# ANALYSIS OF VARIANCE AND ITS APPLICATIONS IN MACAU EDUCATIONAL RESARCHES

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*ABSTRACT*

*In 2012, Macau government approved and passed the "System Framework for Private School Teaching Staff of Non-tertiary Education" in the legislative council. It is aimed at improving non-tertiary teachers' professionalism in terms of setting hierarchies and provides training continuously. Teachers having a high level of research capacity can improve and solve education issues in Macau. Education Statistics are one of the important methods in research capacity. To develop this idea, therefore, my topic is "Analysis of variance and Its Applications in Macao Educational Researches".In this paper a series of statistical methods will be studied, namely, ANOVA, ANCOVA and MANCOVA. They can be used to analyze multivariate data. Knowledge of these techniques will enable researchers to investigate and answer a vast array of research questions. This paper will apply also a real example in educational field in order to explain the manipulation of ANOVA, ANCOVA and MANOVA for data analysis.*


*Keyword:   ANOVA   ANCOVA   MANOVA   Educational Researches*

## 1.    ISSUE ON NON-RESEARCH COMMITING TEACHERS IN MACAU

In 2012, Macau government approved and passed the "System Framework for Private School Teaching Staff of Non-tertiary Education" (below it is called "framework") in the legislative council. It is aimed at improving non-tertiary teachers' (below it is called "teacher") professionalism in terms of setting hierarchies and provides training continuously. The framework regulates teacher with many aspects of evaluations. Educational evaluation is one aspect of educational researches. In addition, some of the teachers will conduct educational researches in order to develop their professional development. Therefore, educational researches are essential in Macau. Moreover, we need to apply many statistical instruments into educational researches. Thus, it is very important for understanding statistical knowledge in Macau.

On the aspect of training, however, Universities and government focus on developing teaching methodology of the teachers in Macau, yet leave their research capacity completely behind when it comes to evaluations. Teachers having a high level of research capacity can improve and solve lots of education issues in Macau. Education Statistics are one of the important

methods in research capacity. In 2012/2013 academic year, there are 5,284 teachers in Macau. In 2011/2012 academic year, there are 126 postgraduates studying master degree of educations. And there are 60 master graduates in educational field in 2011.

Educational researches should have been very popular and prominent in Macau because of the large number of teachers and researchers engaged in. Yet the reality is that the workloads of teachers are overburdened. Daily administrative works and various workshops have already consumed most of their time. Indeed they do not have much spare time to carry out researches, not even to read a book. Another problem is the lack of practice of research methodology and instruments, especially in the field of statistical analysis. Teachers generally do not know very much how to conduct in-depth statistical analysis in educational researches. Usually teachers may get some general descriptive results, but the degree of interpretations can be enriched further. These factors are obstructing the development of educational research in Macau.

The definition of statistical method is the means of a person deployed in one's data to collect, analyze and concluded a series of results. Statistical method can generally be divided into two categories: "Descriptive Statistics" and "Statistical Inferences". In general, Descriptive Statistics refers to the quantitative data processing in order to show the overall tendency of data into charts and table. Statistical Inferences, on the other hand, concludes a result from dataset under a parameter in the principle of random variation. In this article, the method of Statistical Inferences will be used in discussing the statistical models.

## 2. HOW TEACHERS IN MACAU CAN APPLY ANALYSIS IN EDUCATION RESEARCH

Teachers and researchers of education in Macau are mainly focusing on two major areas of emphasis, namely, History of Education" and "Curriculum and Instruction". Subsequent interested disciplines will be "Educational Psychology", "Guidance and Counseling", "Educational Administration" and "Educational Evaluation ". Most of these fields' research method commonly adopts quantitative research. Therefore, analysis of variance is one of the common statistical tools to utilize. About the popularity of the models, researchers concentrate on the one way variance analysis (ANOVA), yet the multi-variance analysis is usually left behind comparatively. However, the solely use of one way variance analysis is not sufficient to provide in-depth analysis, because it is not able to provide analysis on the relationship among continuous variance. Researchers in Macau seldom apply this method, not because the method itself is difficult to master, but because it does not have much application examples and experience.

