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Use of Statistical Mix to understand statistical competency of agricultural education students

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Abstract— **Investment in research is indeed a "rational" investment. Thesis issues and projects in higher education are the sources of research at educational institutions and have an evident role in helping professionals and researchers. However, lack of fit scientific methods along with the ignorance of the proper processes of science has somewhat diminished the importance of research. This study points out the dire need to examine "standards" which are based on the statistical competency in graduates. Preliminary survey investigations and content analysis of PhD dissertations (N_1= 69) and M.Sc. thesis (n=246 out of N_2=648) in agricultural extension, education and development in Iran showed that the applied statistical procedures were rarely eligible and appropriate. For this study were used combines quantitative methods (survey) and qualitative (content analysis). In the end, student could improve knowledge content about statistic when consideration and using from sequential statistics by agricultural extension and education students, can give them holistic view from using statistical test to exploit of mix and together statistical test.**

Keywords— Statistical Mix; sequential statistical road map; statistical procedure, behavioral research; statistical competency; graduate and post graduate research.

Introduction

Science requires objective evidence before making decisions about the truth or falsehood of a theory. Answering scientific questions demands unbiased observation and testing. Also to obtain appropriate data, knowing and dominating on the superior plan or approach is necessary, so using mix and sequential proper statistical tests to realize accurate outcomes help researchers. Flyvbjerg (2001) argued many researches were driven by a continuing belief that the social and political world could be measured through objective, empirically testable and law-like data indicators. Fincher (1991) stressed that “research on the substantive issues is handicapped by higher education's lack of status and recognition as an academic discipline and or professional specialty”, the issue of understanding research as a disciplined inquiry is still stealth, especially in higher education. Likewise, Dijkum (2001) indicated that analysis of the practice of social research shows there is no easy answer to the question of how the knowledge of the natural sciences can be used to further understanding in the social sciences. It is useful to know that the inseparable section of scientific inquiry is statistical analysis and one of the important sections of statistics is using tests to analyze data. To obtain appropriate data, knowing and dominating on the superior plan or approach is necessary, so using mix and sequential proper statistical tests to realize accurate outcomes help researchers. In this regard, the main problem in conducting M.Sc. theses, Ph.D. dissertations or, even, onward academic or institutional research is that researchers either do not realize their crucial role in choosing, applying appropriate statistical tests and the process of choosing and applying the right test for the right situation (variable combination), or they are not fully aware of the coherence of required consecutive statistical procedures as a core ‘Statistical Mix’. Consequently, choosing and applying the statistical tests seems to become a mere copy-and-paste process for which no initial arguments and intellectual reasoning are offered(MalekMohammadi,2009). In the other hand we need to study that are followed the challenges of combining complex statistics with individual stories, particularly in relation to the ongoing iteration between these different data sets, and issues of validity and reliability(kington et al., 2011)

To eliminate this feeling needs dominate on with improving statistical knowledge and understanding the analysis process. So three key concepts are important in understanding the analysis process. These concepts are (1) system, (2) relationship, and (3) model.

1. A *System* is a group of interrelated, interacting or interdependent elements forming a complex whole. A process or operation may be a system. In this standard the term system refers to the system, process, operation, or other subject being analyzed.
2. A *Relationship* is a statement about the similarities, differences, or interactions of two or more quantities or measurements called variables. Much of the work of operations research lies in identifying the proper variables and true relationships for use in solving a particular problem or evaluating alternatives.
3. A *Model* is a useful representation of the relationships that define a system or situation under study. It may be a set of mathematical equations, a computer program, and a hand played game, a written scenario, an

experiment, or other type of representation ranging from verbal statements to physical objects(Operations Research Series, 1996). So there is need the sequential roadmap based on statistical competency.

But, as indicated by Windish and Diener-West (2006) and Govindrajulue (2004), there are a few, if any, references to the use of sequential statistics in the literature. Although choosing the right statistical test for a particular set of data appears to be an overwhelming task, to Wheater and Cook (2000), particularly if such decisions are rendered after the data are collected, what is overwhelming really, is the sequences and placements (array) of statistical tests to understand their role and mission in the first place. Wheater and Cook (2000) believe that the investigator is definitely responsible for the choice of statistical methods used. Therefore, the researcher must be able to use statistics effectively to organize, evaluate, and analyze the data (Whitney, 2005) and to apply the proper statistical tests. To ease the dilemma, it is helpful to identify the statistical test, as stated by Hoffman (2004), which is a procedure for deciding whether an assertion (e.g., a hypothesis) about a quantitative feature of a population is true or false. There are a few cautionary steps to follow in selecting a statistical test in educational research; firstly, because of the high number of variables involved and secondly, because of the involvement of a considerable number of latent (unobserved) (Vermunt and Magidson, 2003), hidden (Moyulsky, 1995), and discrete variables.

