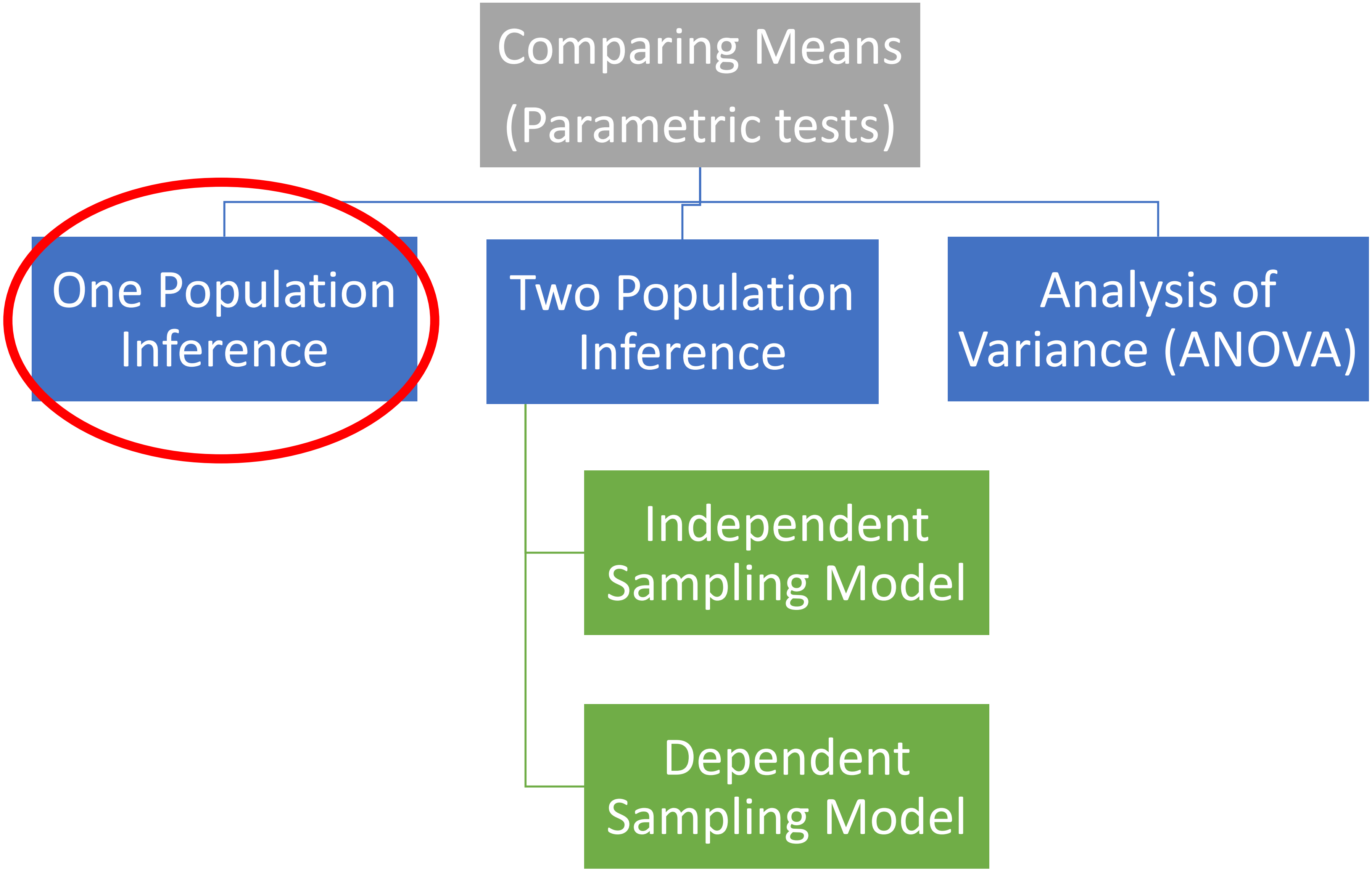
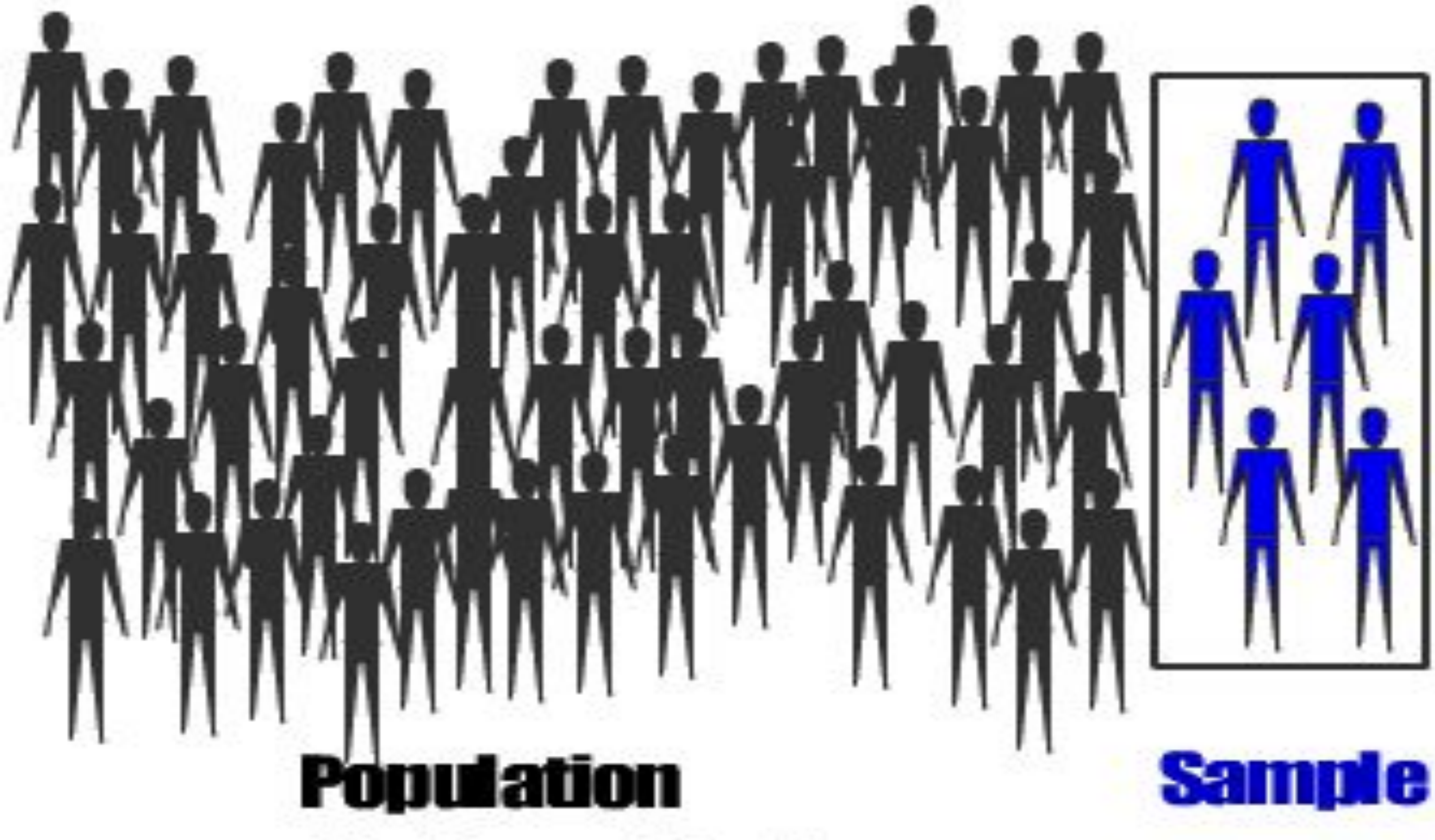
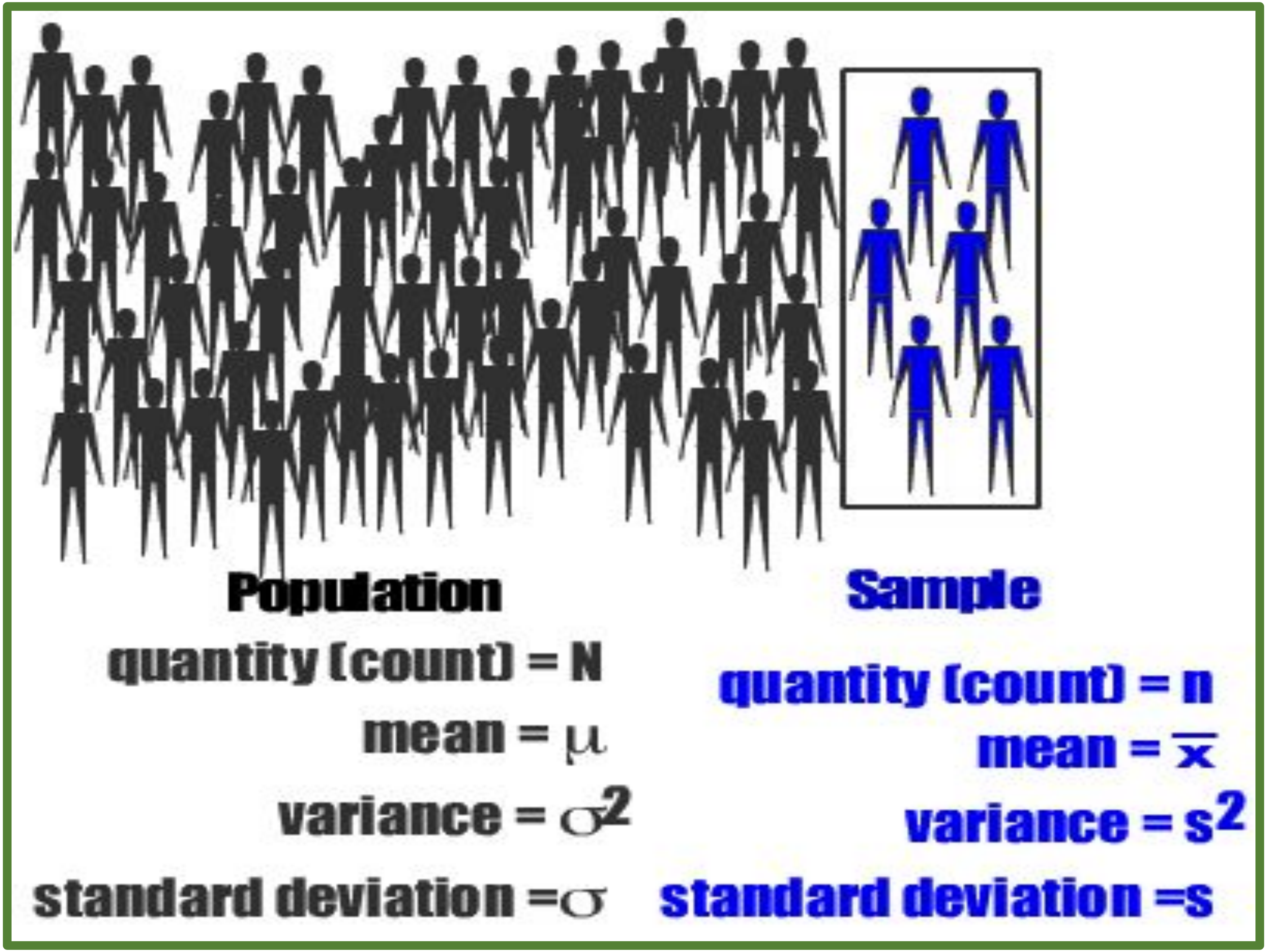
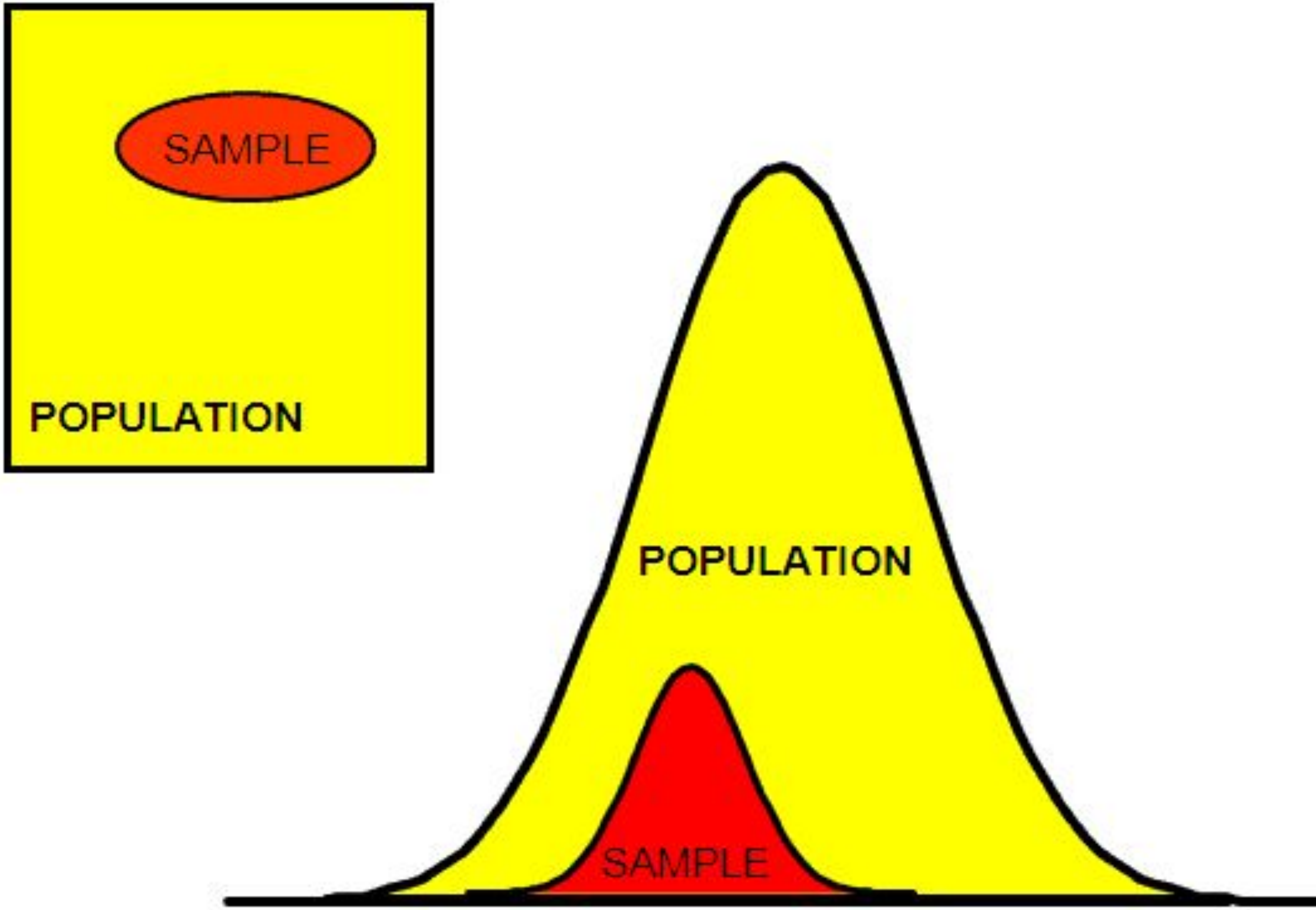

Comparing Means
(Parametric tests)
One Population Inference
Two Population Inference
Analysis of Variance (ANOVA)
Independent Sampling Model
Dependent Sampling Model

Test of population mean vs. hypothesized value, population standard deviation unknown




Population
quantity (count) = N
mean = μ
variance = σ2
standard deviation =σ
Sample
quantity (count) = n
mean = x̄
variance = s2
standard deviation =s