The main content of this article is the discussion on Analysis of Variance with its applications to educational researches. Using Analysis of Variance ANOVA can generate more in depth information and provide a more comprehensive analysis. I hope this article can successfully serve as a reference for all the interesting parties when they are trying to apply Analysis of Variance ANOVA to identify situations and assist analyzing accuracy.

## 3. INTERRELATIONSHIP ACROSS DIFFERENT TYPES OF ANALYSIS OF VARIANCE, THAT IS, ANOVA, ANCOVA AND MANCOVA.

### I. Analysis of Variance (ANOVA)

ANOVA is used to uncover the main and interaction effects of categorical independent variables (called "factors") on an interval dependent variable. It tests the null hypotheses that group means do not differ. It is not a test of differences in variances, but rather assumes relative homogeneity of variances. Thus some key ANOVA assumptions are that the groups formed by the independent variable(s) are relatively equal in size and have similar variances on the dependent variable ("homogeneity of variance")

### II. Analysis of Covariance (ANCOVA)

ANCOVA is used to test the main and interaction effects of categorical variables on a continuous dependent variable, controlling for the effects of selected other continuous variables that cover with the dependent. The control variable is called the "covariate." There may be more than one covariate.

### III. Multivariate Analysis of Variance (MANOVA)

MANOVA is the technique used for assessing group differences across multiple metric dependent variables simultaneously, based on a set of categorical (non-metric) variables acting as independent variables.

Since, Analysis of Variance (ANOVA) is a method; I will discuss what it is all about, including the meaning in statistical definition, how this principle comes out, and the methodology to conclude and to analyze data. On the other hand, it's true that it is often treated as an application or program in computer software. Therefore, we have to understand how we can use this application to generate results in viewing the operation in software.

Similarly on one hand, their dependent variables must be continuous, and share the same foundation in their principle: Identifying F-value. On the other hand, they have different focuses and foundations that make them different. The main difference of ANOVA, ANCOVA, MANOVA is following.

i   ANOVA: There is only one continuous variable in constituting the dependent variable.
ii   ANCOVA: In the independent variables, at least one continuous variable will be presented. That is covariate.
iii   MANOVA: More than one continuous variables in constituting the dependent variables.

# 4. SONE PRACTICAL EXAMPLES OF USING ANALYSIS OF VARIANCE IN EDUCATION RESEARCH

We use Ms Ho's data. Her objective is to know Meaning of Life for high school student in Macau. In her thesis, Ms Ho used One-way ANOVA to respectively investigate the correlations between Meaning of Life and family condition.

Table 1 illustrates the high school students of different perceived Family Conditions. It includes Financial Condition, Harmonic Phenomenon, Normal Family and Single Parent Family.

Table 1. The Sample Distribution of Family Condition

| Family Condition | Item | Frequency | Percentage |
|---|---|---|---|
| Financial Condition | Excellent | 50 | 4.38 |
| | Good | 326 | 28.57 |
| | Average | 700 | 61.35 |
| | Bad | 65 | 5.70 |
| | Total | 1141 | 100.00 |
| Harmonic Phenomenon | Excellent | 116 | 10.17 |
| | Good | 401 | 35.14 |
| | Average | 541 | 47.41 |
| | Bad | 83 | 7.27 |
| | Total | 1141 | 100.00 |
| Normal Family | Live with parents | 896 | 78.53 |
| | Mother work aboard and live with father only | 11 | 0.96 |
| | Father work aboard live with mother only | 62 | 5.43 |
| | Parents work aboard and live with relatives | 23 | 2.02 |
| | Total | 992 | 86.94 |
| Single Parent Family | Divorce and live with father | 12 | 1.05 |
| | Divorce and live with mother | 55 | 4.82 |
| | Single parent work aboard and live with relatives | 14 | 1.23 |
| | Single parent and live with relatives | 40 | 3.51 |
| | Total | 121 | 10.61 |
| Missing Value | | 28 | 2.45 |
| Total | | 1141 | 100.00 |

The "Meaning of Life" is a measurement that tests one's perspective towards his live. It is initially set in the questionnaire design. They are a series of questions, each of which are categorical variable. Then we compare the reliability (0.8690) of a set of variables. If the reliability is not too low, then we could sum them up to become a continuous variable.