Watt and Berg (2002) stressed that the choice of the correct statistical test depends on the definition of the variables, particularly upon their level of measurement. It also depends on the research design used and the nature of the hypotheses: are they comparative or related; is there more than one independent variable?

Since, students have problems to learn statistics (Meletiou & Lee, 2002). It may be because of some wrong learned statistical concepts and applications. Malek Mohammadi (2009) posed a model in the sequential statistical analysis approach (SSAA) to present a mixed and sequential method. In this model, he mixed three phases and divided each phases to several steps that researchers should use them to refine and improve research; they are as following:

According to Tabachnick and Fidell (2007), since each statistical technique has specific assumptions, therefore, before applying any technique, or sometimes even before choosing a technique, it should be determined how the data fits some very basic assumptions underlying most of the multivariate statistics. Moreover, each statistical technique has some limitation along with its advantages.

Therefore no statistical test can replace the other under the very same circumstances. For instance, while Hill and Lewicki (2007) identified multiple regression as "a seductive technique as plug in as many predictor variables as you can think of and usually at least a few of them will come out significant". Eventually, many difficulties tend to arise when there are more than five independent variables in a multiple regression equation.

One of the most frequent is the problem of two or more independent variables being highly correlated to one another. This is called multicollinearity. If a correlation coefficient matrix with all the independent variables indicates correlations of 0.75 or higher, then there may be a problem with multicollinearity. Primary investigations of M.Sc. theses and Ph.D. dissertations as supervisor, co-supervisor, external examiner, and researcher, revealed major challenges concerning selection and application of legitimate statistical techniques. This investigation showed that in majority of the cases, graduate and post graduate students are seduced (due to their lack of statistical literacy, reasoning and/or thinking) by widely applied statistic decision trees and/or statistical tables, and do not consider the authors' guidelines appropriately. Therefore, unintentionally, apply inappropriate tests.

What was found commonly neglected in graduate researches under this study is that all groups involved in their studies were taken as independent groups, while potentially, all or some of them have been dependent in their nature.

However, in some cases, as having one DV and two or more IVs with independent groups and with ordinal or interval nature of DV, suitable statistical tests are lacking.

Also, when there is one interval IV and one DV with interval and nominal nature in one case, and ordinal or interval nature in another case, correlation and nonparametric correlation are recommended, respectively, but this does not sound quite right because of very rare conditions that correlation may imply causation as explained by Huck (2009).

In numerous cases of hypotheses testing when the "pvalue" was significant, then the researcher usually has not cared that some other tests would give a smaller (more significant) *p*-value. If the *p*-value is not significant, then the researcher usually considers whether there is a better test (Dixon, 2003). This is often true with graduate students whose hypotheses were mostly rejected; they usually try some other statistical tests to possibly change their results (Type I error). Likewise, when the study reaches a conclusion of "no statistically significant difference", it should not necessarily be concluded that the treatment was ineffective. Otherwise, a Type II error happens, as was the case in many thesis and dissertations. Consequently, the power of the statistical tests (the probability of rejecting null hypothesis when it is false) is questioned due to the fact that for a fixed Type I error rate ( ) the goal of constructing and testing a hypothesis is to maximize *Power* (Anderson-Cook and Dorai-Raj, 2003).

Regarding misapplication of statistical procedures, the following four consecutive phases were developed along with their components to build up SSAA. Each phase is composed of a few steps through which general and specific criteria for selecting and applying statistical tests are being discussed as follows.

I. DESCRIPTIVE PHASE

A) *Variable mining and measurement*

This entails listing of variables involved in the study and measuring them after a scrutiny of some general research notions as: research problem and research question (Bruin, 2006; Marion, 2004); the goal of the analysis (Tabachnick and Fidell, 2007); nature of the data, research design, kind of research (Moyulsky, 1995; Wadsworth, 2005; Dinove, 2008); kind of variables (Wheater and Cook, 2000); and variable mathematical nature (nominal, ordinal, interval, or ratio) (Healey, 2005; Windish and Dinner-West, 2006; Kaminsky, 2008); and finally, number of variables (Tabachnick and Fidell, 2007).

B- *Variable sorting out techniques*

There are a few variable sorting out techniques to come up with the optimum IVs prior to involving all variables in the hypotheses-testing process. The following are some procedures that are already implemented by the author in different projects:

Reliability: Applying this technique makes it possible for a researcher to eliminate variables with low Cronbach's alpha (Ferrando, 2009); Kudar Richardson (Rudner and Schafer, 2001), and recently, ordinal Theta coefficient (Zumbo et al., 2007).