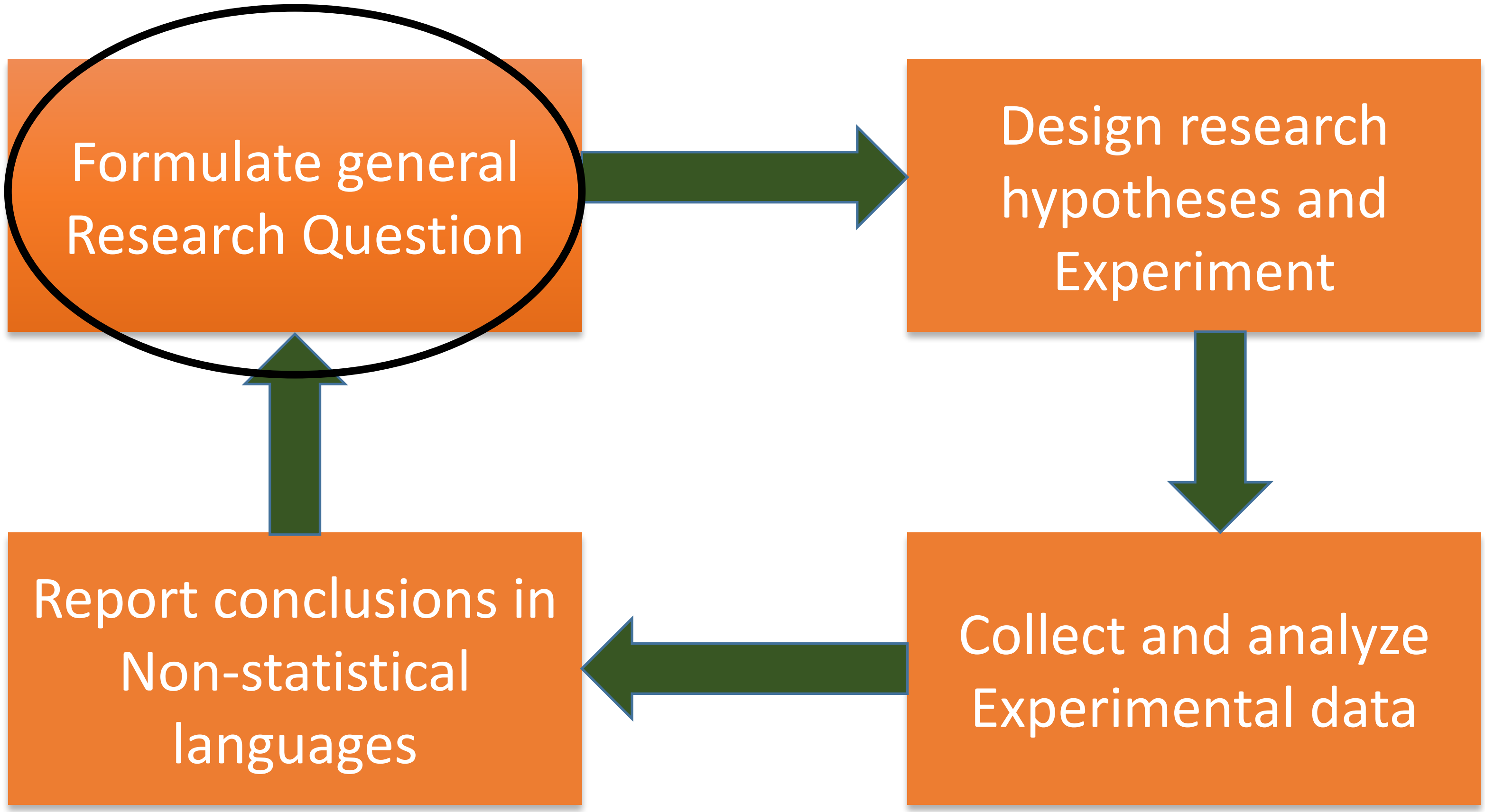

SAMPLE
POPULATION
POPULATION
SAMPLE

Exercise (13)

Exercise (13):

It is known that the mean Haemoglobin percent (Hb%) of adult females in a community is 89%. A researcher wanted to test whether pregnancy has a significant effect on hemoglobin level. He randomly selected 25 pregnant females and conducted measurement of their Hb level. The mean Hb% for the sample was of 86 ± 7%. The researcher selected level of significance $\alpha = 0.05$. The critical value at df of 24 and level of significance 0.05 is 2.064.

Procedures of Hypotheses Testing and the Scientific Method

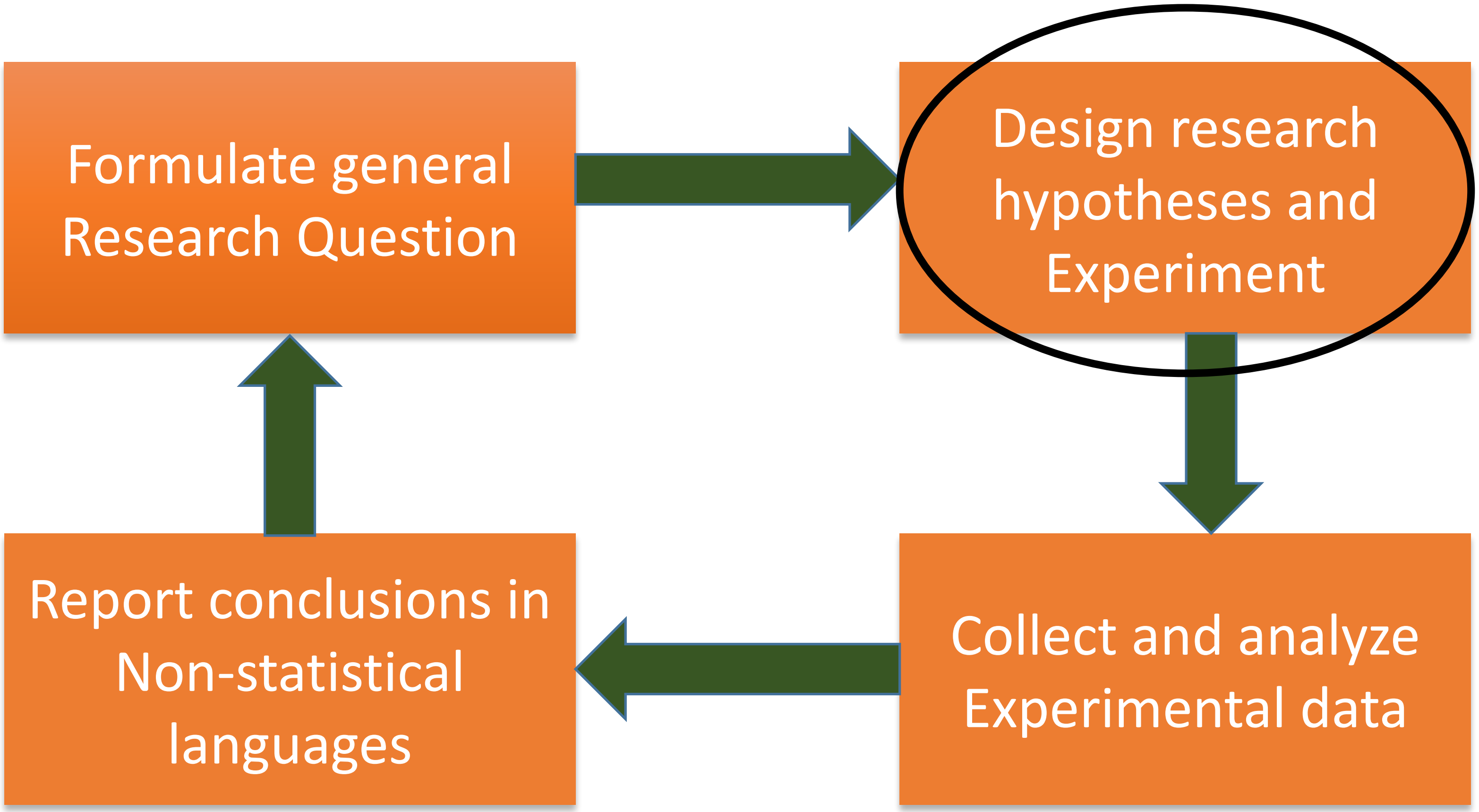


I. Formulate general Research Question

I. Formulate general Research Question

Does pregnancy have significant effect on mean Hb%?

Procedures of Hypotheses Testing and the Scientific Method



II. State Research Hypotheses

III. What is the appropriate test statistic?

IV. What is the appropriate test Model? (One or Two tailed)

II. State Research Hypotheses

Ho: μ = X (pregnancy has no significant effect on mean Hb%)

Ho: μ ≠ X (pregnancy has significant effect on mean Hb%)

III. What is the appropriate test statistic?

IV. What is the appropriate test Model? (One or Two tailed)

II. State Research Hypotheses

Ho: μ = X (pregnancy has no significant effect on mean Hb%)

Ho: μ ≠ X (pregnancy has significant effect on mean Hb%)

III. What is the appropriate test statistic?

One sample t test

$$t = \frac{\bar{X} - \mu_o}{s/\sqrt{n}}$$

IV. What is the appropriate test Model? (One or Two tailed)

II. State Research Hypotheses

Ho: µ = X (pregnancy has no significant effect on mean Hb%)

Ho: µ ≠ X (pregnancy has significant effect on mean Hb%)

III. What is the appropriate test statistic?

One sample t test

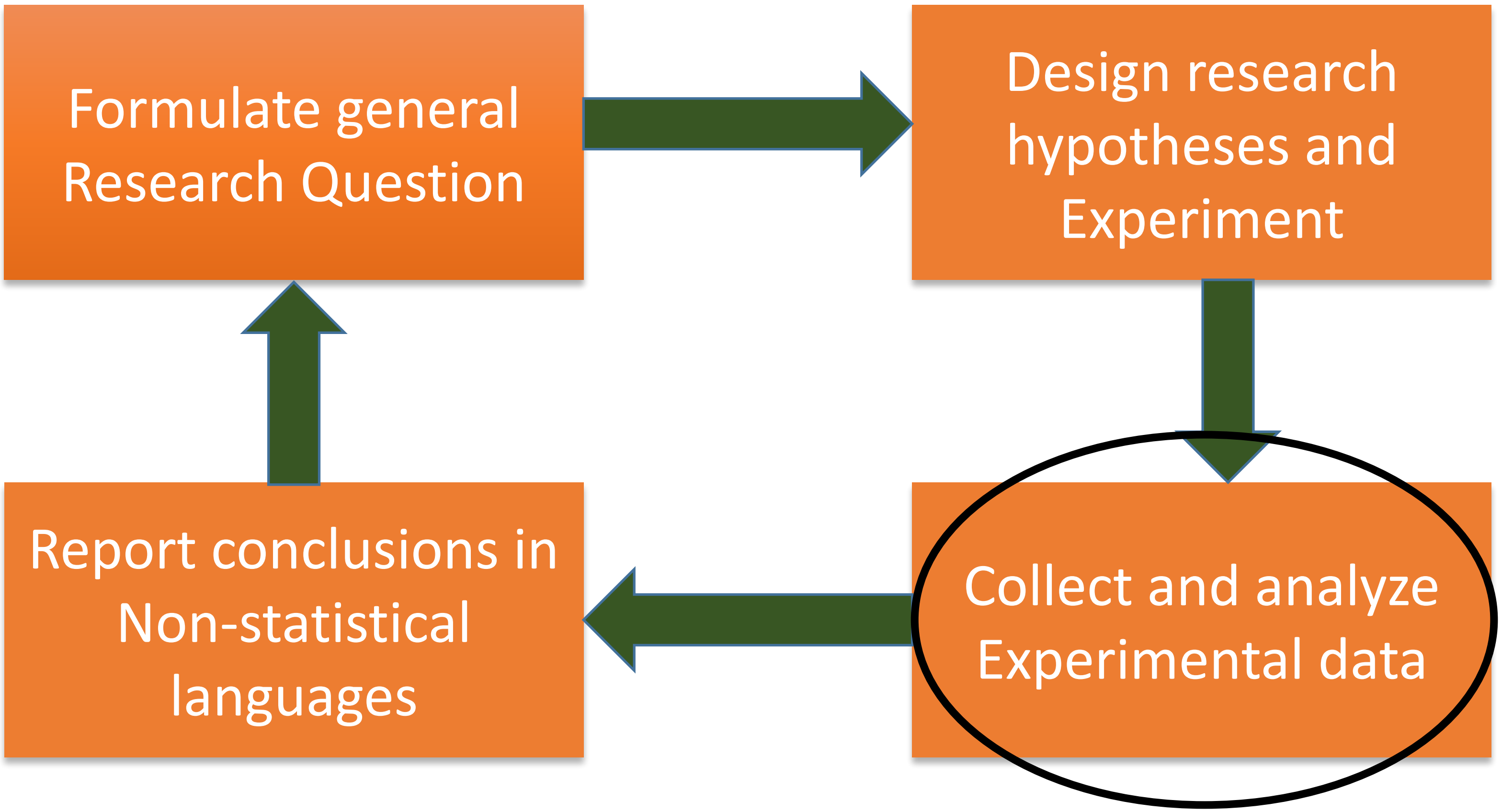
$$t = \frac{\bar{X} - \mu_o}{s/\sqrt{n}}$$

IV. What is the appropriate test Model? (One or Two tailed)

Two Tailed Test Model

Design Research Hypotheses and Experiment

Procedures of Hypotheses Testing and the Scientific Method



V. Calculate test statistic

VI. Make a Decision regarding Research Hypotheses (Specify the Decision Method)

V. Calculate test statistic

$$t = \frac{\bar{X} - \mu_o}{s/\sqrt{n}}$$

$$t = \frac{(86 - 89)}{\frac{7}{\sqrt{25}}} = 2.14$$

VI. Make a Decision regarding Research Hypotheses

(Specify the Decision Method)

V. Calculate test statistic

$$t = \frac{\bar{X} - \mu_o}{s/\sqrt{n}}$$

$$t = \frac{(86 - 89)}{\frac{7}{\sqrt{25}}} = 2.14$$

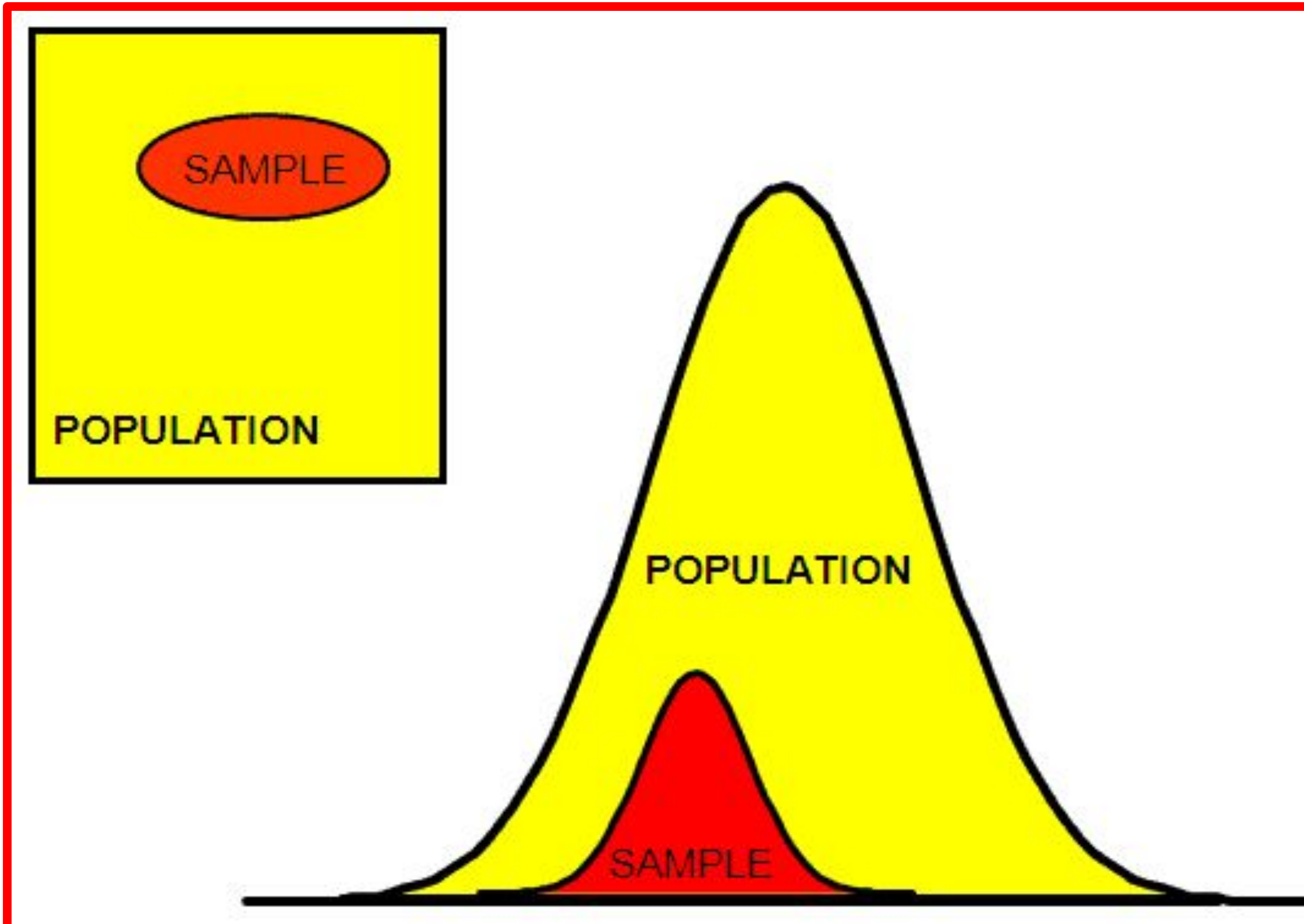
VI. Make a Decision regarding Research Hypotheses (Specify the Decision Method)