Table2: The Distribution of Meaning of Life

| Item | | Frequency | Percent |
|---|---|---|---|
| Meaning of Life | Below 85 | 362 | 31.73 |
| | 85 to 101 | 391 | 34.27 |
| | Above 101 | 388 | 34.01 |
| | Total | 1141 | 100.00 |

The highest and the lowest score in this variable are 140 and 11. We divide this variable "Meaning of Life" into 3 groups: Below 85 (31.73%); Between 85 to 101 (34.27%); and above 101 (34.01%). The reason why it is better to break this variable into 3 groups is because of the calculability. Breaking the values into 3 groups can change the type of the variable from continuous to discrete. A discrete variable is convenient for researchers to observe the frequency and generalize results.

**I. The example of ANOVA**

After identifying the tendency, we can use ANOVA to identify whether there are differences between the above variables and Meaning of Life.

We select a small part only to find out the difference between Family Condition and Meaning of Life. The independent variables are personal background, Family Condition and Meaning of Life. This is because they contain some relationships between them, which cannot be reflected by using ANOVA.

The row labeled "Between Groups", having a probability value associated with it, is the only one of any great importance at this time. The other rows labeled "Within Groups" are used mainly for computational purposes. Researchers would most probably first look at the value "0.000" located under the "Sig." column.

Of all the information presented in the ANOVA table, the major interest of the researchers is most likely the values located in the "Sig." column. If the numbers found in this columns are less than the critical value ($\alpha$) set by the experimenter, then the effect is said to be significant. Since this value is usually set at 0.05, any value less than this will result in significant effects, while any value greater than this value will result in non-significant effects.

Table3: One-way ANOVA of Family Condition and Meaning of Life

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Financial Condition Vs Meaning of Life | Between Groups | 22040.8 | 3 | 7346.9 | 22.4 | 0.000 |
| | Within Groups | 373660.7 | 1137 | 328.6 | | |
| | Total | 395701.5 | 1140 | | | |
| Harmonic Phenomenon Vs Meaning of Life | Between Groups | 46604.1 | 3 | 15534.7 | 50.6 | 0.000 |
| | Within Groups | 349097.4 | 1137 | 307.0 | | |
| | Total | 395701.5 | 1140 | | | |
| Normal family Vs Meaning of Life | Between Groups | 2850.7 | 3 | 950.2 | 2.7 | 0.043 |
| | Within Groups | 343721.8 | 988 | 347.9 | | |
| | Total | 346572.4 | 991 | | | |
| Single Parents Family Vs Meaning of Life | Between Groups | 546.1 | 3 | 182.0 | 0.6 | 0.648 |
| | Within Groups | 38628.7 | 117 | 330.2 | | |
| | Total | 39174.8 | 120 | | | |

If the effects are found to be significant using the above procedure, it implies that the means differ more than they would be expected by chance alone. In terms of the above experiment, it would mean that the treatments were not equally effective. This table does not tell anything about what the effects are, just that they are most likely real effects.

If the effects are found to be insignificant, then the differences between the means are not great enough to tell that they are different. In that case, no further interpretation is attempted.

This result of the investigation shows that Single Parent Family is not different regarding Meaning of Life. The Normal Family, Financial Condition and Harmonic Phenomenon are different in Meaning of Life. The investigation shows that there is a notable difference between different Financial Condition and Meaning of Life, Harmonic Phenomenon and Meaning of Life. The result that I have found is consistence with Ms. Ho's research finding in.

**II. The example of ANCOVA**

In this following part, I will run the ANCOVA with reference to Ms. Ho's data. She did not analyze using this method in her thesis. Therefore, I will apply this method to see whether it complies with the result she found.