Coefficient of variability (CV): Coefficient of variation (Calvine, 2004) is recommended in this article for the purpose of consistency and accountability measurement as well as setting priority or even ranking variables. By applying CV, the researcher can select the most consistent variables with the lowest risk, and leave out the least consistent variables from the study.

Correlation matrix: Variables with statistically significant and higher correlation coefficient may be more legitimate and subject to further investigations in the research process. Therefore, variables with low or no significant correlation coefficient in the matrix can be eliminated.

II. ANALYTICAL PHASE

A) *Variable refinery*

To isolate the sensitive cases and exclude them from the main study, personal characteristics of the respondents are being tested against each one of the dependent variables (DV) (Malakmohammadi, 2008). By applying this technique, the researcher can extract as few appropriate independent variables as he/she should, due to the limited capacity of inferential statistical techniques (that is, regression, path analysis and structural equation modeling), to enhance research reliability and create favorable environment to applying appropriate statistical tests.

B) *Variable reduction*

Following the above technique and developing from what Thompson (2004) and, Tabachnick and Fidell (2007) explained about Exploratory Factor Analysis (EFA), this technique is implemented in SSAA as a converter to group numerous single variables into few "supervariables" or "factor/s", and explicit relevant discrete or continuous latent variables in the study on which the subject differs.

C) *Latent variable measurement*

Multiple regression analysis is highlighted in SSAA due to its capability to identify and measure latent variable/s in the study through a mathematical model. Of course, IVs (predictors) involved in predicting latent DVs (indicator/s) can be latent construct (factor) as the outcome of exploratory factor analysis, or simple variables. Either one of these should be specified prior to regression analysis. Notably, the scale or mathematical nature (Healey, 2005), of criterion variable is worthy of consideration in choosing the right regression model.

That is, when criterion variable is nominal dichotomous; Logistic Regression (LR), when it is ordinal (discrete); Ordinal Logistic Regression (OLR) (Conne, 2006; Hilbe, 2009), and when it is quantitative (continuous); Ordinary Regression (OR) suits the model.

Although it is stated that multiple regression is a seductive technique: "plug in" as many predictor variables as you can think of and usually at least a few of them will come out significant (Statistica, 2008), but, to Palmer (MND), it is possible that the independent variables could obscure each other's effects. To prevent this situation, SSAA is considering multiple regression (in either forms), as another converter technique with dual simultaneous role to be applied after EFA. The first role deals with the limitation of regression analysis in embedding numerous variables in the equation. In this case, super-variables (the explicated latent variables through EFA) will be entered in the equation to measure variation of a latent predictor that could not be measured directly before. And, MRA, in its' second role eliminates those variables with no significant impact on the predictor variable. What remains will be utilized next in the SSAA inferential phase.

D) *Inferential phase*

As indicated by Bruin (2006), to enable one infer from his/her population data, procedures that use significance tests must be employed. Rationales behind inferential phase to help the applicants choose appropriate statistical tests are as follows.

E) *Variables, data, and groups*

Variables (independent/dependent) (Hill and Lewicki, 2007; Tabachnick and Fidell, 2007), or exogenous/ endogenous (Streiner, 2005); matched or paired data (Kaminsky, 2008); Kind of samples being compared (independent/dependent) and; number of groups being compared (one, two, or more than two).

F) *Hypotheses testing (choosing the legitimate statistical technique)*

A hypothesis is a statement that describes or explains a relationship between or among variables (Graveter and Forzano, 2008). Also, a statistical hypothesis test is defined by Lehmann and Romano (2005) as a method of making statistical decisions using experimental data. If there is no hypothesis, then there is no statistical test. Pvalue (Calvine, 2004); effect size (Denis, 2003; McCloskey, 2008; Graveter

and Forzano, 2008); sample size (NN, 2007); central limit theorem (McDonald, 2008);
number of independent hypotheses or multiple comparisons (Moyulsky, 1995; Wadsworth, 2005); paired or unpaired (Moyulsky, 1995); parametric/nonparametric (Motulsky, 1995; Dixon, 2003; Dinove, 2008; McDonald, 2008) are detected as major criteria for testing a hypothesis and considered in SSAA to choosing eligible statistical test.

G) Structure or model phase

To Bartholomew (1998), a model is:

1) An abstraction of the real world in which the relevant relations between the real elements are replaced by similar relations between mathematical entities.

2) A set of assumptions about the relationship between the parts of the system. Its adequacy is judged by the success with which it can predict the effects of changes in the system.