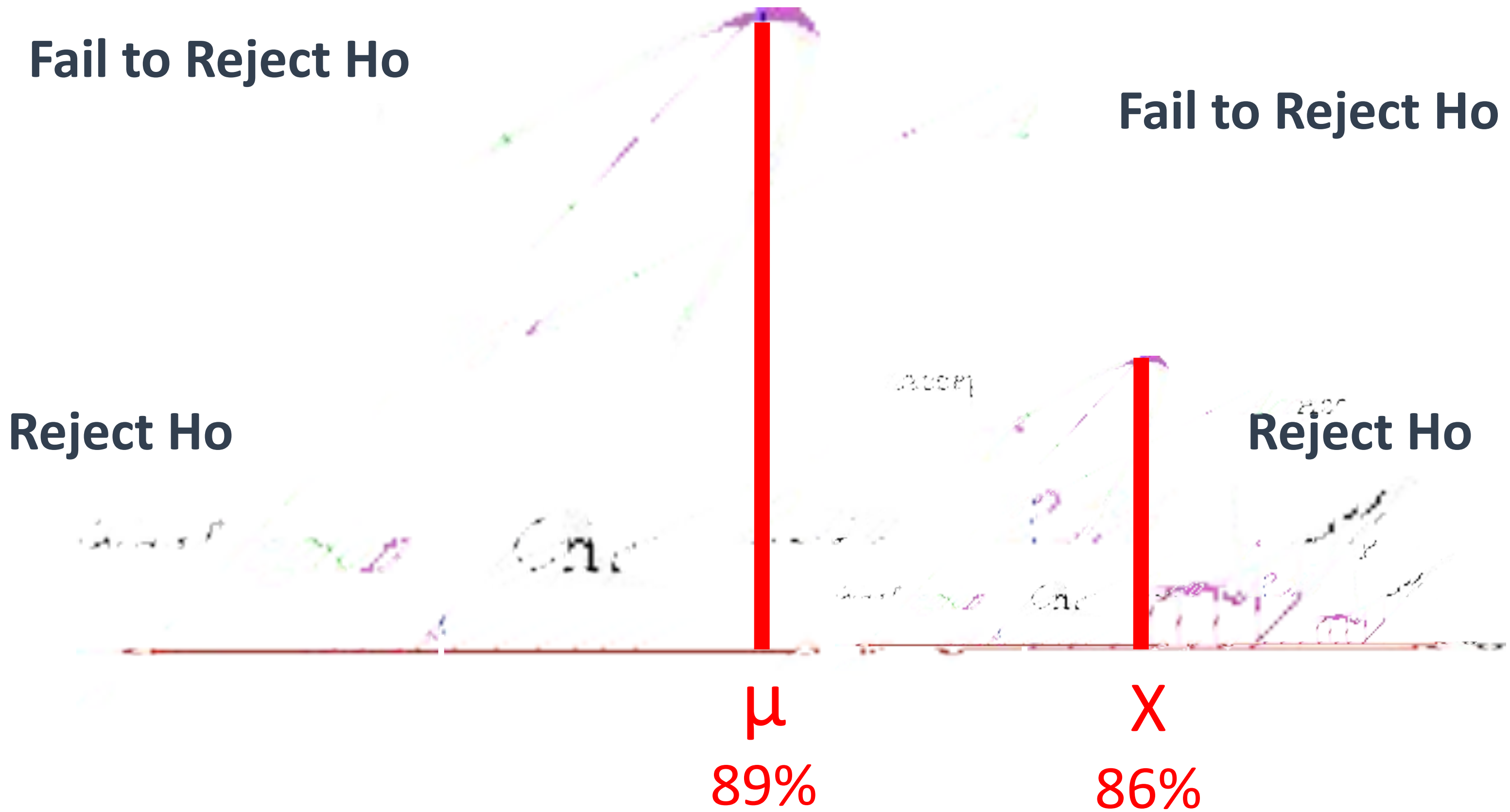
Reject Null Hypothesis Ho

Test statistic (t=2.14) > critical value (2.064)

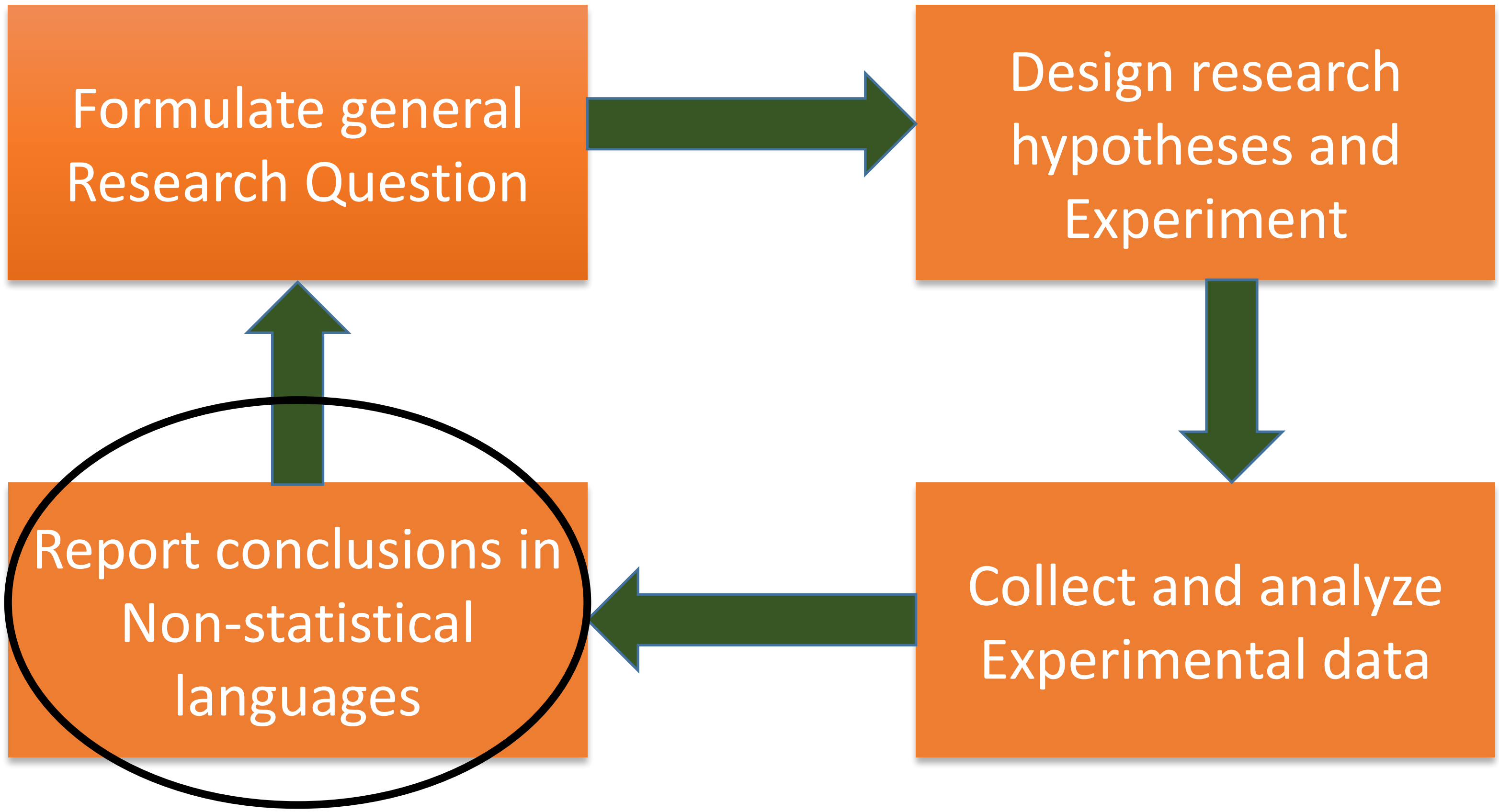
(Critical value method)

Collect and Analyze Experimental Data


SAMPLE
POPULATION
POPULATION
SAMPLE


Fail to Reject Ho
Reject Ho
μ
89%
Fail to Reject Ho
Reject Ho
X
86%

Procedures of Hypotheses Testing and the Scientific Method



VII. Report a conclusion

VII. Report a conclusion

Pregnancy has a significant effect on mean Hb%.

The mean Hb% of pregnant females (86%) was significantly lower than the mean Hb% of adult females in the community (89%).

Comp
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One P

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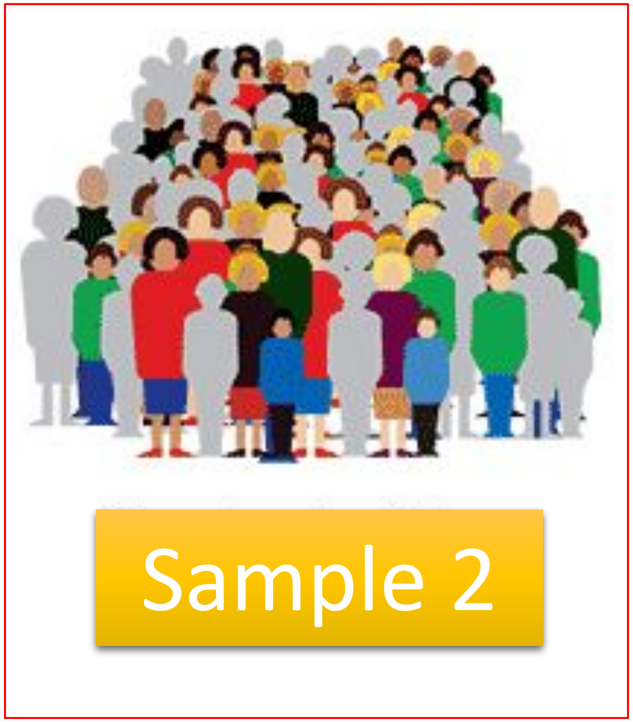
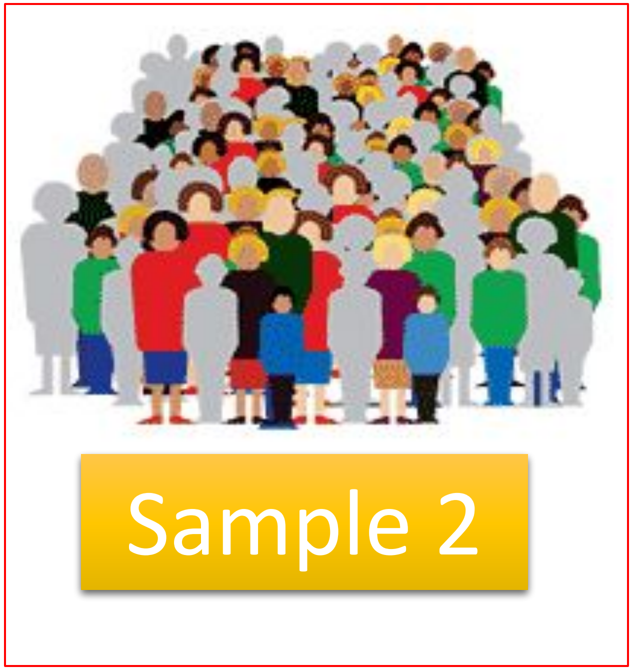
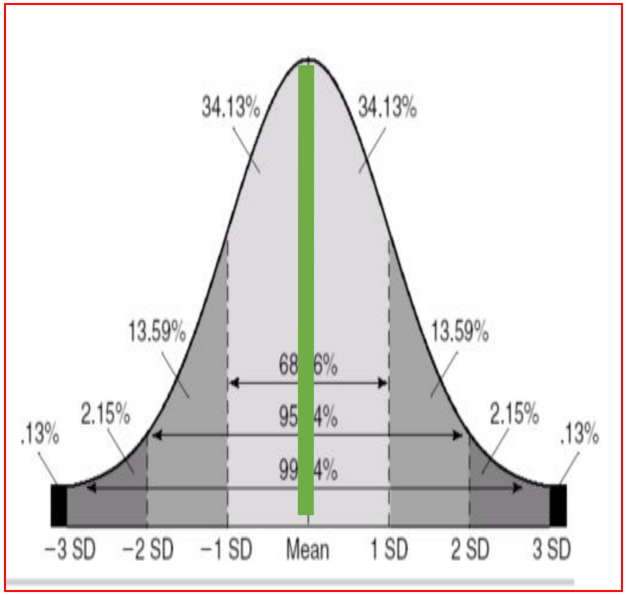
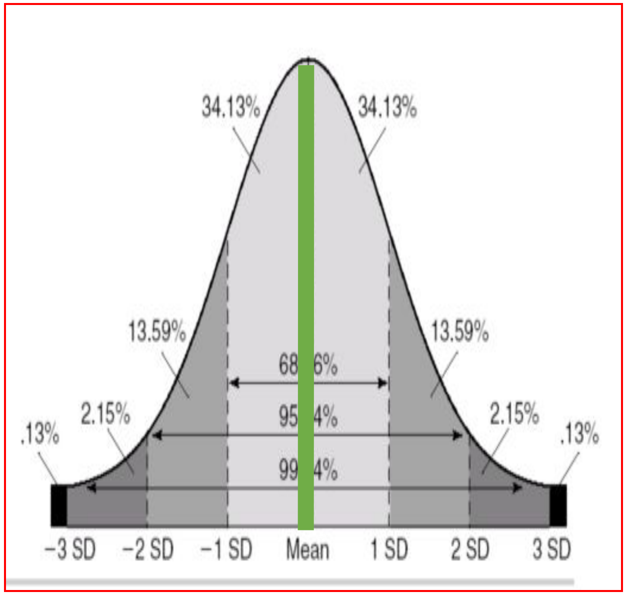
The data is collected by two simple random samples from separate and unrelated populations. This data will then be used to compare the two population means. This is typical of an experimental or **treatment** population versus a **control** population.





n_1
$\bar{X}_1$
S_1





n_2
$\bar{X}_2$
S_2

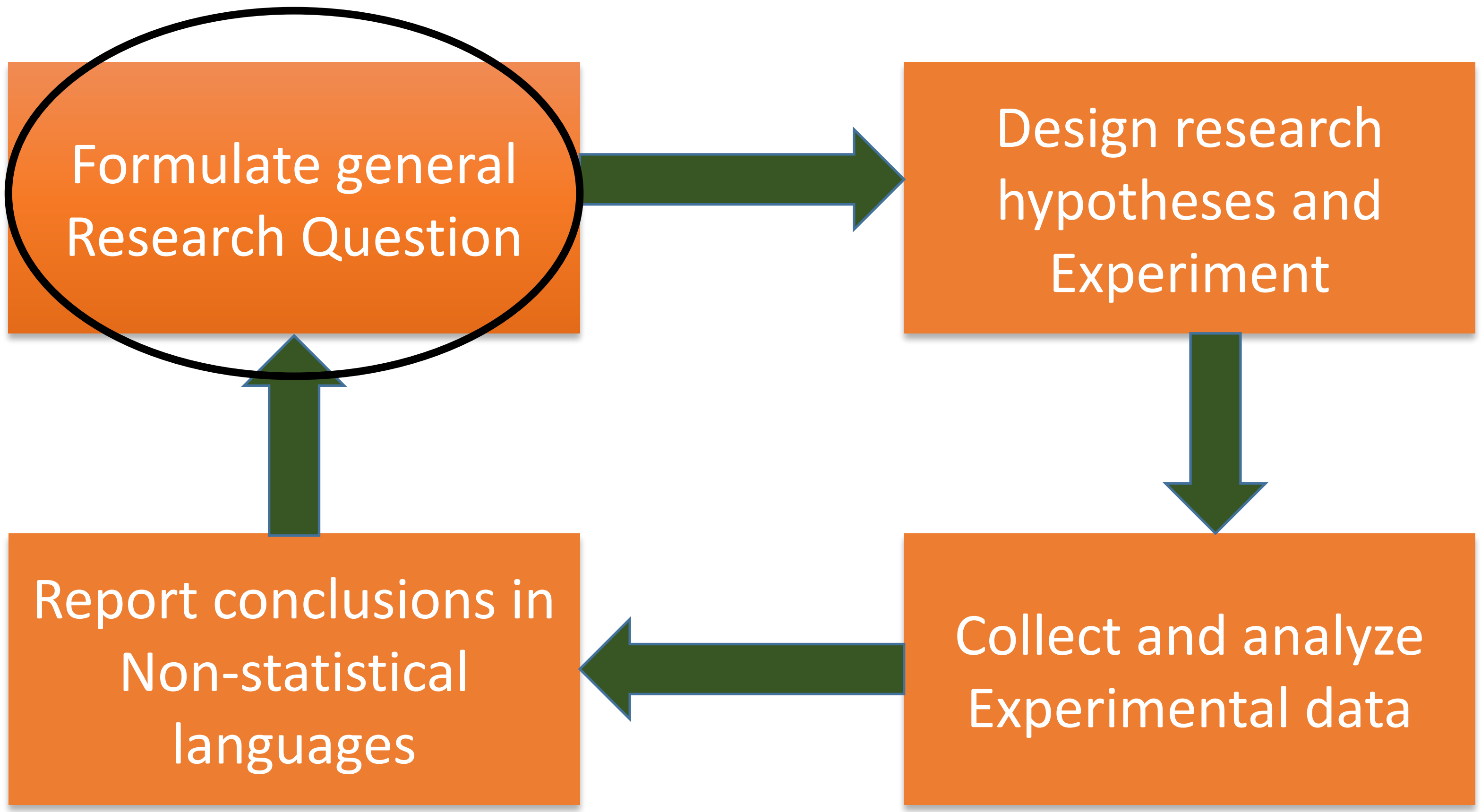
Exercise (14)

Researchers were motivated to test a new antihypertensive drug (A) on a group of patients. They needed to know whether Drug (A) achieves significant reduction in the systolic blood pressure compared with the conventional antihypertensive drug (B).

