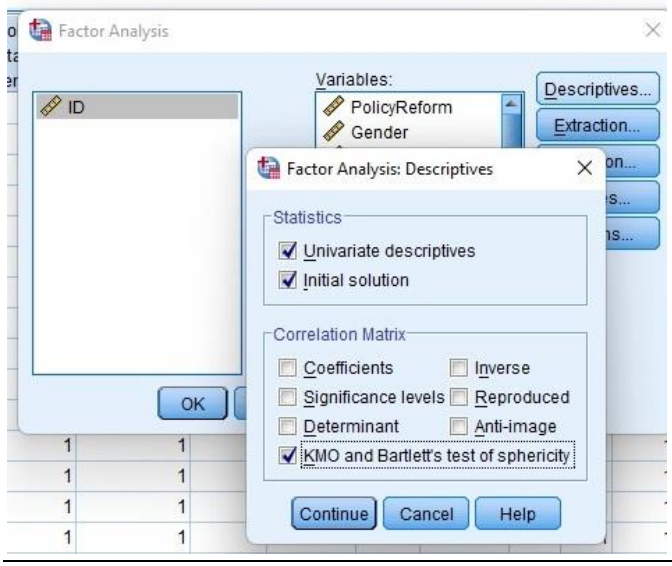


Figure 4 showing Statistics

Descriptives

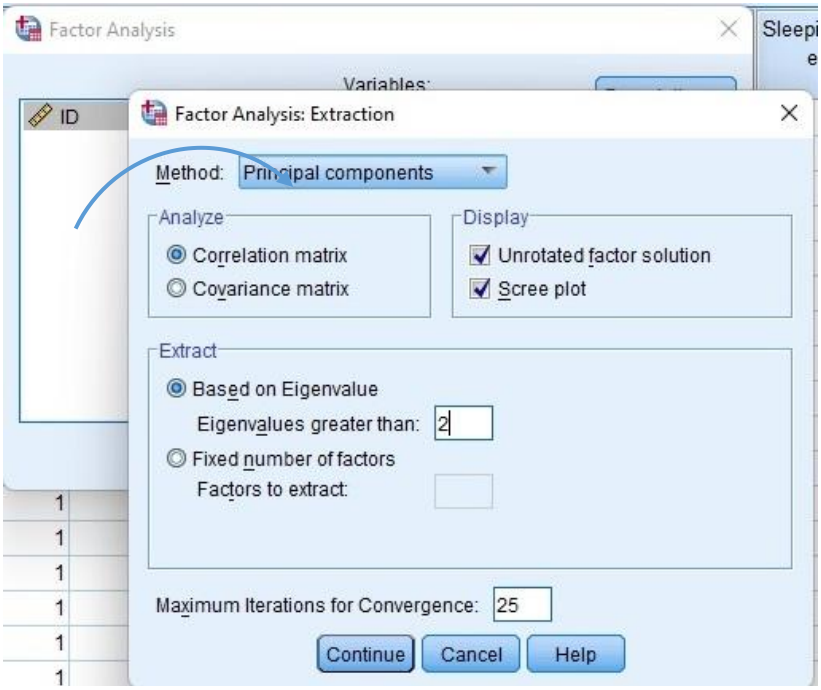


Figure 5 showing Statistics

Extraction > Scree Plot

Eigenvalues greater than 2

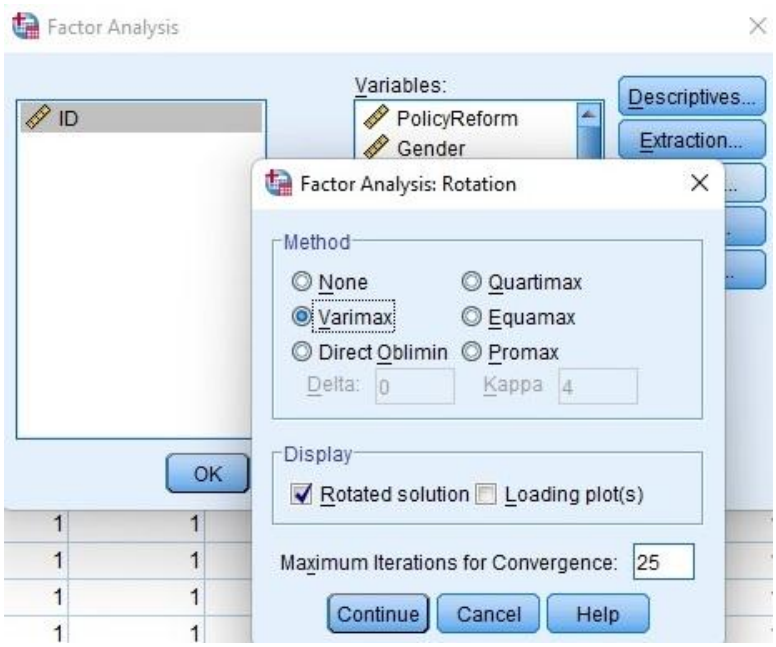
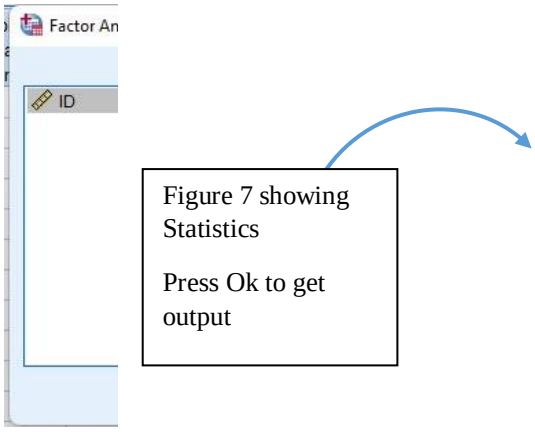


Figure 6 showing Statistics