Structural Equation Modeling (SEM): Haenlein and Kaplan (2004), referring to Gefen et al. (2000), named regression analysis as a first-generation technique, which analyzes only one layer of relationships among multiple independent and dependent variables. At the same time, they recommended SEM as a secondgeneration technique that allows simultaneous modeling of relationships among multiple independent and dependent constructs. Raykov and Markoulides (2006) observed that SEM enables researchers to readily develop, estimate, and test complex multivariable models as well as to study both direct and indirect effects of variables involved in a given model. The combination of direct and indirect effects makes up the total effect of an explanatory variable on a dependent variable.

Garson (2008) believes that “SEM grows out of and serves purposes similar to multiple regression, but in a more powerful way, which takes into account the modeling of interactions, nonlinearities, correlated independents, measurement error, correlated error terms, multiple latent independents each measured by multiple indicators, and one or more latent dependents, also each with multiple indicators. SEM may be used as a more powerful alternative to multiple regression, path, factor and time series analyses, as well as analysis of covariance". This technique combines factor analysis, canonical correlation, and multiple regressions to evaluate whether the model provides reasonable fit to the data and the contribution of each of the IVs to the DVs (Tabachnick and Fidell, 2007). While Garson (2008) views SEM as a confirmatory rather than an exploratory procedure, Raykov and Markoulides (2006) consider four types of SEM: path analysis model, confirmatory factor analysis model (CFA), structural regression model, and latent change model. Having the capacity of testing modeling hypotheses, SEM is installed in SSAA to develop structures or models considering the following applications of path analysis and CFA.

Path analysis (PA): To Streiner (2005), path analysis is an extension of multiple regression therefore, it goes beyond regression to allow the analysis of more complicated models. Although, despite its previous name of “causal modeling,” Streiner does not believe in path analysis as to establish causality or even to determine whether a specific model is correct; rather, it can only determine whether the data are consistent with the model. However, it is extremely powerful for examining complex models and for comparing different models to determine which one best fits the data.

To Salkind (2008), path analysis basically examines the direct relationships through the postulation of some theoretical relationships between variables and then tests to see if the direction of these relationships is substantiated by the data.

Confirmatory factor analysis CFA: CFA is usually employed to examine patterns of interrelationships among several latent constructs. According to Raykov and Markoulides (2006), “no specific directional relationships are assumed between constructs, only that they are potentially correlated to one another”. The starting point of CFA is a very demanding one, requiring that the complete details of a proposed model be specified before it is fitted to the data.” The latter statement by Raykov and Maroulides was more clearly explained by Stapleton (1997) when he described CFA as “a theory-testing model as opposed to a theory-generating method like EFC.

III- Materials and Methods

The methodology used in this study involved a combination of descriptive and quantitative. To gather pure and first hand data, thesis and dissertations were assessed by content analysis. Actually, extracted information from them was compared with standard check list to recognize measure and percentage of accordance of applied statistical methods and sequential statistical analysis approach (SSAA) (Malek Mohammadi, 2009). The level of statistical literacy, reasoning and thinking of graduated students, extracted from questionnaire, were actively supported by standard form such as ILS (Vermunt and Vermetten, 2004), SRA (Garfield, 2003) and SATs (Sorto, 2004; Burrren, 2008). Applied statistical methods according to SSAA were assessed in term of sex, age, educational level, different majors and universities to make sure we have covered all bases.

The population of this study included agricultural extension and education master and PhD graduated student, (N = 750) in selected seven university in Iran, of which 315 student was selected that appraisal for SSAA. Also 315 graduated students were asked by questionnaires to extract another variable. The research based on the Cochran formula and using stratifies random sampling, questionnaires and checklists. Questionnaires face validity was established by a panel of experts consisting of faculty members and graduate students at Tehran University and Islamic Azad University, Iran. A pilot test was conducted with 25 students in the same field.

Questionnaire reliability was estimated by calculating Alfa Cronbach, Ordinal Theta and Compose Reliability methods by spss, R and Lisrel software. Reliability for the overall instrument was estimated at 0.91, 0.93 and 0.90 %

respectively. Also, questions that decrease each of above coefficients eliminate.

IV- Result and Discussion

Table 1 shows the Summaries of demographic profile and descriptive statistics. The results of descriptive statistics indicated that most of students were men (51.3%). It was reported that slightly more than 83% of Graduated students had master degree whose maximum level of literacy was PhD. Over 84% of them were studied in agricultural extension and education major. Mean their dissertations and thesis marks were 18.93.

To appraisal the statistical competency of student in dissertation and thesis was used from statistical mix (sequential statistical approach) as a standard. In this assessment, compliance and noncompliance of standards by students in their dissertation was studied by option "Yes" and "No" in the prepared check list. the most frequency of option " Yes" was to measure cases " Review related research and literature (RRRL)" with 308 cases (98.1%) in the thesis. the most frequency of option " No" was to measure cases "Eliminate items with low reliability coefficient" with 312 cases(99.1%)(table 2).