In the current research, 200 randomly selected patients suffering from essential hypertension and fulfilled the inclusion and exclusion criteria were included. The participants were randomly allocated into two groups; 100 patients were given drug (A) and 100 were given the drug (B). The researchers selected level of significance $\alpha = 0.05$.

After a period of 10 weeks, the mean systolic blood pressure of the first group receiving drug (A) decreased by 12 ± 2.36 mm Hg while that of the second group decreased by 9 ± 5.69. The collected data were typed onto computer and analyzed using SPSS software program. The program revealed the value of the test statistic=2.56 ($p=0.06$)

Procedures of Hypotheses Testing and the Scientific Method

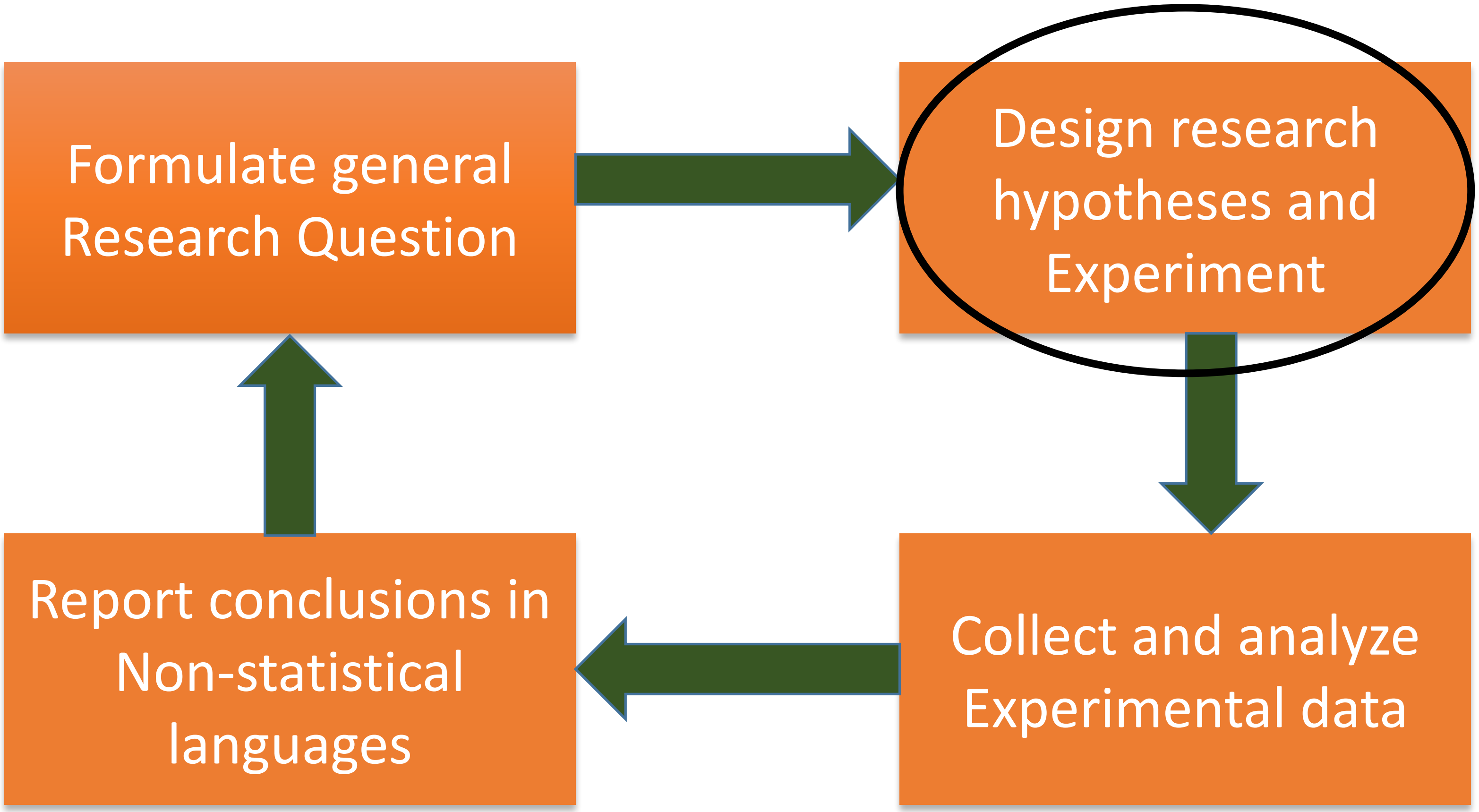


I. Formulate general Research Question

I. Formulate general Research Question

Is there any significant difference in the mean reduction of systolic blood pressure achieved by drug (A) and drug (B)?

Procedures of Hypotheses Testing and the Scientific Method



II. State Research Hypotheses

III. What is the appropriate test statistic?

IV. What is the appropriate test Model? (One or Two tailed)

II. State Research Hypotheses

Ho: $\overline{X}_1 = \overline{X}_2$

There is no significant difference in the mean reduction of systolic blood pressure achieved by drug (A) and drug (B)

Ha: $\overline{X}_1 \neq \overline{X}_2$

There is a significant difference in the mean reduction of systolic blood pressure achieved by drug (A) and drug (B)

III. What is the appropriate test statistic?

IV. What is the appropriate test Model? (One or Two tailed)

II. State Research Hypotheses

Ho: $\overline{X}_1 = \overline{X}_2$

There is no significant difference in the mean reduction of systolic blood pressure achieved by drug (A) and drug (B)

Ha: $\overline{X}_1 \neq \overline{X}_2$

There is a significant difference in the mean reduction of systolic blood pressure achieved by drug (A) and drug (B)

III. What is the appropriate test statistic?

Two Independent sample t test

$$t = \frac{(X_1 - X_2)}{\frac{S^2p}{n_1} + \frac{S^2p}{n_2}}$$

IV. What is the appropriate test Model? (One or Two tailed)

II. State Research Hypotheses

Ho: $\overline{X}_1 = \overline{X}_2$

There is no significant difference in the mean reduction of systolic blood pressure achieved by drug (A) and drug (B)

Ha: $\overline{X}_1 \neq \overline{X}_2$

There is a significant difference in the mean reduction of systolic blood pressure achieved by drug (A) and drug (B)

III. What is the appropriate test statistic?

Two Independent sample t test

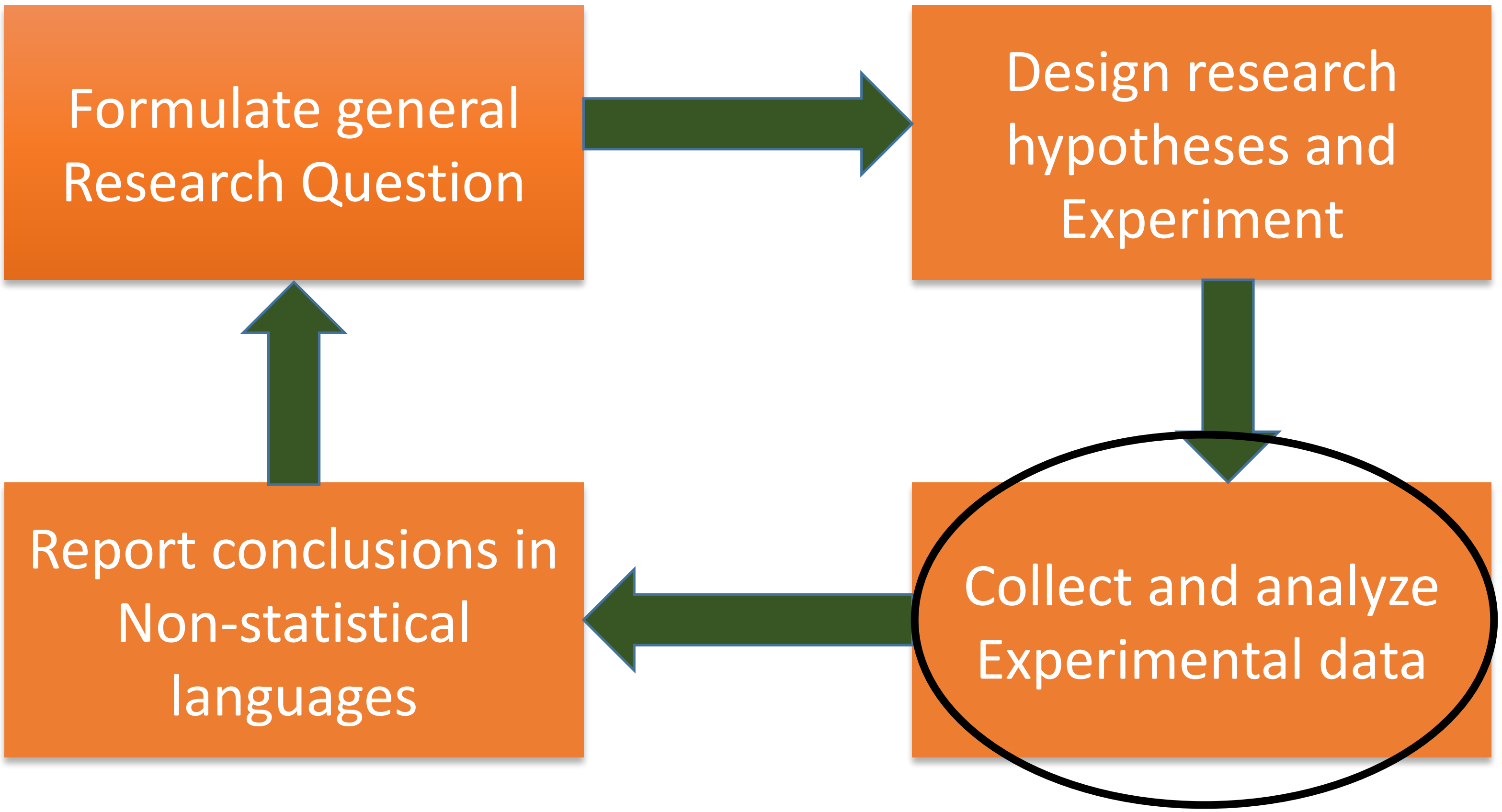
$$t = \frac{(X_1 - X_2)}{\frac{S^2p}{n_1} + \frac{S^2p}{n_2}}$$

IV. What is the appropriate test Model? (One or Two tailed)

Two Tailed Test Model

Design Research Hypotheses and Experiment

Procedures of Hypotheses Testing and the Scientific Method



V. Make a Decision regarding Research Hypotheses (Specify the Decision Method)

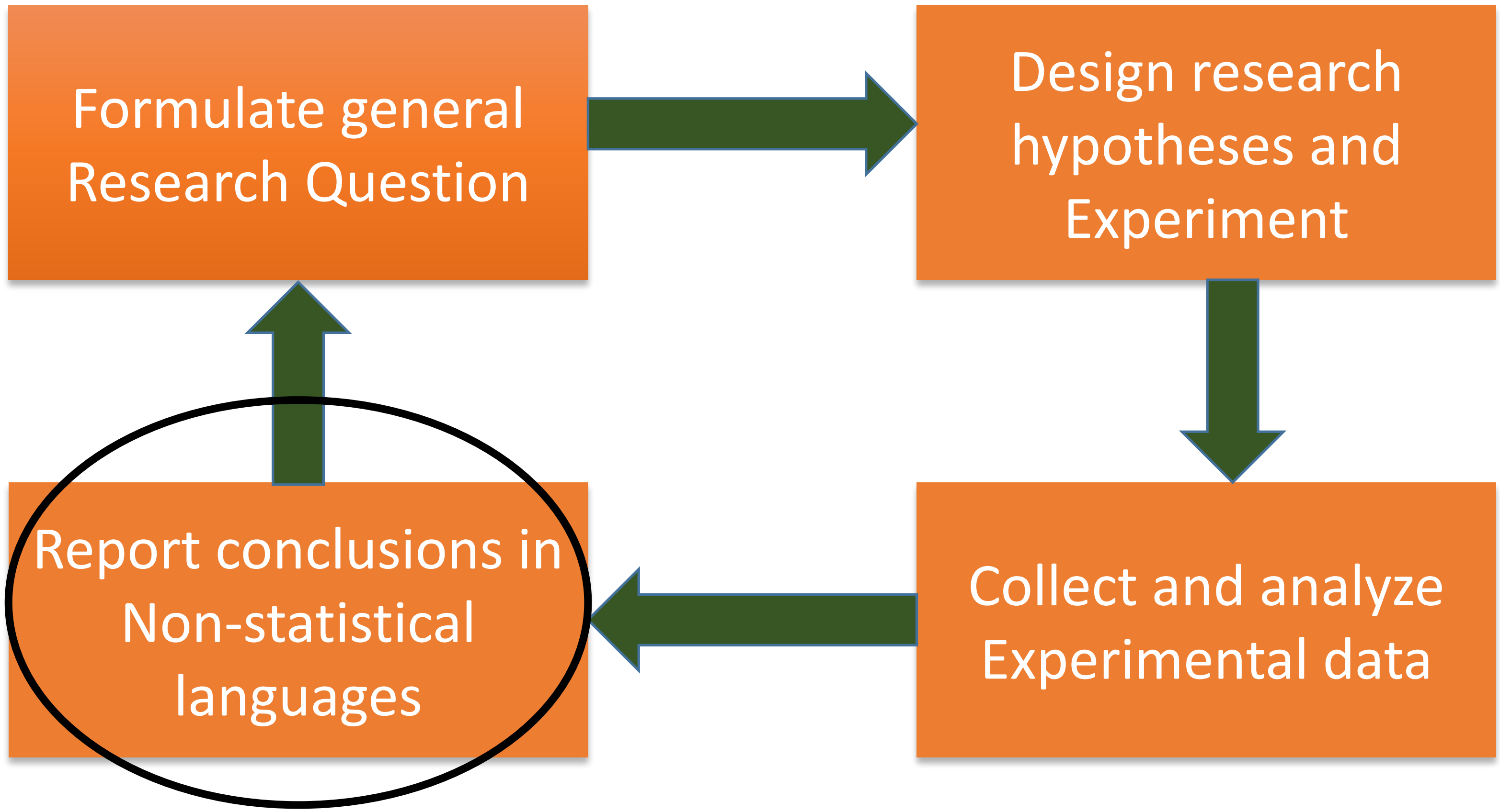
Fail to Reject Null Hypothesis Ho

P-value (0.6) > α (0.05)

(p-value method)

Collect and Analyze Experimental Data

Procedures of Hypotheses Testing and the Scientific Method



VI. Report a conclusion

VI. Report a conclusion

There is insufficient evidence to support the claim that there is a significant difference in the mean reduction of systolic blood pressure achieved by drug (A) and drug (B)

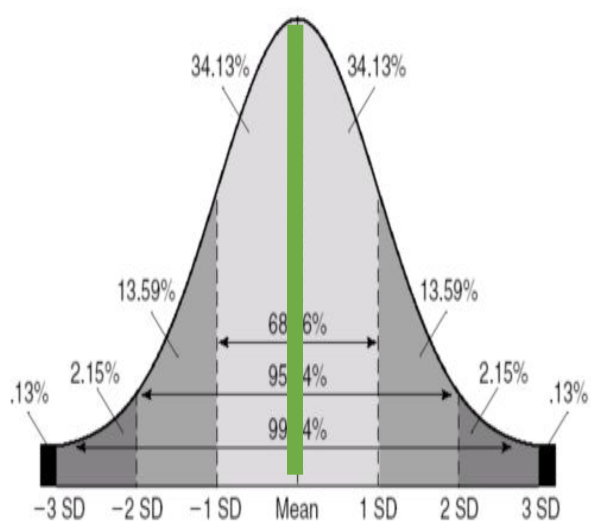
Drug (A)