Rotation > Varimax



The scree Plot generated was as follows.

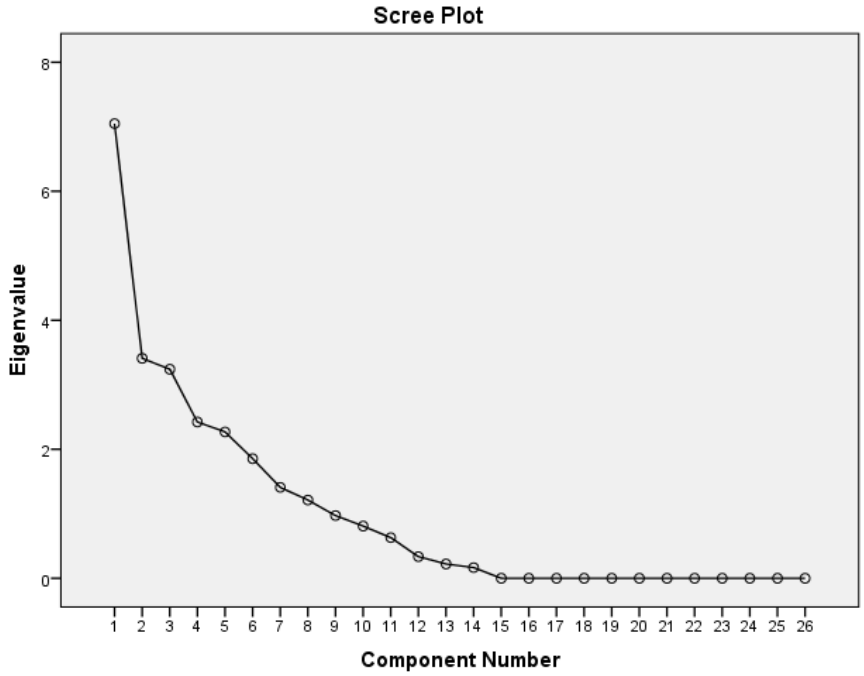


Figure 8 Scree Plot for Sample A boys Affected .Source From SPSS IBM processed output

The procedure was repeated for the other sample A , B and C. From the Output of the analysis, two important deductions can be extracted;