Table 4: ANCOVA of Family Condition and Meaning of Life

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 58904.93 | 4 | 14726.23 | 51.0 | 0.000 |
| Intercept | 268494.94 | 1 | 268494.94 | 929.1 | 0.000 |
| Future Perspectives | 36842.07 | 1 | 36842.07 | 127.5 | 0.000 |
| Financial Conditions | 19349.64 | 3 | 6449.88 | 22.3 | 0.000 |
| Error | 326259.04 | 1129 | 288.98 | | |
| Total | 10202060.00 | 1134 | | | |
| Corrected Total | 385163.97 | 1133 | | | |
| Corrected Model | 83372.79 | 4 | 20843.20 | 78.0 | 0.000 |
| Intercept | 276109.54 | 1 | 276109.54 | 1032.9 | 0.000 |
| Future Perspectives | 38689.60 | 1 | 38689.60 | 144.7 | 0.000 |
| Harmonic Phenomenon | 43817.50 | 3 | 14605.83 | 54.6 | 0.000 |
| Error | 301791.17 | 1129 | 267.31 | | |
| Total | 10202060.00 | 1134 | | | |
| Corrected Total | 385163.97 | 1133 | | | |
| Corrected Model | 39434.28 | 4 | 9858.57 | 32.5 | 0.000 |
| Intercept | 144554.75 | 1 | 144554.75 | 477.0 | 0.000 |
| Future Perspectives | 36502.17 | 1 | 36502.17 | 120.5 | 0.000 |
| Normal Family | 3617.02 | 3 | 1205.67 | 4.0 | 0.008 |
| Error | 297267.24 | 981 | 303.02 | | |
| Total | 8941046.00 | 986 | | | |
| Corrected Total | 336701.51 | 985 | | | |
| Corrected Model | 3388.86 | 4 | 847.21 | 2.7 | 0.032 |
| Intercept | 29008.84 | 1 | 29008.84 | 94.0 | 0.000 |
| Future Perspectives | 2842.74 | 1 | 2842.74 | 9.2 | 0.003 |
| Single Parent Family | 672.04 | 3 | 224.01 | 0.7 | 0.538 |
| Error | 35785.93 | 116 | 308.50 | | |
| Total | 1042086.00 | 121 | | | |
| Corrected Total | 39174.79 | 120 | | | |

Table 4 also shows that the Financial Condition and Harmonic Phenomenon are different in Meaning of Life. The interesting result is that the Normal Family is different in Meaning of Life. The Single Parent Family is not different in Meaning of Life. The control variable (covariate) is Future Perspectives. The meaning of ANOCVA plays an important role to certify whether the

quality of the results obtained from ANOVA is good enough to justify the "real" significant level. Others may draw special accounts in this result to questions about the subjectivity to the Type1 error, and lead to problems in conclusion accuracy.

This is confirmed and reflected in the conclusion provided by Ms. HO. In addition, it is more stable and assured by adding a control variable. If we want to see whether adding the control variable would change the deviation result of those variables, we have to use ANCOVA instead of ANOVA simply because ANOVA can't provide the answer. In the science of education, students' conduct is affected by some particular factors (i.e.: Normal Family), and those factors could not be easily changed, which could be regarded as "stable". We could set them as control variables and see whether it can provide other interesting findings to understand the cause of certain behaviors or conducts in students.

### III. The example of MANOVA

We use MANOVA, we must do so analysis.
1. Multivariate tests between interpersonal relationships in two dependent variables.
2. The sample distribution of personal background.
3. The distribution in different parts of Meaning of Life.
4. The mean and deviation of Meaning of Life in personal background.
5. The correlation of the different part of Meaning of Life.

First, we run the correlation table to determine whether the variables are correlated. The purpose is to design a single, overall statistical test on this set of variables instead of performing multiple individual tests, and use this type of variables to run MANOVA table. MANOVA works well in situations where there are moderate correlations between dependent variables. Therefore, as shown in the table, we have chosen Meaning of Life and A Sense of Independences.

This table illustrates the unvaried effects for the 2 sampled factors and interaction. Same methods regarding the interpretations for the significance of F-test and mean-squared are shared in the multivariate analysis as well as in ANVOA. In this example, all unvariate effects in "Interpersonal Relationship", Meaning of Life is significant, A Sense of Independence is not significant; In the Financial Condition categories factor, Meaning of Life and A Sense of Independence is significant. However, if we figure out the interaction of Interpersonal Relationship and Financial Condition, an interesting result is that they also are significant. The "corrected model" effect reflects the variation in the dependent attributed to other effects (except the intercept).