The perception of respondents about the statistical reasoning was displayed in Table 3. The lowest coefficient variation refers to "Outcome orientation" (CV = 17.60%) and the highest coefficient variation refers to "Groups can only be compared if they have the same size" (CV = 32.46%).

The perception of respondents about the statistical thinking was displayed in Table 4. The lowest coefficient variation refers to "measurement of univariate", and the validity of conclusions “(CV= 16.35%) and the highest coefficient variation refers to "Evaluate published reports that are based on data by examining the design of the study, the appropriateness of the data analysis " (CV= 26.28%).

V- Conclusion

This paper is intended to be a concise guide for choosing a statistical test with regard to notions extracted from SSAA and statistical literacy, reasoning and thinking for education assessment and for interpreting and analyzing educational studies without relying on mathematical theories. To provide a framework for understanding statistical concepts and to illustrate the decision-making process needed to choose a statistical test, we’ve presented an educational intervention detailing the hypothesis testing, data analysis, and interpretation of the results. Big ideas are shown to embed as SSAA process, with three phases becoming meaningful through the statistical competency.

Meanwhile, they could improve knowledge content about statistic when apply this roadmap scientifically, also consideration and using from sequential statistics by agricultural extension and education students, can give them holistic view from using statistical test to exploit of mix and together statistical test. Whereas student can see statistical test in to the system that conduct to superior realize of relationship between level and phases and suppose them as group of interrelated, interacting or interdependent elements that forming a complex whole.

Finding synthetic test enable student to refine data and variables and extract appropriate and correct data and variable to extract pure result and ultimately pure knowledge.

researchers and graduate students who are after accurate application of statistical methods, and secondly, this will lower their stat phobia by leading them towards a 50-strategic-sequential-statistic-roadmap for choosing and applying appropriate statistical tests, interpreting their findings, and implementing scientific analysis more realistically in a creative research enterprise.

Table 1: Personal characteristics of respondent

Variables	Scale	Measure
Sex	Men	51.3%
Degree	Master	83%
Major	Agricultural extension and education	84%
Thesis score	Mean	18.93

Table 2: Statistical Mix (Sequential statistical analysis approach (SSAA)).

A- Initial phase	**Yes**	**No**
Variable mining and measurement process		
1- Identify research problem/s.	65.1	34.9
2- Specify research question/s.	54.1	45.6
3- Articulate research objective/s.	96.8	2.8
4- Review related research and literature (RRRL).	98.1	1.9
5- Provide theoretical contingency table (TCT)	30.4	69.3
6- Select high frequency issues (HFI) in TCT.	20.3	79.4
7- Design theoretical framework (TF) embodying HFIs	31.3	68.7
8- Configure specific research method and materials (RMM)	17.7	82
9- Construct research instrument to collect data.	94.9	4.7
Variable reduction (refinery)		
10- Look at the validity of a measure	92.1	7.6
11-Test the reliability of RI (pilot research instrument).	86.4	13.3
12- Eliminate items with low reliability coefficient	0.9	99.1
13- Define research population (RP) and sampling procedure.	2.8	96.8
14- Collect the data	2.8	96.8
15-obtain measures of central tendency and dispersion; frequency distributions; graphs);	93.4	6.3
16- Calculate the variables’ coefficient of variability (CV).	15.8	83.9
17- Eliminate variables with higher CV, if applicable.	15.5	84.2
18- Identify sustained variables in the study		
19- Develop a correlation matrix .	5.1	94.8
20- Eliminate variables with no significant correlation coefficient	30.8	69.2
21- State refinery hypotheses (test variables).	9.8	89.6
22- Eliminate variables highly affected by sample characteristics	0.9	99.1
Variable or respondent grouping process		
23- Apply R-type Exploratory Factor Analysis (EFA)	16.5	82.9
24- Eliminate variables with lower than 1 eigen value.	22.5	77.5
25- Identify new grouped (factor/s) variables (basically latent).	21	79
26- Compare factor analysis output with theoretical model	19.7	80.3
27- Design conceptual model by compatible variables.	19	81
B- Intermediate (inferential) phase		
- Hypotheses development		
29- State the research hypothesis (RH)	47.9	52.1