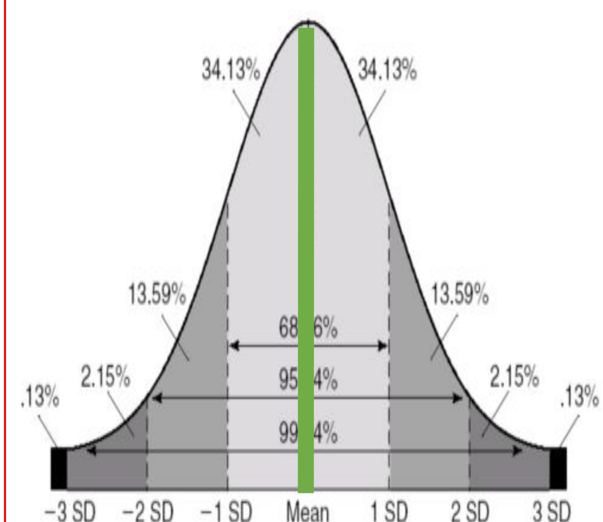
Drug (B)

n_1

$\bar{X}_1$

S_1

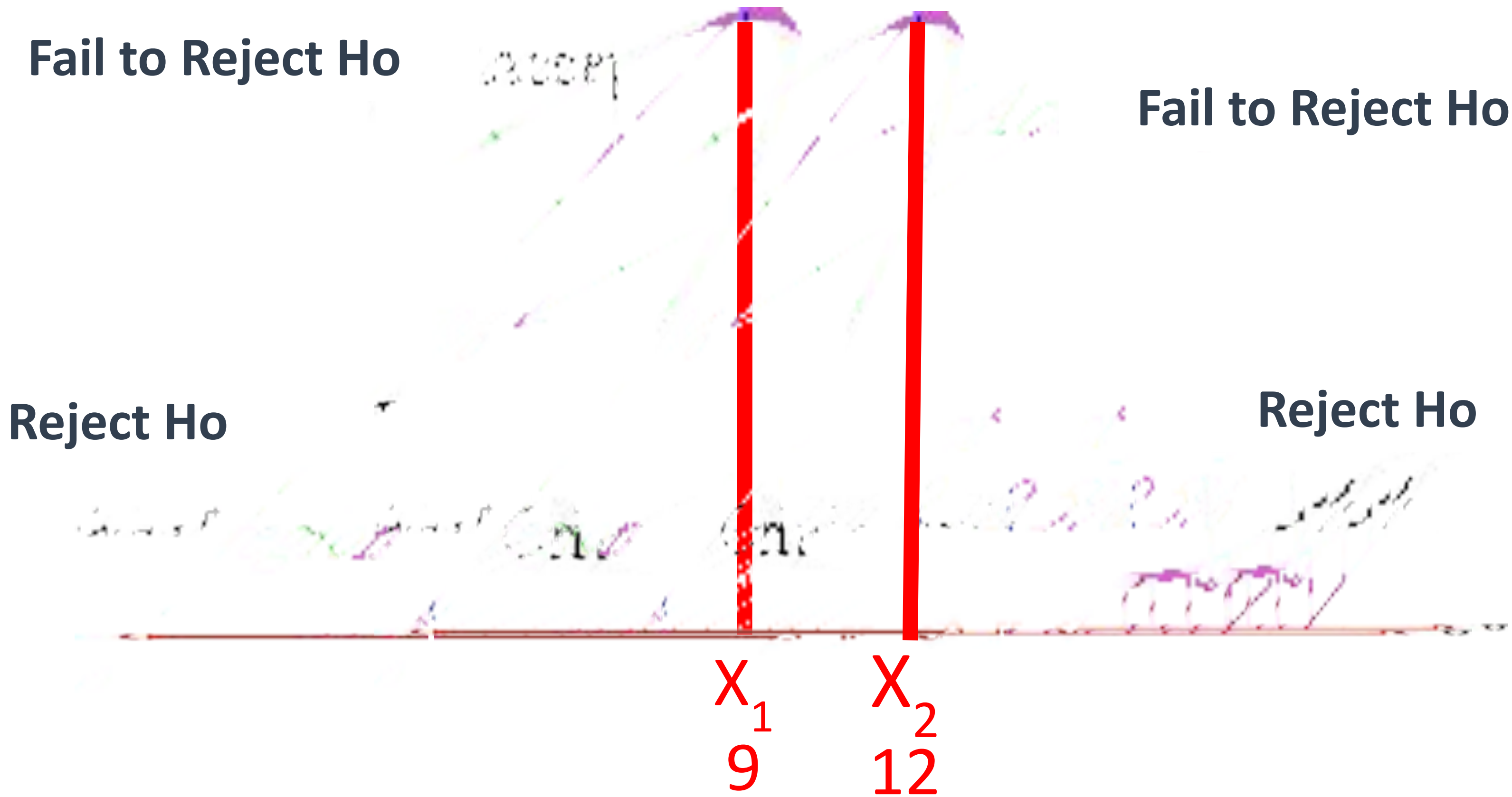




n_2

$\bar{X}_2$

S_2


Fail to Reject Ho
Fail to Reject Ho
Reject Ho
Reject Ho
X_1
9
X_2
12

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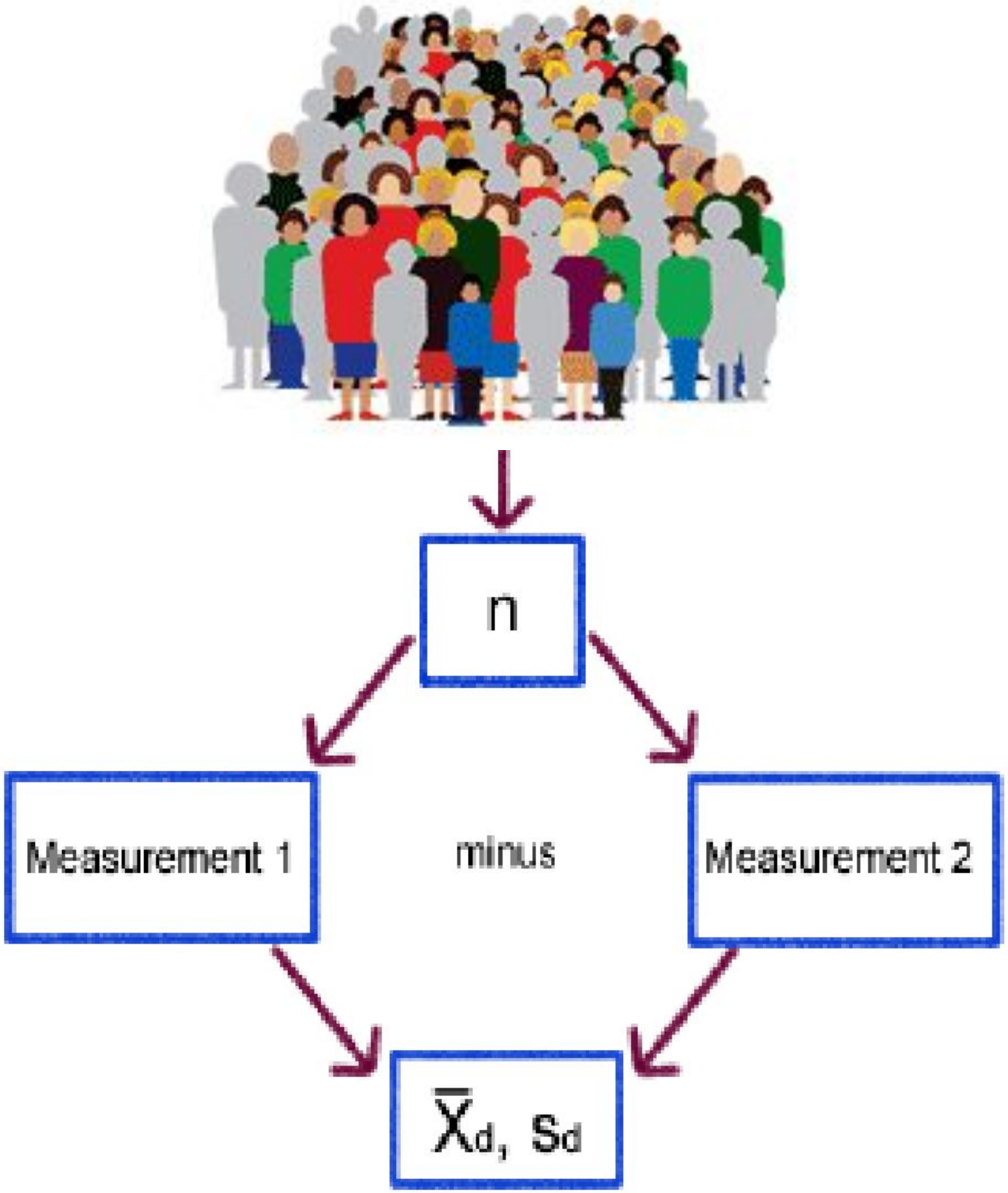
The data consists of a single population and two measurements. A simple random sample is taken from the population and pairs of measurement are collected. This is also called related sampling or matched pair design.



X_d **is the sample mean of the differences of each pair**

S_d **is the sample standard deviation of the differences of each pair**

Matched pairs t-test

compares the means for two dependent populations

(paired difference t-test)

Model Assumptions

Variable is quantitative continuous

Data is normally distributed

Dependent sampling

Matched pairs t-test

compares the means for two dependent populations

(paired difference t-test)

Test Statistic

$$t = \frac{\bar{X}_d - \mu_d}{s_d/\sqrt{n}} \qquad df = n - 1$$

$X_d = X_1 - X_2$

$\bar{X}_d = \bar{X}_1 - \bar{X}_2$ approximately Normal

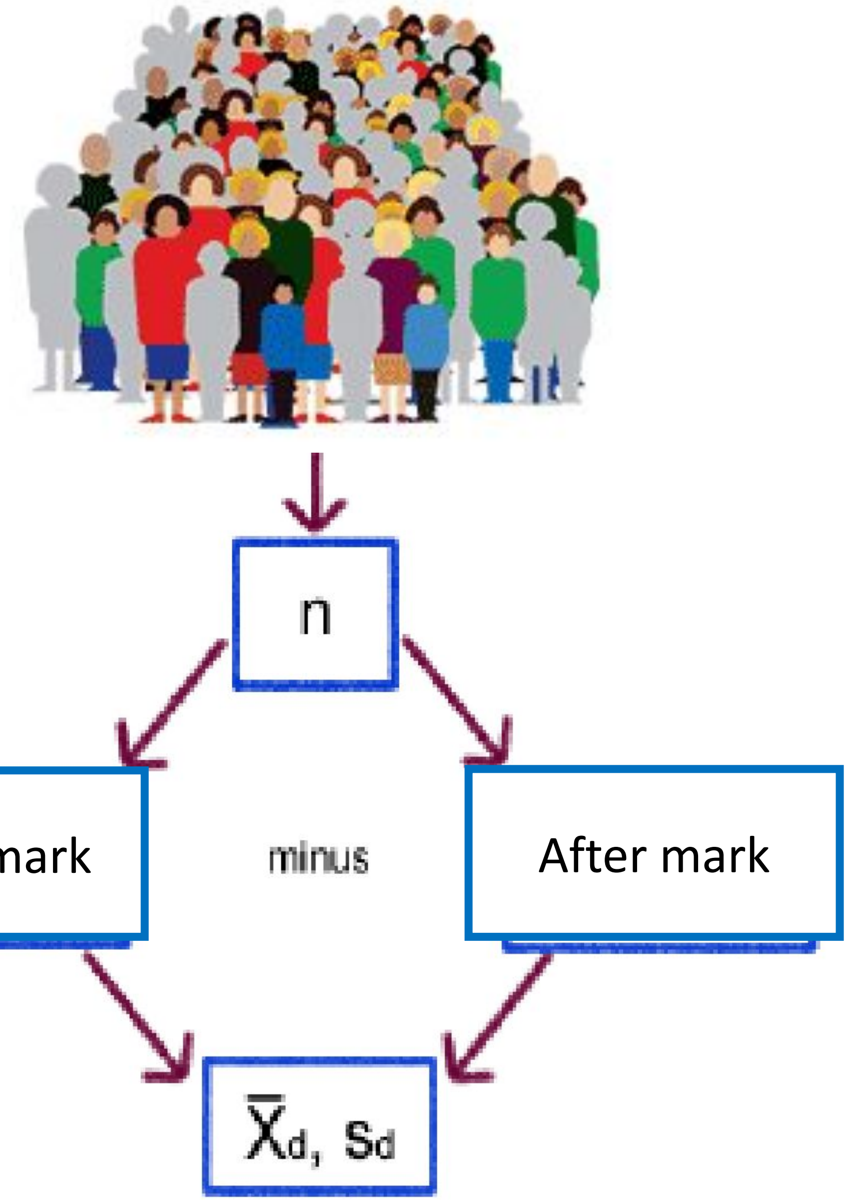
X_d **sample mean of the differences of each pair**

S_d **sample standard deviation of the differences of each pair**

Exercise (15)

Exercise (15):

An instructor of Anatomy course wants to know if student marks are different on the second midterm compared to the first exam after implementation of a new teaching intervention; TBL (team-based learning). The first and second midterm marks for 35 students were taken and the mean difference in marks is determined.



X_d is the sample mean of the differences of each pair (2.05)
S_d is the sample standard deviation of the differences of each pair

Diff	After Mark	Before Mark	Student
4	22	18	1
4	25	21	2
1	17	16	3
2	24	22	4
-3	16	19	5
5	29	24	6
3	20	17	7
-4	19	2	9
.	.	.	.
.	.	.	.
.	.	.	.
4	19	15	34
-1	16	17	35
2.05	20.45	18.40	Mean

Data were typed and analyzed using SPSS software program. The level of significance was 0.05. The appropriate statistical test was conducted and revealed test statistic = 3.23 (p=0.004). The followings are SPSS output tables.

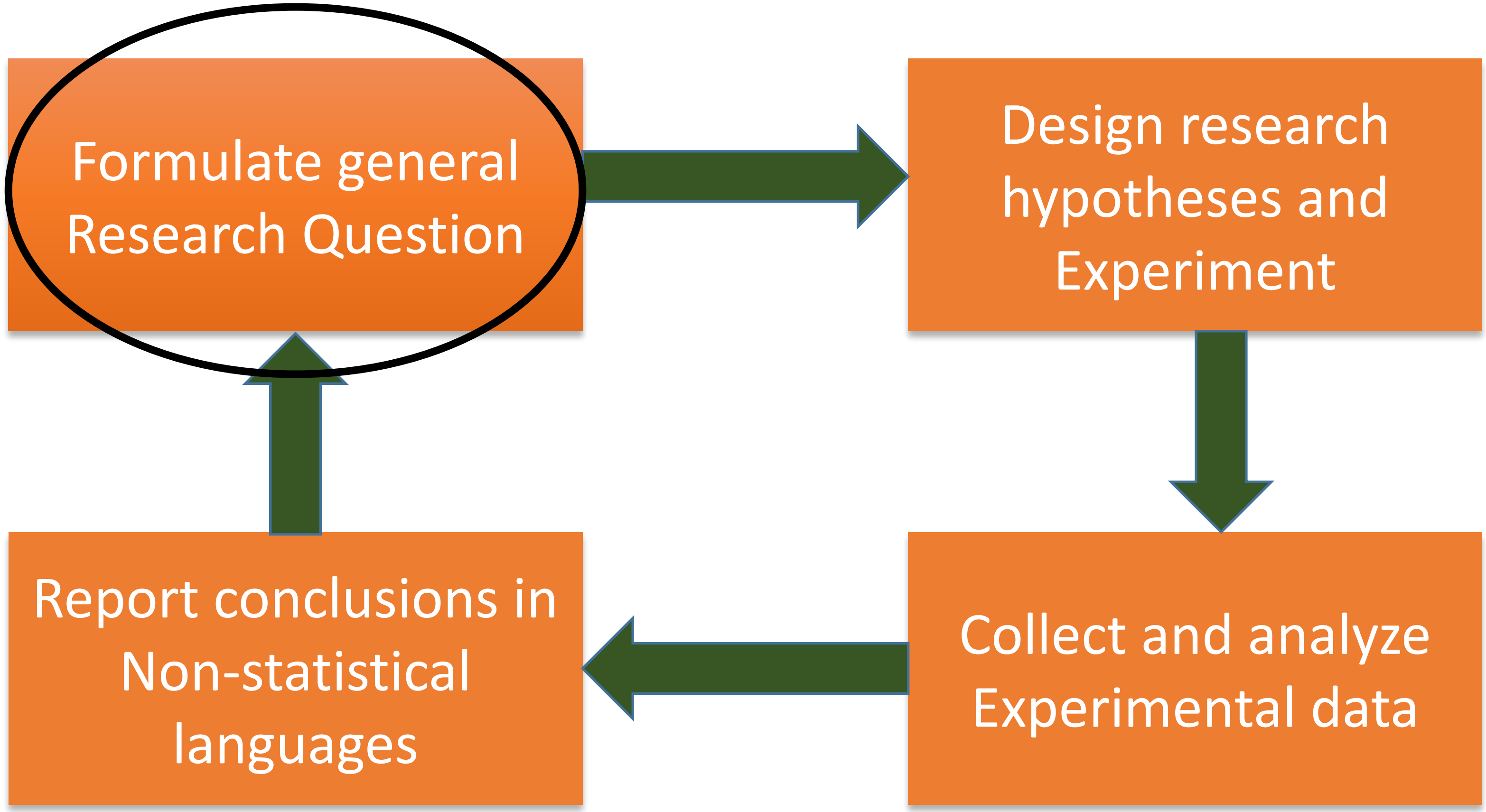
Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Mark after	20.45	35	4.058	.907
	Mark before	18.40	35	3.152	.705

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Mark after - Mark before	**2.050**	2.837	.634	.722	3.378	3.231	19	**.004**