Table5: Tests of Between-Subjects Effects Between Interpersonal Relationship, Financial Condition and Meaning of Life

| Item | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Interpersonal Relationship | Meaning of Life | 6574.092 | 3 | 2191.364 | 7.537 | 0.000 |
| | A Sense of Independence | 70.57162 | 3 | 23.52387 | 2.524 | 0.060 |
| Financial Condition | Meaning of Life | 7732.989 | 3 | 2577.663 | 8.865 | 0.000 |
| | A Sense of Independence | 161.0772 | 3 | 53.69239 | 5.762 | 0.000 |
| Interpersonal Relationship & Financial Condition | Meaning of Life | 6554.943 | 9 | 728.327 | 2.505 | 0.010 |
| | A Sense of Independence | 204.4919 | 9 | 22.72132 | 2.438 | 0.010 |
| Error | Meaning of Life | 324778.3 | 1117 | 290.7595 | | |
| | A Sense of Independence | 10408.59 | 1117 | 9.318347 | | |
| Total | Meaning of Life | 10192747 | 1133 | | | |
| | A Sense of Independence | 112070 | 1133 | | | |
| Corrected Total | Meaning of Life | 384872.1 | 1132 | | | |
| | A Sense of Independence | 10944.13 | 1132 | | | |

Since MANOVA is used to understand the deviations and influences between multi-variables, regardless the concept of related variables, it is seen as a more complicated application comparing with ANOVA and ANCOVA. However, it also provides the richest information and is useful in educational research. It is useful because there are a lot of factors to explain a student's performance. Some are reflected in dependent variables (i.e. Marks or Performance), others may be in independent variables (Gender or Class). Therefore, we should not rely on a single variable to do the analysis; instead, it requires multi-facets and multi-dimensional thinking and analysis. It is specially the case if educational researchers can apply MANOVA as part of the analysis, results could become more interesting, and provide a deeper dimension.

**5. SOME PROBLEMS AND SUGGESTIONS FOR TEACHERS IN EDUCATION RESEARCH IN MACAU**

Currently there are 5,284 non-tertiary teachers in academic year 2012/2013 in Macau. And it is expected to have more and more teachers joining this field after the approval of the framework. We can see many teachers actually have the ability to become a research-oriented (or academic-oriented) type. We had mentioned in Macau we have 60 graduates in educational discipline each year. And these so called "front-line teachers" can definitely be able to become research-oriented teachers. However, only a very limited number of teachers will conduct researches, mainly due to the lack of demand of these types of teachers. The reason is because our society only wants teachers to so call "teach the students well", and have a high percentage of graduation rates. However, this ignores the essence of education on solving apparent rather than those underlying real issues. These will only accumulate and deepen the problems during the teaching process. On the other hand, some teachers who do not want to become a research-based teacher are mainly due to the excessive workload of teachers, which gives too much pressure to them. Research works often consume a lot of recession time, and finally drain teachers into toil. They will eventually keep working on both researches and teaching simultaneously, and running between deadlines, which will reduce their rest and private time as well.

Another problem is that, whenever studies reveal a variety of issues, it requires teachers, or researches, to analyze and resolve by having proper statistical knowledge. Currently Macau faces two very common issues: first, to create a proper "problem statement" or "research topic"; second, capability of statistical analysis. In fact, when teachers encounter problems on teaching methodology, often they would like to investigate the underlying reasons. This will motivate teachers to begin to conduct researches. However, usually teachers tend to think the "know-how", while ignoring a simple and important step is to "know-what". A good research topic can set a clearer research direction, and reduce the impacts when one is working on a vague topic or idea.

Some of the teachers in Macau do not have sufficient recognition on different statistical tools, and they often conceive of two wrong concept: Research methodology equals the use of certain statistical software; or data collection methods equal statistical analysis. Therefore, teachers tend to think that statistical analysis method is a simple task, and that they failed to take advantage of using proper statistical analysis. The consequence of undermining the statistical analysis process will affect the conclusions, and thus the results are not in-depth enough to understand and apply into real situations. Teachers will soon find difficulties of writing conclusion. Eventually they consider doing researches is a difficult task. To me it is a waste of opportunities as well as their academic capacities. They do not believe that they actually have the abilities to accomplish researches, and disapprove those who have the passion and abilities to become

research-oriented teachers.