30- State the null hypothesis (NH)	47.9	52.1
31- Assess the relationship of each independent variable, one at a time, with the dependent variable	66.7	33.3
Variable and group identification		
32- Identify variables' nature (scale) and role (IV/DV) and groups' essen	53.7	46.3
Hypotheses testing (choosing appropriate statistical test)		
33- Choose specific P value/s to test the null hypotheses by appropriate statistical tests Choose appropriate statistical test for prediction and/or comparison based on the information	61.3	38.7
34- Test the null hypotheses.	53	47
C- Advanced (Modeling) phase		
Regression (multiple and multivariable)		
35- Design regression analysis (multiple and/or multiple)	48.3	51.7
36- Identify independent variable/s and dependent variable in the hypothetical multiple regression equation to (Logistic Regression for nominal dichotomous DV, Ordinal Logistic Regression for ordinal or discrete DV and Ordinary Regression basically for continuous DV).	30.5	69.5
37- Calculate appropriate statistic suitable to the regression model (that is, F for quantitative regression model)	45.1	54.9
38- Eliminate equation/s with no significant F value (for the whole regression equation).	30.8	69.2
39- Calculate and examine appropriate measures of association and tests of statistical significance for each coefficient	34.3	65.7
40- Eliminate predictors with no significant R value (when F value for the equation is significant).	1.6	98.4
41- Regress each explanatory variable against a constant and the remaining explanatory variables.	32.1	67.6
42- Reject or accept the research hypothesis	27.9	72.1
43- Eliminate variables with insignificant coefficients, but one at a time to find the superior model	30.8	69.2
Structural Equation Modeling (SEM)		
44- Apply SEM utilizing EQS, LISREL or M*plus*	2.9	97.1
Path analysis		
45- Explain the practical implications of findings for further investigation through path analysis as threshold for SEM.	6.7	93.3
46- Apply path analysis (PA) and draw the path diagram (casual model).	6.7	93.3
47-Compare the PA outcome with conceptual research framework to argue challenges.	12.4	87.3
Confirmatory Factor Analysis (CFA)		
48- Identify and explain endogenous and exogenous variables.	1.3	98.7
49- State the SEM hypotheses.	1.3	98.7
50- Apply confirmatory factor analysis (CFA)	1.3	98.7

Table 3: ranking of student statistical reasoning

options	**Mean**	**SD**	**CV**	**Rank**
Correct reasoning scale				
Correctly interprets probabilities	4.59	1.139	24.81	6
Understands how to select an appropriate average	4.87	0.864	17.74	2
Correctly computes probability, both understanding probabilities as ration, and using combinatorial reasoning	4.68	1.166	24.91	7
Understands independence	4.76	1.247	26.19	9
Understands sampling variability	5.16	1.105	21.41	4
Distinguishes between correlation and causation	4.94	1.056	21.37	3
Correctly interprets two-way table	4.54	1.213	26.71	10
Understands the importance of large sample	4.85	1.313	27.07	12
Misconception scales				
Misconceptions involving averages	5.11	1.255	24.55	5
Outcome orientation	**5.13**	**0.903**	**17.60**	**1**
Good sample have to represents a high percentage of the population	4.85	1.258	25.93	8
Law of small numbers	5.04	1.571	29.18	14
Representativeness misconception	4.67	1.248	26.72	11
Equiprobability bias	4.92	1.409	28.63	13
Groups can only be compared if they have the same size	**4.01**	**1.302**	**32.46**	**15**

(0 = nothing; 7 = strongly agree)

Table 4: ranking of student statistical thinking

Options	Mean	SD	CV	Rank
Understand the differences among various kinds of studies and which type of inferences can legitimately be drawn from each	4.83	0.999	20.68	5
Know the characteristics of well-designed studies, including the role of randomization in surveys and experiments	4.92	0.992	20.16	4
Understand the meaning of measurement data categorical data, of univariate and bivariate data, and of the term variable	5.06	0.891	17.60	2
Understanding histograms, boxplots, and scatterplots and use them to display data	4.93	0.962	19.51	3
Compute basic statistics and understand the distinction between a statistic and a parameter	4.80	1.125	23.43	9
For univariate measurement data, be able to disply the distribution , describe its shape, and select and calculate summary statistics	**5.95**	**0.973**	**16.35**	**1**
For bivariate measurement data, be able to display a scatterplot, describe its shape and determine regression coefficients, regression equations, and select and calculate summary statistics	4.90	1.095	22.34	6
Recognize how linear transformation of univariate data affect shape center, and spread	4.95	1.138	22.98	8
Identify trends in bivariate data find functions that model the data or transform the data so that they can be modeled	4.92	1.200	24/39	10
Use simulations to explore the variability of sample statistics from a known population and to construct sampling distributions	5.04	1.314	26.07	12
Understand how sample statistics reflect the values of population parameters and use sampling distributions as the basis for informal inference	4.84	1.196	24.71	11
Evaluate published reports that are based on data by examining the design of the study, the appropriateness of the data analysis, and the validity of conclusions	**4.93**	**1.296**	**26.28**	**13**
Understand how basic statistical techniques are used to monitor process characteristics in the workplace	5.10	1.162	22.78	7

(0 = nothing; 7 = strongly agree)