Note (1) The elbow shape appears well defined indicating that there are some impacting factors extracted. The Eigen Value was set to value of 2 and 5 factors were Extracted having an impact. The table of Total Variance Explained as shown below on figure 9 displays the % Variance of the factors.
Note (2) School leadership factor overshadows all the other factors as having more impacted. Teacher , Revision time , peer pressure and Policy factors have a strong impact. Pandemic Factor in the Sample B , shows to be impacting on students performance.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.048	27.106	27.106	7.048	27.106	27.106	5.802	22.315	22.315
2	3.410	13.115	40.221	3.410	13.115	40.221	3.656	14.061	36.376
3	3.241	12.465	52.686	3.241	12.465	52.686	3.354	12.901	49.277
4	2.423	9.318	62.004	2.423	9.318	62.004	3.069	11.806	61.083
5	2.269	8.727	70.731	2.269	8.727	70.731	2.509	9.648	70.731
6	1.854	7.130	77.860						
7	1.409	5.420	83.280						

Figure 9 displays the % Variance of the factors

Note (3) As it can be seen on figure 10, If a line is drawn at the set Eigen Values of 2, it can be deduced that below the line indicates weak impacting factors. Above the line are Strongly impacting factors.

Note (4) If some factors that are less impacting are Excluded from the plot, another scree plot can be plotted as seen on figure 11.