With the above issues, here are some suggestions:

i.  To pay more attention to research-oriented teachers. Whenever a front-line teacher would like to carry out researches, more supports will be very much appreciated from their school. Government can consider providing assistances in terms of research funding to good topics. Schools can provide assistance in terms of data collection efforts, or to reduce the number of teaching hours in certain periods so that they can focus to finish researches on time. Policy review on this issue will show more research supports and encourage teachers in Macau to nurture more research-oriented teachers, which will eventually create a good atmosphere in doing various researches.

ii.  Teachers should participate in different study topics. Research capacity can be accumulated by experience. If teachers can participate in various research work, even it is only a small part of a research project, the ability will be able to improve.

iii.  Teachers should try different types of research methods. Not only one can try quantitative research, but also qualitative research, behavioral research and experimental research etc. On a similar or same topic, one can also use a variety of research tools, which can help accumulating more research experience. In turn, teachers can know more different ways statistical analysis, which will increase the ability of summarizing data.

iv.  Encourage teachers to publish or present their findings. Teachers can organize their own research work, compile into articles or reports. And then publish them into journals or different institutions for more discussions. For sure teachers can broaden their vision, as well as to update their education professionalism.

v.  Macau government, community and universities should also help to create the environment for teachers to research. They can organize more training courses for teachers who are interested in doing researches. As a beginning stage, the community can host competitions, seminars and conferences to invite interested parties to publish their findings. Researches can also be considered to count as training hours to fulfill the requirement from the framework. Government, local associations or universities can also invite frontline teachers to be involved in research activities. In this case, the ability of doing researches can be increased. At the same time, our society can also train up more research-oriented teachers.

In fact, educations in Macau have many issues yet to be solved. And these issues can be transformed into different kinds of research topics. Teachers should get to play on,

providing our community will be able to provide a little more support to create such environment. I believe education in Macau will be better ever, and we must achieve a higher educational research outcome.

REFERENCES

[1] Dick Wittink. (1988). *The Application of regression Analysis.* Allyn and Bacon, Inc, 1988, ISBN: 0-20-511252-8

[2] James Lattin , Doucglas Carroll and Paul Green, *Analyzing Multivariate Data*. China Machine Press, 2002, ISBN: 0-53-434974-9

[3] Harold Lindman, *Analysis of variance*, Springer-Verlag New York, Inc. 1992, ISBN: 0-71-670774-8

[4] Bruce King and Edward Minium, *Statistical Reasoning in Psychology and Education*, Fourth Edition, Hoboken, New Jersey: John Wiley & Sons, Inc. 2002, ISBN: 0-47-121187-7

[5] Harlod Lindman, *Analysis of variance in complex experimental designs,* San Francisco: W. H. Freeman & Co. 1974, ISBN: 0-71-670774-8

[6] Andy Field, *Discovering Statistics using SPSS for Windows, Advanced Techniques for the Beginner,* SAGE Publications London. Thousand Oaks. New Delhi. 2000, ISBN: 0-76-195755-3

[7] Rick Turner and Julian Thayer, *Introduction to Analysis of Variance, Design, Analysis, & Interpretation,* SAGE Publications International Educational and Professional Publisher Thousand Oaks. London. New Delhi. 2001, ISBN: 0-80-397075-7

[8] Andrew Rutherford, *Introducing ANOVA and ANCOVA, A GLM Appoach.* SAGE Publications Londo. Thoiusand Oaks. New Delhi. 2001, ISBN: 0-76-195716-1

[9] 詹世煌 方世榮, *統計學導論,* 曉園出版社有很公司, 1990, ISBN: 957-12-0003-4

[10] 朱經明, *教育統計學,* 五南圖書出版有限公司, 1996, ISBN: 957-11-0202-4

[11] 楊曉明, *SPSS 在教育統計中的應用 ,* 高等教育出版社, 2004, ISBN: 7-04-014643-6

[12] 何彩雲, *澳門中學生生命意義感知探討 ,* 碩士論文, 澳門大學, 2006.

[13] 林發欽, *首屆澳門人文社會科學大會論文集 ,* 澳門教育研究的回顧與思考, 澳門基金會, 2007, ISBN: 978-99937-1-042-4