REFERENCES

[1] Anderson-Cook, M, Dorai-Raj S. Making the Concepts of Power and Sample Size Relevant and Accessible to Students in Introductory Statistics Courses using Applets. J. Statistics Educ., [Online], 11(3). 2003

[2] Bartholomew J. Social Process. London School of Economics and Political Science. Data and Sources of Collinearity. New York: John Wiley & Sons. 1998
[3] Bruin J. Newtest: Command to Compute New Test. UCLA: Academic Technology Services, Statistical Consulting Group. http://www.ats.ucla.edu/stat/stata/ado/analysis/. 2006
[4] Calvin D. Choosing and Using Statistics, a Biologists Guide. Blackwell Publishing Company. MA. USA. 2004
[5] Conne A. Logistic Regression Models for Ordinal Response Variables. Sage Publications Inc. Thousand Oaks, Cl, USA., Pp. 10- 25. 2006
[6] Denis D. Alternatives to Null Hypothesis Significance Testing. J. Theory. Sci., 4-1 The International Consortium for the Advancement of Academic Publication, Athabasca, Canada. 2003
[7] Dinove I. Choose the Right Test. From http://www..stat.ucla.edu Accessed in May 2009. 2008
[8]Dixon, P. Choosing Statistical Methods. Iowa State University, USA. From http://www.bcb.iastate.edu/faculty/Dixon_CV.pdf. Accessed in March 2009. 2003
[9] Ferrando P. A General Factor-Analytic Procedure for Assessing Response Bias in Questionnaire Measures. Structural Equation Modeling: A Multidisciplinary J., 16(2):364–381. DOI: 10.1080/10705510902751374.2009
[10] Garfield, J. "Assessing Statistical Reasoning," *Statistics Education Research Journal* [Online], 2(1), 22-38. http://www.stat.auckland.ac.nz/~iase/serj/SERJ2(1).pdf .2003
[11] Garson. D.. 'Structural Equation Modeling' from Statnotes: Topics in Multivariate Analysis. North Carolina State University, Retrieved May 25, 2009.http://faculty.chass.ncsu.edu/garson/pa765/statnote.htm. 2008
[12] Govindrajulue Z. Sequential Statistics. World Scientific Publishing Inc. NJ, USA. 2004. p. 1
[13] Graveter F, Forzano L. Research Methods for the Behavioral Science. Third ed. 2008. PP:19-22. Thomson/Wadsworth, ISBN0495091456, 9780495091455.
[14] Haenlein M, Kaplan A. A Beginner's Guide to Partial Least Squares *Analysis*. Lawrence Erlbaum Associates Inc. Understanding Stat. 2004. 3(4): 283-297.
[15] Healey J. A Tool for Social Research. 7th ed. Wasdworth, Thomson Learning Academic Resource Center, CA, USA. 2005
[16] Hill T, Lewicki P. Statistics Methods and Applications. StatSoft, Tusla, OK. 2007
[17] Hilbe J. Logistic Regression Models. Chapman & Hall/CRC Press, Texts in Statistical Science. NY.USA. PP: 353-3 Hill, T. 2009
[18] Kington,A. Sammons, P. Day,C. Regan,E.Stories and Statistics: Describing a Mixed Methods Study of Effective Classroom Practice . Journal of Mixed Methods Research 1558689810396092, first published on February 21, 2011 as doi:10.1177/1558689810396092.
[19] Lewicki, P.. STATISTICS Methods and Applications. StatSoft, Tulsa, OK. USA. 2007
[20] Hoffman H. Internet Glossary of Statistical Terms in: Statistics Explained . www.animatedsoftware.com/statglos/statglos.htm). 2004
[21] Huck S. Statistical Misconceptions. Taylor and Francis Group, NY, USA. 2009. pp. 43.
[22] Kaminsky J. Qualitative and Quantitative Analysis. Kwantlen Polytechnic University. BNS Nursing Program. Greater Vancouver, British Columbia, Canada. 2008
[23] Lehmann E, Romano J. Testing Statistical Hypotheses (3rd ed.). New York: Springer. ISBN 0387988645.www.virtualcurriculum.com/N4120/LA9_Figure8.pdf. Accessed on March 2009. http://www.ats.ucla.edu/stat/sas/notes2/ Accessed in March, 2009. 2005
[24] Malakmohammadi I. Variables Refinery Process to Ensure Research Unbiasedness (Validity) and Invariance (Reliability) in Agricultural Extension and Education. Am. J. Agric, Biolo. Sci., 2008.3(1): 342-347.
[25] Malek Mohammadi,I. Sequential Statistical Analysis Approach (SSAA) towards Contingency Framework Purification in Bevavioral Research and Practice. Presenred at First International Conference on Educational Research and Practice. University Putra Malaysia . 2009