Procedures of Hypotheses Testing and the Scientific Method

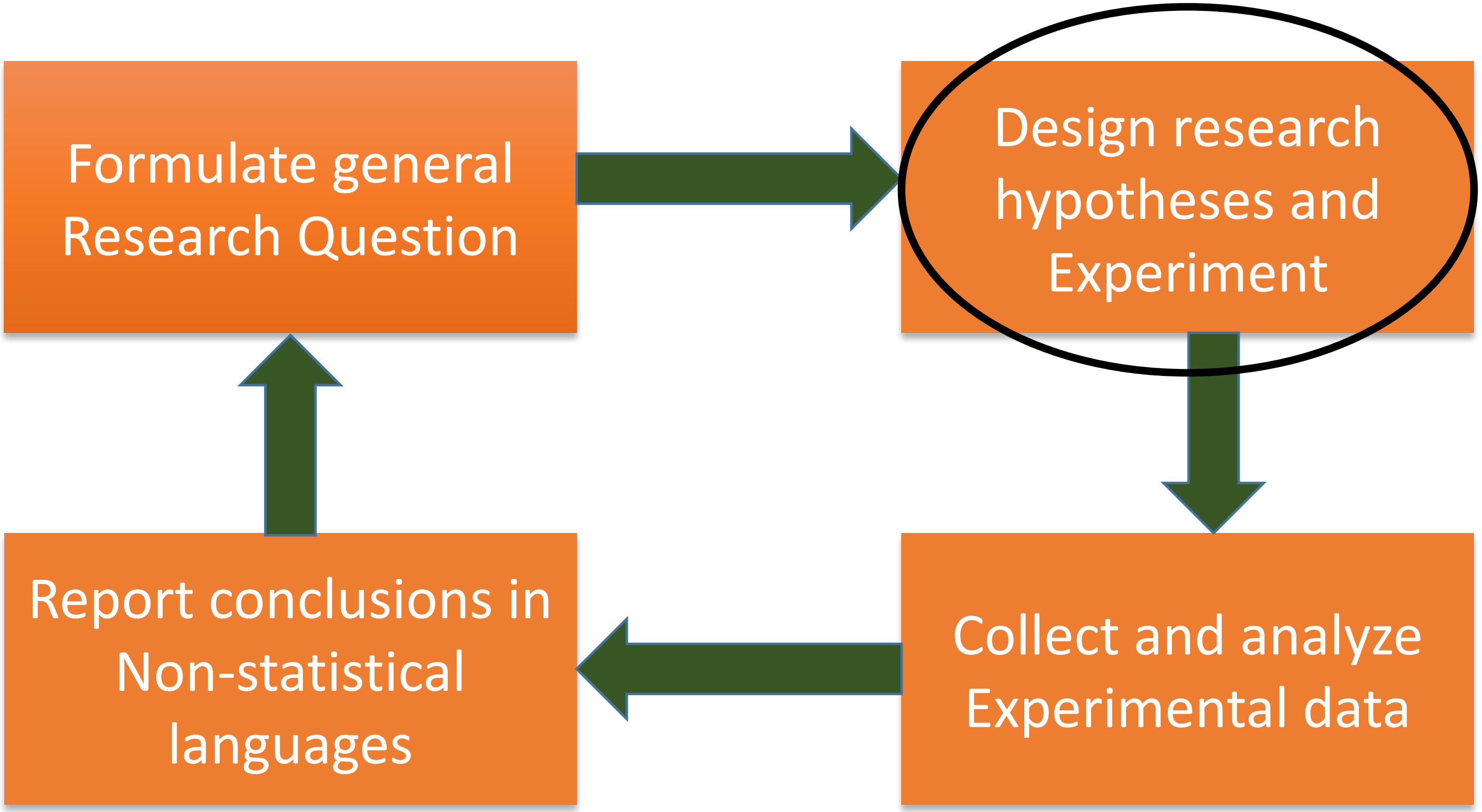


I. Formulate general Research Question

I. Formulate general Research Question

Is there a **difference** in students' marks following implementation of TBL (Team-based Learning)?

Procedures of Hypotheses Testing and the Scientific Method



II. State Research Hypotheses

III. What is the appropriate test statistic?

IV. What is the appropriate test Model? (One or Two tailed)

II. State Research Hypotheses

Ho: There is no difference in mean pre- and post-TBL marks

H1: There is a difference in mean pre- and post-TBL marks

III. What is the appropriate test statistic?

IV. What is the appropriate test Model? (One or Two tailed)

II. State Research Hypotheses

Ho: There is no difference in mean pre- and post-TBL marks

H1: There is a difference in mean pre- and post-TBL marks

III. What is the appropriate test statistic?

Matched pairs t-test

$$t = \frac{\bar{X}_d - \mu_d}{s_d/\sqrt{n}} \qquad df = n - 1$$

IV. What is the appropriate test Model? (One or Two tailed)

II. State Research Hypotheses

Ho: There is no difference in mean pre- and post-TBL marks

H1: There is a difference in mean pre- and post-TBL marks

III. What is the appropriate test statistic?

Matched pairs t-test

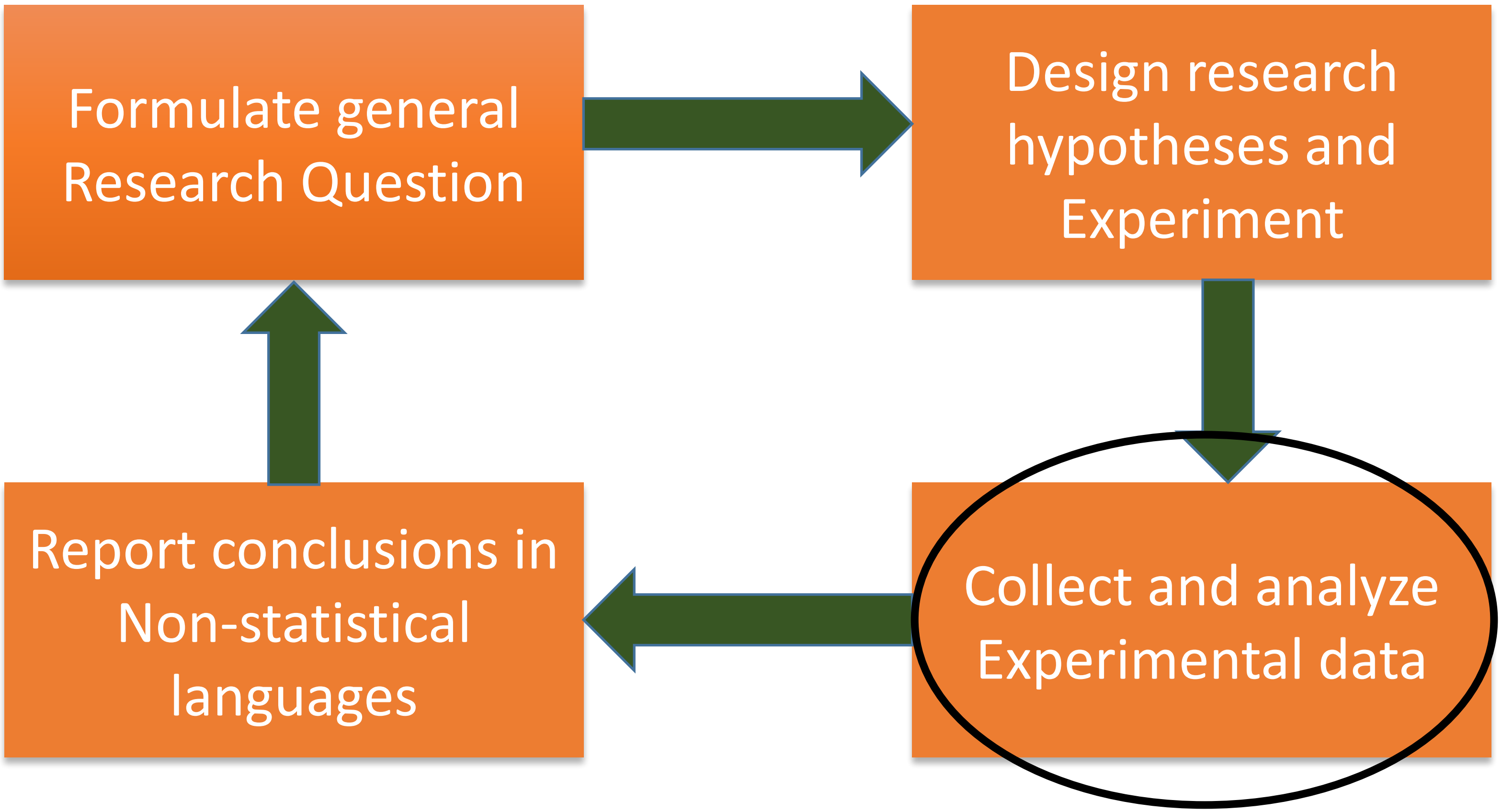
$$t = \frac{\bar{X}_d - \mu_d}{s_d/\sqrt{n}} \qquad df = n - 1$$

IV. What is the appropriate test Model? (One or Two tailed)

Two Tailed Test Model

Design Research Hypotheses and Experiment

Procedures of Hypotheses Testing and the Scientific Method



Collect and Analyze Experimental Data

V. Make a Decision regarding Research Hypotheses

(Specify the Decision Method)

Data were typed and analyzed using SPSS software program. The level of significance was 0.05. The appropriate statistical test was conducted and revealed test statistic = 3.23 (p=0.004). The followings are SPSS output tables.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Mark after	20.45	35	4.058	.907
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Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Mark after - Mark before	**2.050**	2.837	.634	.722	3.378	3.231	19	**.004**

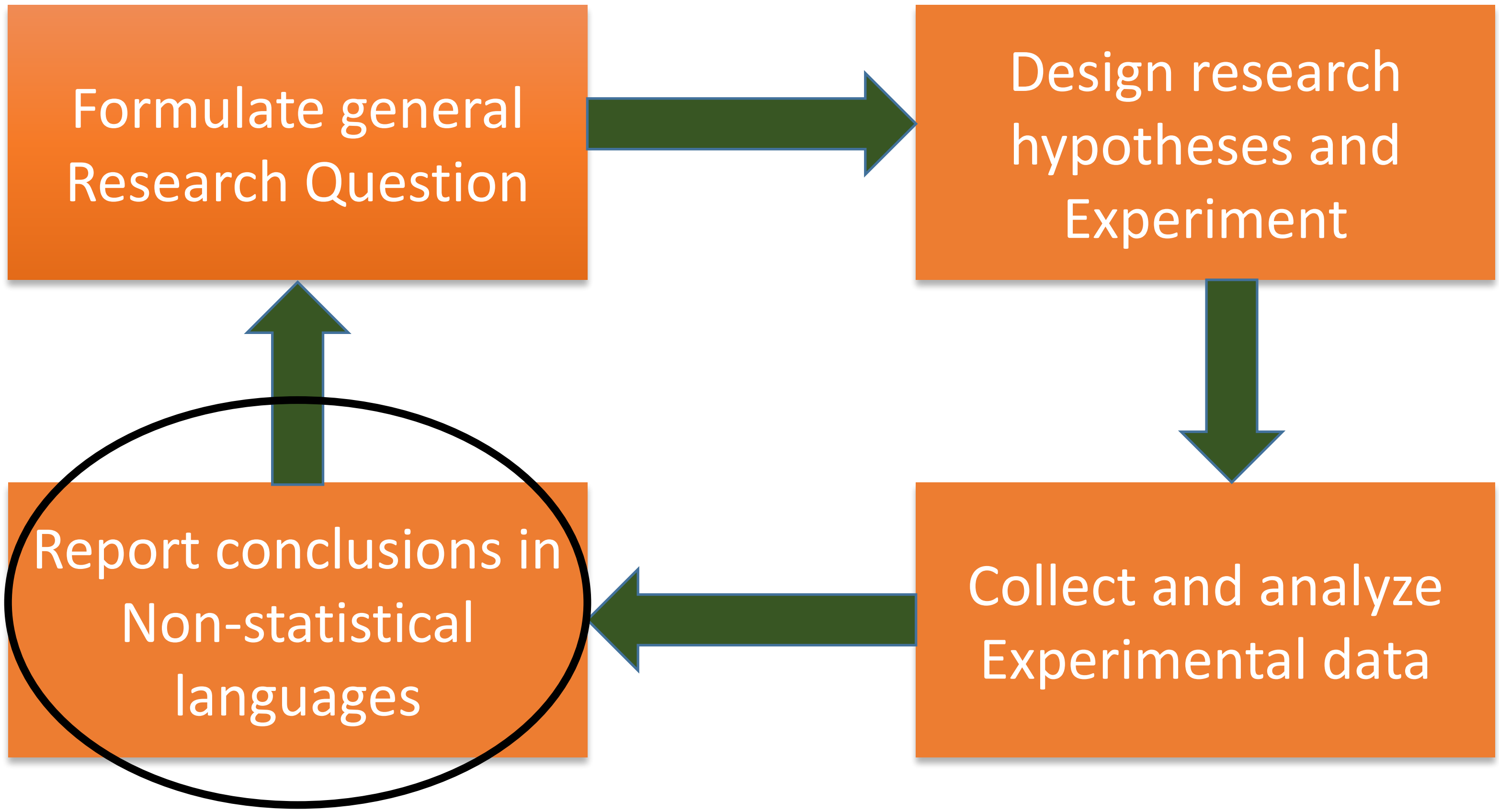
V. Make a Decision regarding Research Hypotheses (Specify the Decision Method)

Reject Null Hypothesis Ho

P-value (0.004) < α (0.05)

(p-value method)

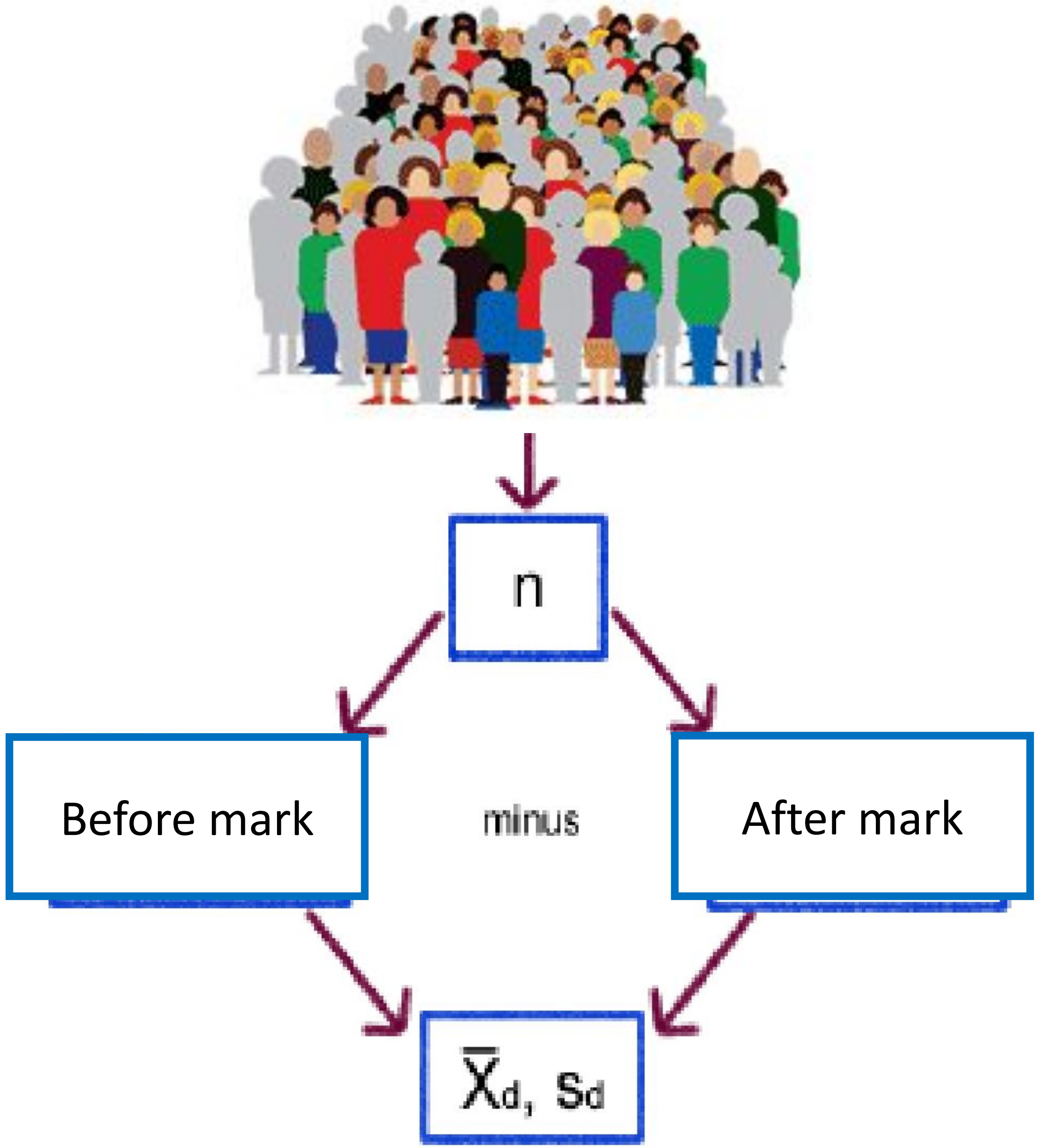
Procedures of Hypotheses Testing and the Scientific Method