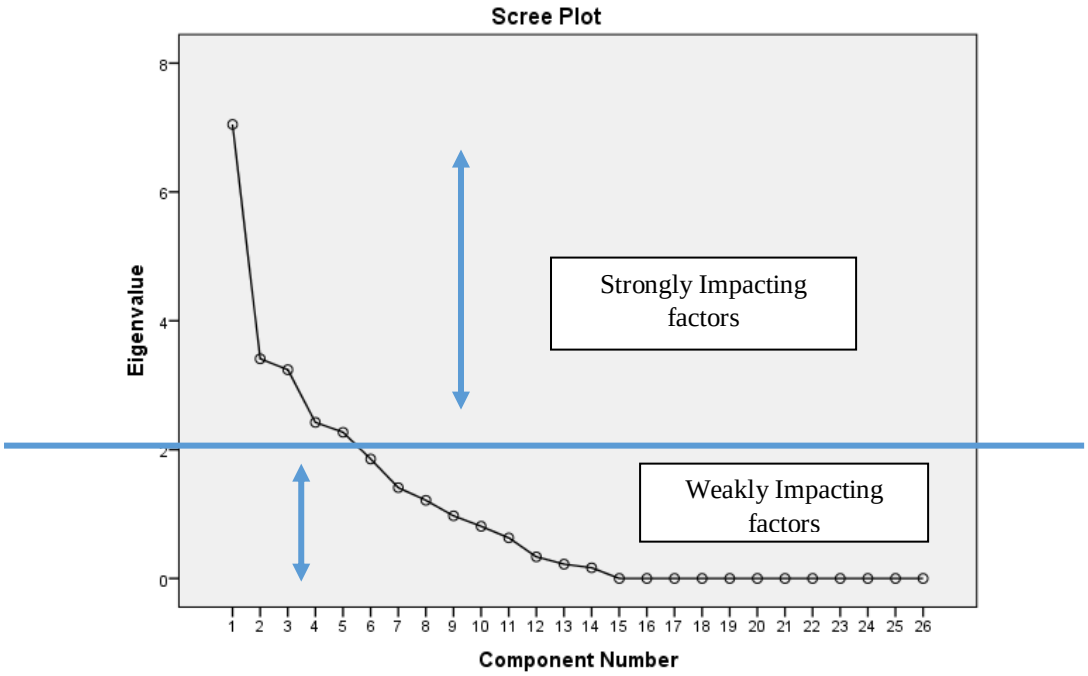


Figure 10 Showing Strong and Weak factors , drawn at Eigen Value

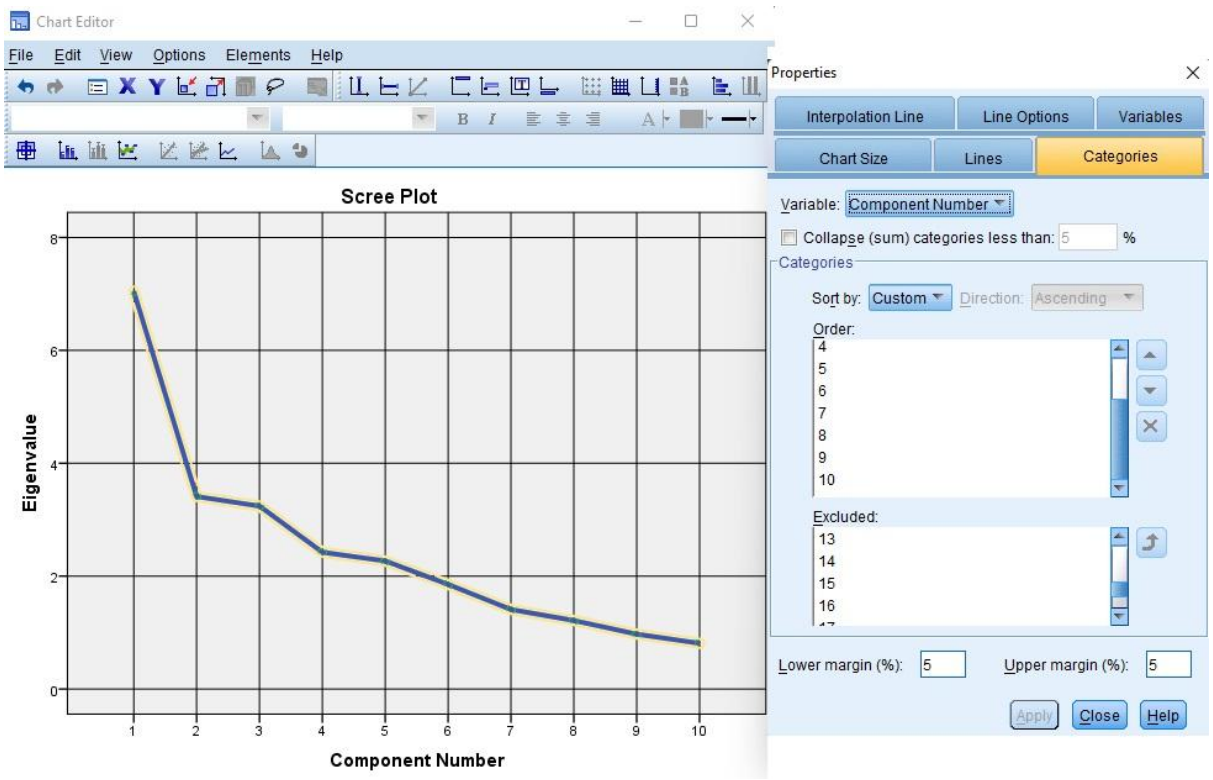


Figure 11 showing Scree Plot with some Excluded variables.

It is also interesting to observe that even if a researcher has several variables, anyone with sound knowledge of SPSS can easily excluded some variables that are too weak and keep the strongest factors. In this way, the research can be computed with many variables.

V. CONCLUSION

In Greek Mythology , the Titan Atlas is portrayed as carrying a huge stone, the Earth. It is from that posture that the name Scree plot, Elbow shape was named. Scree represents as if falling small pieces of stone.

Figure 12 Showing Titan Atlas. (Source Sparks Gift Wholesalers, 2022)

As conclusion, it can be said that Dimension reduction Technique is a solid and reliable test and very conclusive. It is not just a plot to get a beautiful elbow shape graph but to identify the weak and strong factors. There are certainly several other methods of data reduction , data analysis other than factor analysis and the Scree Plot, but this paper has provided an insight of what factor analysis is about and how it can be used in Educational Research.

3 different samples were used since the factors that impacted and are impacting are significant. The Covid 19 Pandemic had its impact in future results of students. School Leadership has once again been the most impactful factor that impacted on academic performance of students. School Leadership is represented by the Rector, Manager, Principal and even Senior Educators in the school organisations. Teacher was a variable but a Teacher also can demonstrate leadership qualities. Schermerhorn (2011) defined leadership as the process of influencing other people, here it is students and educators, and the process makes it easy for someone or group's effort to accomplish their goals. Macawimbang (2012) stated that leadership is the capability of others to work

together undertakes direction to accomplish certain designated objectives. Pont et al (2008) argued that Educational leadership functions can contribute in making provision of guidance on the main characteristics, tasks and responsibilities of proficient leaders in the field of education.

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DEDICATION

While confined two weeks at home to recover from a Head Surgical Operation, I finished this research paper. I, Mr Yudhistir S.M.F. Jugessur dedicate this Research paper to my mother, who during these difficult times of solitude, has always been by my side and my only support. ' Doing far more, with far less'.