[26] Marion R. The Whole World of Deduction Research Skills for New Scientists. The University of Texas Medical Branch, Texas, USA. 2004
[27] McDonald JH. Handbook of Biological Statistics, Choosing a Statistical Test. Sparky House Publishing, Baltimore, Maryland. 2008 P.282-287.
[28] Moyulsky H. Intuitive Biostatics: Choosing a Statistical Test. Oxford University Press, Inc. 1995
[29] Motulsky H. Analyzing Data with GraphPad Prism. GraphPad Software Inc., San Diego, CA. 1999
[30] McCloskey D. The Cult of Statistical Significance. Ann Arbor: University of Michigan Press. ISBN 0472050079. 2008
[31] NN. Statistical Test: More Complicated Discriminate. PHY310: Lecture 14. http://nngroup.physics.sunysb.edu/~mcgrew/phy310/lectures/phy310-lecture-14-2007.pdfnngroup.physics.sunysb.edu/~mcgrew/phy310/lectures/phy3 10-lecture-14-2007.pdf. 2007
[32] Palmer MND. Multiple Regression. Ordination Method for Ecologists. Oklahoma State University. http://ordination.okstate.edu/MULTIPLE.htm. Accessed Feb. 08, 2009
[33] Ramanathan R. Introductory Econometrics with application. Fifth ed. Harcourt College Publishers. SENGAGE Learning. Florence, KY. 2002
[34] Raykov T, Marcoulides G. A First Course in Structural Equation Modeling. Lawrence Erlbaum Association Inc. Publishers. NJ, USA. pp. 117-118. 2006
[35] Rudner LM, Schafer WD. Reliability. ERIC Digest. Online http://www.ericdigests.org/2002-2/reliability.htm.2001
[36] Salkind N. Statistics for People Who (Think They) Hate Statistics. Excel 2007 Edition. Sage Publication Inc. CA, USA. 2008.pp.326
[37] Sorto, M. A. Prospective Middle School Teachers' Knowledge about Data Analysis and its Application to Teaching. Doctoral dissertation. Michigan State University. East Lansing. 2004
[38] Stapleton C. Basic Concepts and Procedures of Confirmatory Factor Analysis. Paper presented at the Annual Meeting of the Southwest Educational Research Association. Austin, TX, January 23-25. 1997
[39]Statistica.MultipleRegression.ElectronicTextbook.Statsoft,Inc.http://www.statsoft.com/textbook/stmulreg.html. 2008
[40] Streiner D. Research Methods in Psychiatry. Finding Our Way: An Introduction to Path Analysis. The Canadian J. Psych., 2005. 50: 115– 122
[41] Tabachnick B, Fidell L. Using Multivariate Statistics. 5th Ed. Pearson. NJ. USA. 2007. ISBN-13: 9780205459384
[42] Thompson B. Exploratory and Confirmatory Factor Analysis: Understanding Concepts and Applications. Washington, D.C.: American Psychological Association. 2004
[43] Vermunt J, Magidson J. Statistical Innovation. Encyclopedia of Social Science Research Methods, Sage Publications. 2003
[44] Vermunt, J. D. and Vermetten, Y. J., "Patterns in Student Learning: Relationships Between Learning [44] Strategies, Conceptions of Learning, and Learning Orientations," *Educational Pyschology Review*, 2004. 16(4), 359-384.
[45] Wadsworth. Choosing the Correct Statistical Test. Wadsworth Cengage Learning. Florence, KY.http://www.wadsworth.com/psychology_d/templates/student_resources/workshops/stat_workshp/chose_stat/chose_stat_01.html. 2005
[46] Watt J, Berg S. Research Methods for Communication Science. Amazon.com. 2002
[47] Wheater P, Cook P. Using Statistics to Understand the Environment. Routledge, NY, USA. 2000
[48] Whitney. Statistics: A Tool for Social Research. 7th Ed. Thomson Learning, Inc. Thomson Wadsworth. Belmont, CA 94002-3098, USA. 2005
[49]Windish D, Diener-West M. A Clinician-educator's Roadmap to Choosing and Interpreting Statistical Tests. J. Gen. Int. Med., 2006. 21 (9, 8), 1009-1009. DOI 10.1111/j.1525-1497.2006.00390.x
[50] Wild C, Pfannkuch M. Statistical Thinking Models. The Sixth International Conference of Teaching Statistics. Cape Town, South Africa 7 – 12 July. 2002
[51] Zumbo B, Gadermann A, Zeisser C. Ordinal Versions of Coefficient Alpha and Theta for Likert Scale. J. Modern Appl. Stat. Methods, 2007. 6(1): 21-2