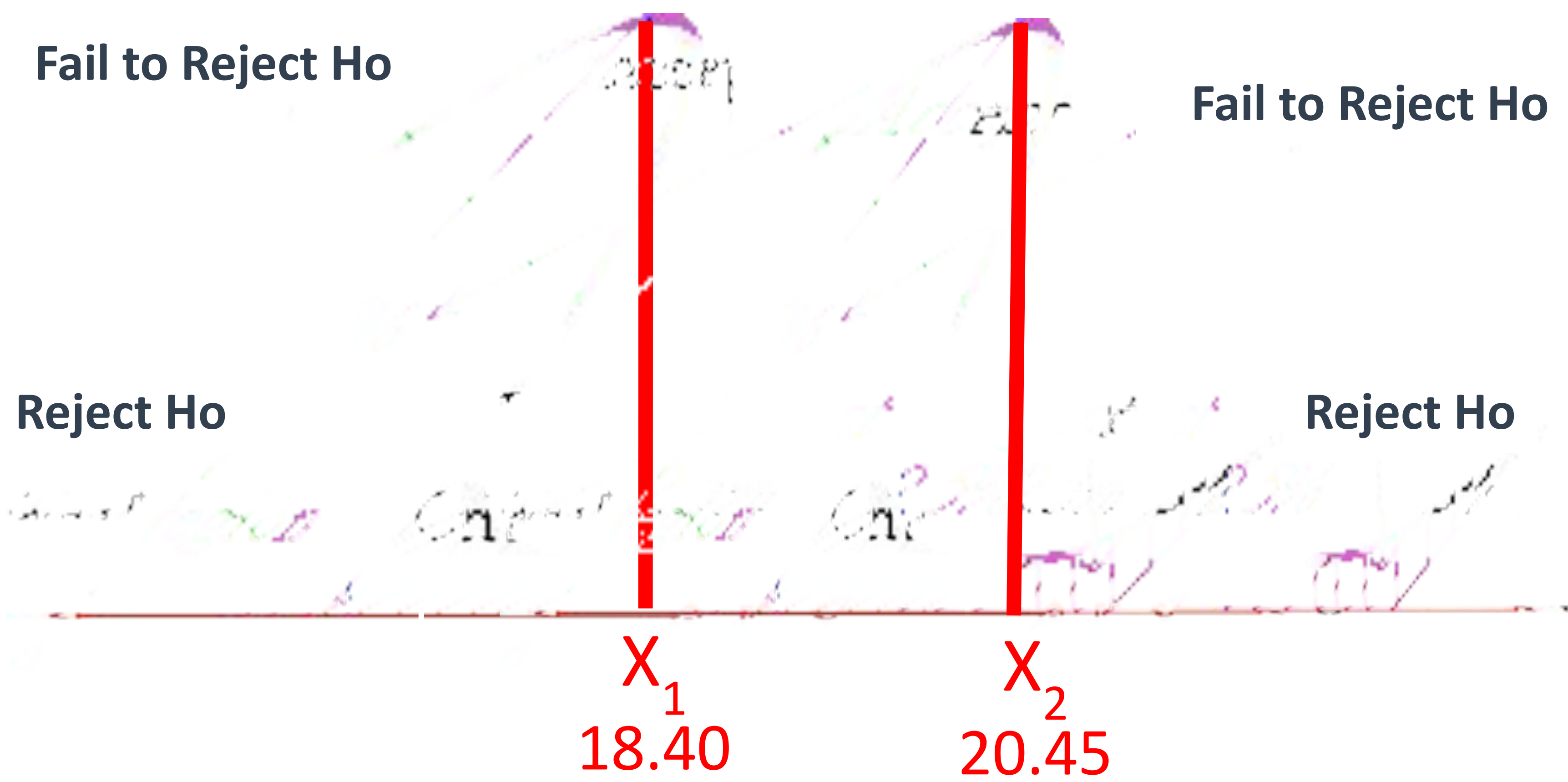
VI. Report a conclusion

VI. Report a conclusion

There is a strong evidence ($t = 3.23$, $p = 0.004$) that TBL as a teaching intervention improves students' marks. In this data set, it improved marks, on average, by approximately 2 points (mean paired difference =2.05).



X_d **is the sample mean of the differences of each pair (2.05)**
S_d **is the sample standard deviation of the differences of each pair**



Fail to Reject Ho
Fail to Reject Ho
Reject Ho
Reject Ho
X_1
18.40
X_2
20.45

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One P

Two P
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One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

Suppose we wanted to compare the means of more than two (k) independent populations and want to test the null hypothesis $Ho: \mu 1 = \mu 2 = \cdots = \mu k$.

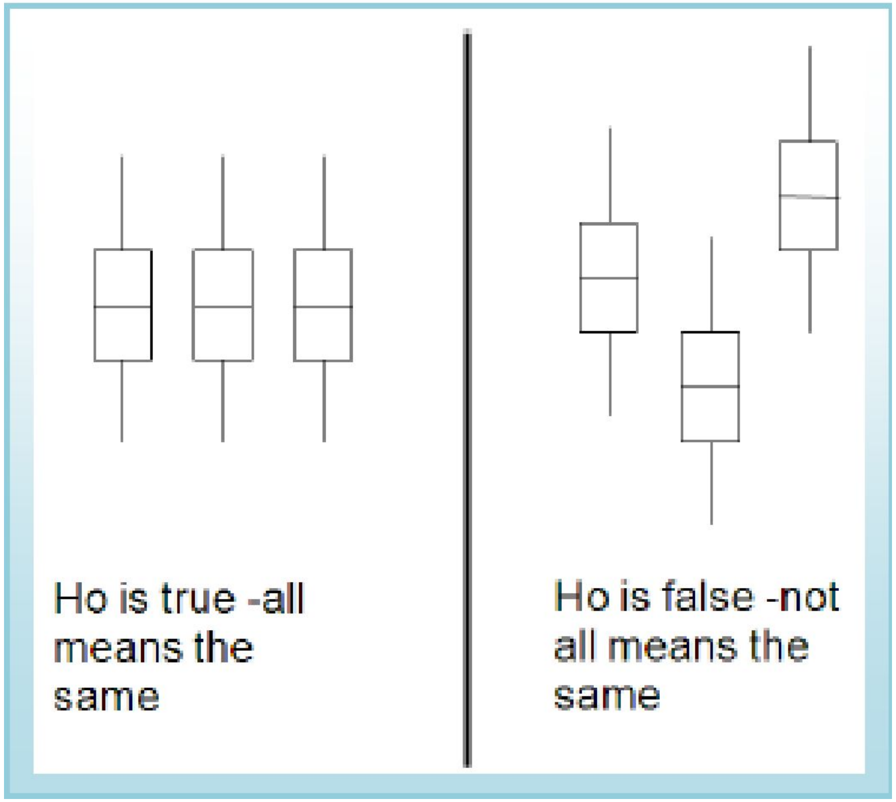
If we can assume all population variances are equal, we can expand the pooled variance t-test for two populations to one factor ANOVA for k populations.

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

If Ho: $\mu 1 = \mu 2 = \mu 3$ is true, then each population would have the same distribution and the variance of the combined data would be approximately the same.

If the Ho is false, then the difference between centers would cause the combined data to have an increased variance.



One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Data Requirements

1. Dependent variable that is continuous.

2. Independent variable (Factor) that is categorical ($\geq$ 3 groups)

3. Cases that have values on both the dependent and independent variables

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Data Requirements

4. Independent samples/groups (i.e., independence of observations); there is no relationship between the subjects in each sample.

   This means that:

   A. subjects in the first group cannot also be in the second group
   B. no subject in either group can influence subjects in the other group
   C. no group can influence the other group

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Data Requirements

5. Random sample of data from the population.

6. Normal distribution (approximately) of the dependent variable for each group (i.e., for each level of the factor)

7. Homogeneity of variances (i.e., variances approximately equal across groups)

8. No outliers

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Model Assumptions

The populations being sampled are normally distributed

The populations have equal standard deviations

The samples are randomly selected and are independent

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Research Hypotheses

H_0: $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$
("all k population means are equal")

H_a: At least one μ_i different
("at least one of the k population means is not equal to the others")

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Test Statistic

P-value	F	Mean Square (MS)	df	Sum of Squares (SS)	Source of Variation
	$F=MS_{Factor}/MS_{Error}$	$MS_{Factor}=SS_{Factor}/K-1$	k-1	SS_{Factor}	Factor (Between)
		$MS_{Error}=SS_{Error}/n-k$	n-k	SS_{Error}	Error (Within)
			n-1	SS_{Total}	Total

SS_{Factor} = the regression sum of squares; SS_{Error} = the error sum of squares
SS_{Total} = the total sum of squares (SST = SSR + SSE)
k = the total number of groups; n = the total number of valid observations
MS_{Factor} = the regression mean square; MS_{Error} = the mean square error

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct an exploratory analysis

Why?

a) Examine descriptive statistics
b) Check for outliers
c) Check that the normality assumption is met
d) Verify that there are mean differences between groups to justify ANOVA

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct One Way ANOVA

Why?

1. Determine whether group means are different form one another (warranting post hoc comparison tests)

2. Check that the homogeneity of variance assumption is met

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct Post hoc comparison test

Why?

To confirm where the differences occurred between groups

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Exercise (16)

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Exercise (16)

A research was conducted to examine if there a difference in mean score of medical students at 4 universities located at different geographical locations (North-East, North-Central, South, and West region).

In order to conduct the research, 400 randomly selected students from the 4 universities were included, and their scores were reported. Data were typed and analyzed by SPSS software program. The statistician selected level of significance = 0.05.

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

I. State the Research Question

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

I. State the Research Question

Are there any differences in the mean score of medical students enrolled at North-East, North-Central, South, and West Universities?

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

II. State the Research Hypotheses

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

II. State the Research Hypotheses

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$

$\mu_{1:}$ mean score of students at North-East University
$\mu_{2:}$ mean score of students at North-Central University
$\mu_{3:}$ mean score of students at North-East University
$\mu_{4:}$ mean score of students at North-East University

H_a: At least one μ_i different

("at least one of the 4 population means is not equal to the others")

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

III. Specify the Dependent and Independent variables

Mention the type of variable and number of groups

Type of variable number of groups	Variable	
		Dependent Variable
		Independent Variable (Factor)

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

III. Specify the Dependent and Independent variables

Mention the type of variable and number of groups

Type of variable number of groups	Variable	
Quantitative Continuous	Score	**Dependent Variable**
Categorical/Qualitative (4 groups)	Geographic Region of Medical School	**Independent Variable (Factor)**

Exercise (17)

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Exercise (17)

A manager of a pharmaceutical company wants to raise the productivity at his company by increasing the speed at which his pharmacists carry out pharmaceutical formulation.

As he does not have the skills in-house, he employs an external agency which provides training in pharmaceutical formulation Development. They offer 3 packages - a beginner, intermediate and advanced course.

He is unsure which course is needed for the type of work they do at his company so he sends 10 pharmacists on the beginner course, 10 on the intermediate and 10 on the advanced course.

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

Exercise (17)

When they all return from the training he gives them a task to formulate certain parenteral drug produced by the company and times how long it takes them to complete the task.

He wishes to then compare the three courses (beginner, intermediate, advanced) to see if there are any differences in the average time it took to complete the task.

The statistician selected level of significance = 0.05

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

I. State the Research Question

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

I. State the Research Question

Are there any differences in the average time taken by the pharmacists who attended the three training courses (Beginner, Intermediate, and Advanced courses), to complete the drug formulation task?

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

II. State the Research Hypotheses

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

II. State the Research Hypotheses

H_0: $\mu_1 = \mu_2 = \mu_3$

μ_1: Mean time (hour) taken by the pharmacists who attended the beginner course to complete the task.

μ_2: Mean time (hour) taken by the pharmacists who attended the intermediate course to complete the task.

μ_3: Mean time (hour) taken by the pharmacists who attended the advanced course to complete the task.

H_a: At least one μ_i different

("at least one of the 3 population means is not equal to the others")

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

III. Specify the Dependent and Independent variables

Mention the type of variable and number of groups

Type of variable number of groups	Variable	
		Dependent Variable
		Independent Variable (Factor)

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

III. Specify the Dependent and Independent variables

Mention the type of variable and number of groups

Type of variable number of groups	Variable	
Quantitative Continuous	Time	**Dependent Variable**
Categorical/Qualitative (3 groups)	Course	**Independent Variable (Factor)**

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct an exploratory analysis

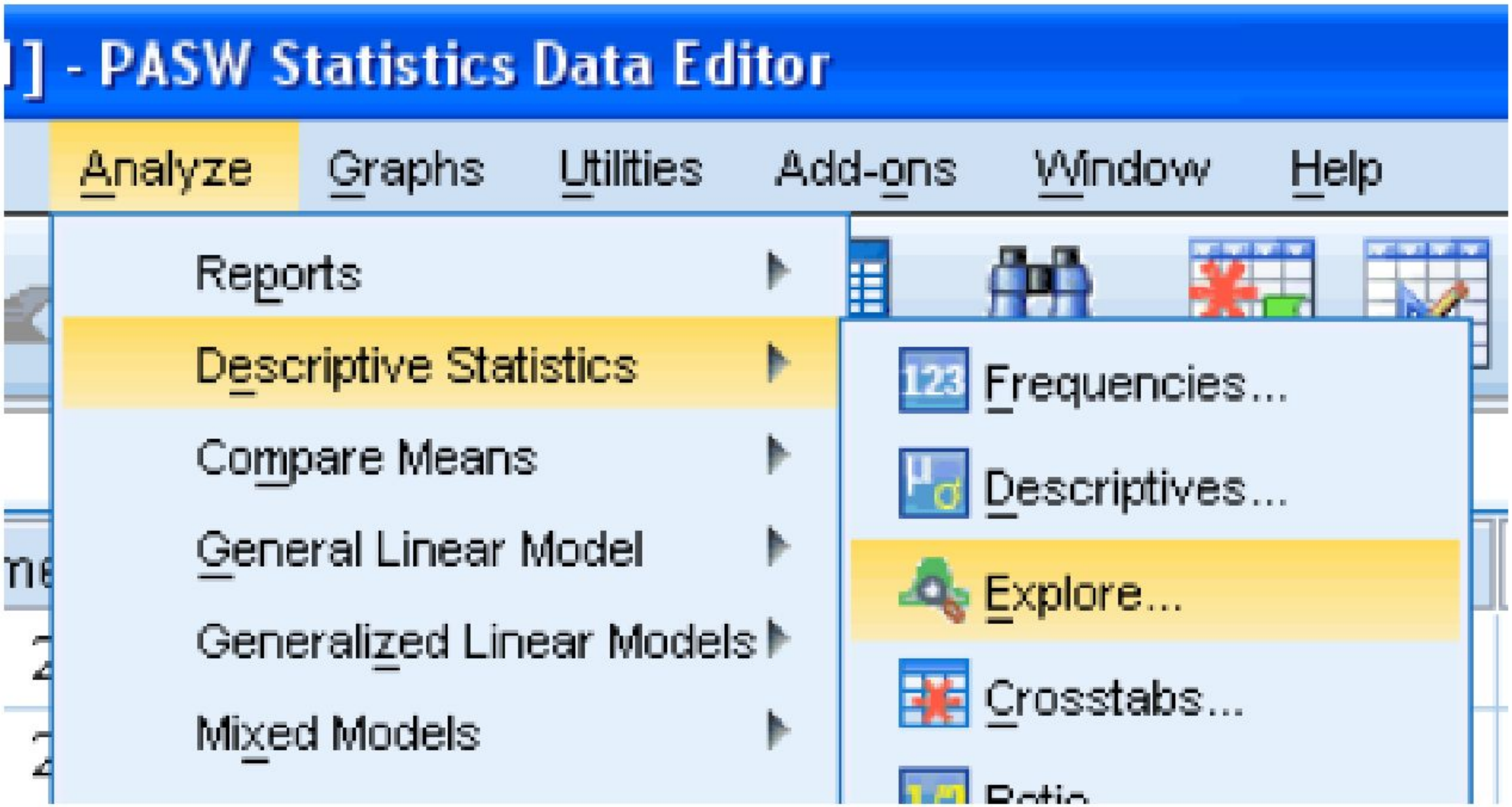
Why?

a) Examine descriptive statistics
b) Check for outliers

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)



One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

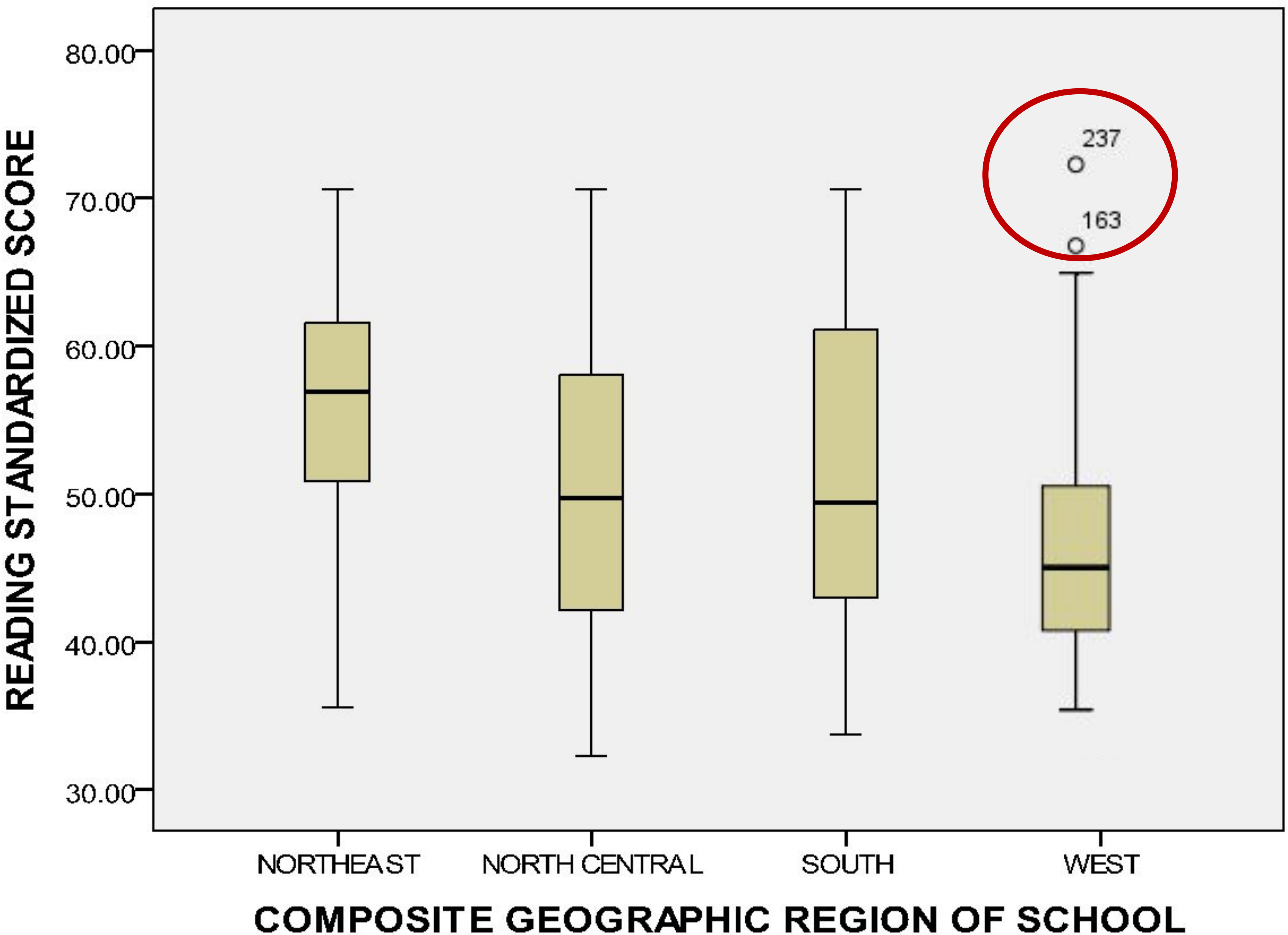
Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Report

READING STANDARDIZED SCORE

COMPOSITE GEOGRAPHIC REGI...	Mean	N	Std. Deviation	Variance	Skewness	Std. Error of Skewness
NORTHEAST	55.8918	100	9.86641	97.346	-.486	.316
NORTH CENTRAL	50.8328	100	10.01432	100.287	.224	.267
SOUTH	51.3382	100	10.00440	100.088	.246	.241
WEST	49.0311	100	9.81560	96.346	.502	.304
Total	51.5901	400	10.14505	102.922	.152	.141

Box plot graph


80.00
70.00
60.00
50.00
40.00
30.00
READING STANDARDIZED SCORE
237
163
NORTHEAST
NORTH CENTRAL
SOUTH
WEST
COMPOSITE GEOGRAPHIC REGION OF SCHOOL

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

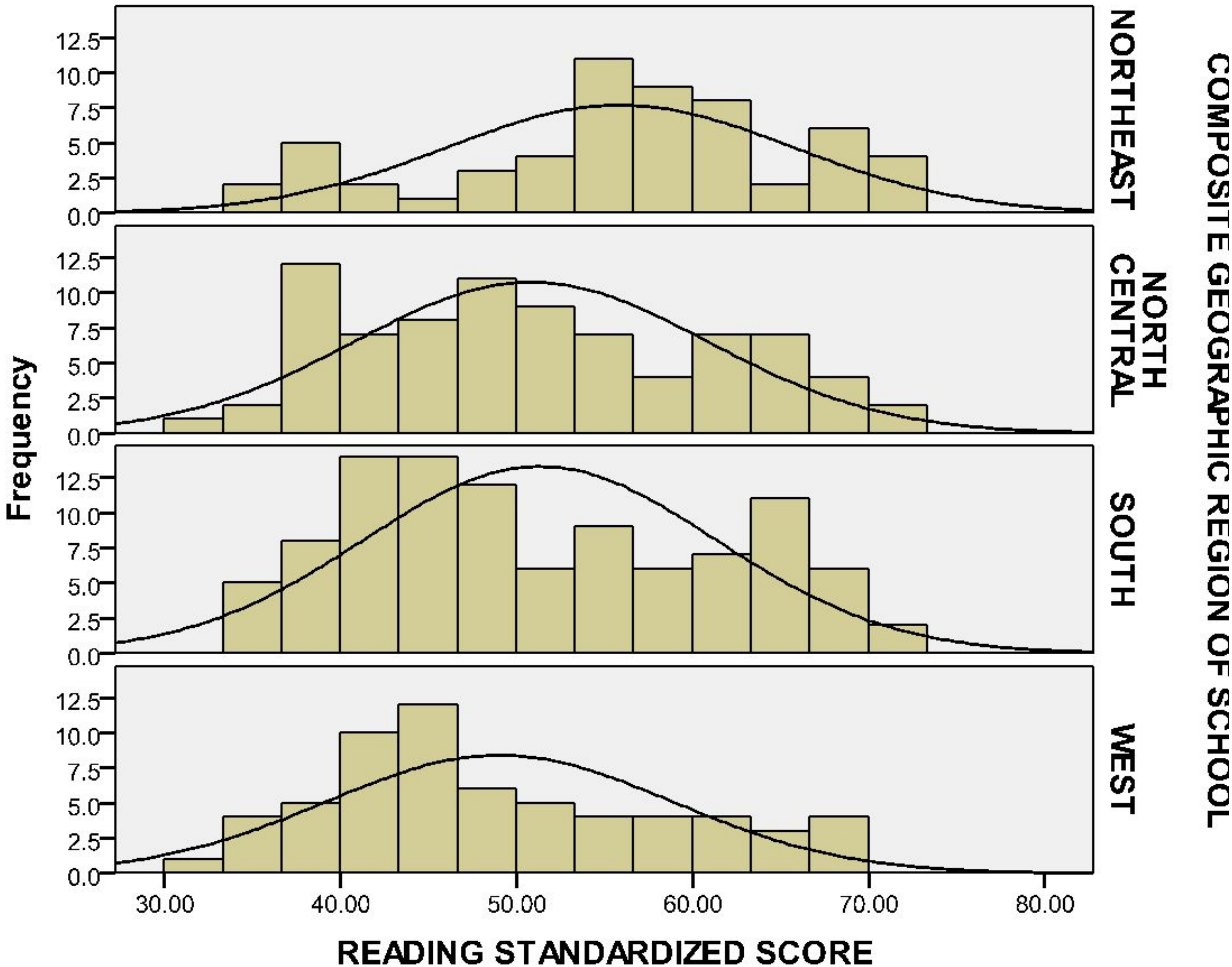
Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct an exploratory analysis

Why?

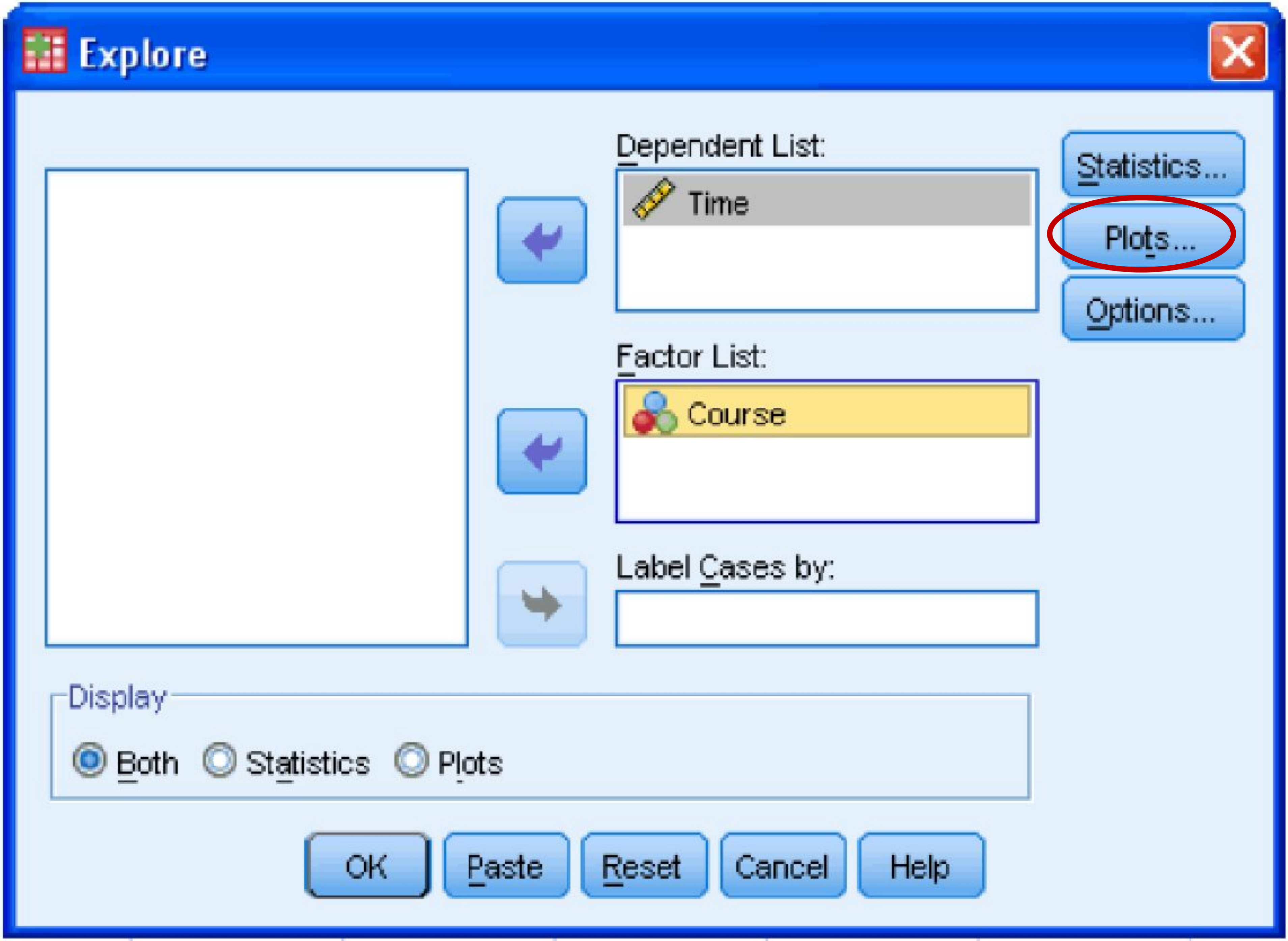
a) Examine descriptive statistics
b) Check for outliers
c) Check that the normality assumption is met

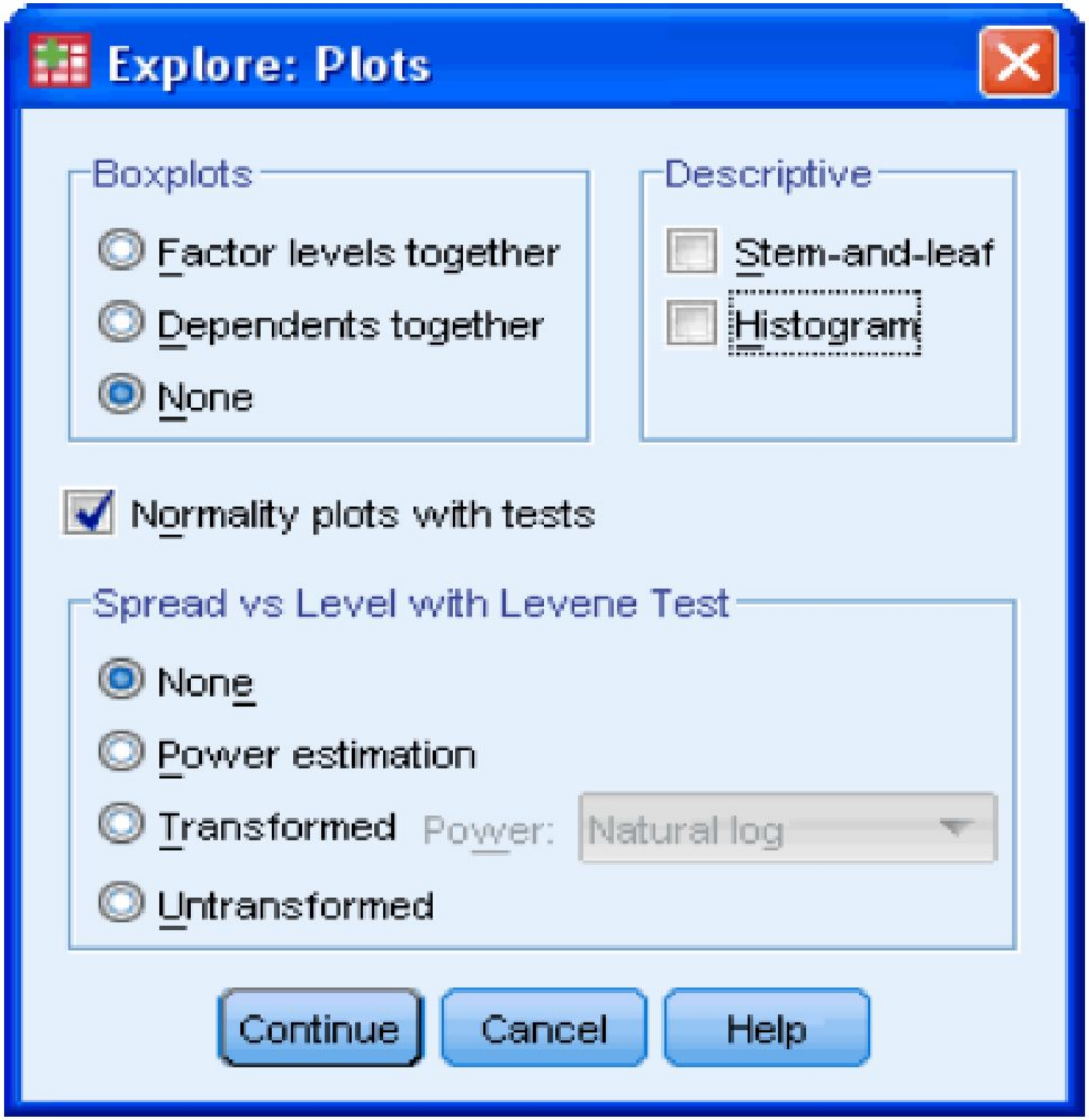
Histogram



COMPOSITE GEOGRAPHIC REGION OF SCHOOL
NORTHEAST
NORTH CENTRAL
SOUTH
WEST
Frequency
0.0
2.5
5.0
7.5
10.0
12.5
30.00
40.00
50.00
60.00
70.00
80.00
READING STANDARDIZED SCORE

Tests of Normality


Explore
Dependent List:
Time
Factor List:
Course
Label Cases by:
Statistics...
Plots...
Options...
Display
Both
Statistics
Plots
OK
Paste
Reset
Cancel
Help


Explore: Plots
Boxplots
Factor levels together
Dependents together
None
Descriptive
Stem-and-leaf
Histogram
Normality plots with tests
Spread vs Level with Levene Test
None
Power estimation
Transformed
Power:
Natural log
Untransformed
Continue
Cancel
Help

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Shapiro-Wilk Test of Normality

Tests of Normality

	Course	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Time	Beginner	.177	10	.200*	.964	10	.827
	Intermediate	.166	10	.200*	.969	10	.882
	Advanced	.151	10	.200*	.965	10	.837

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

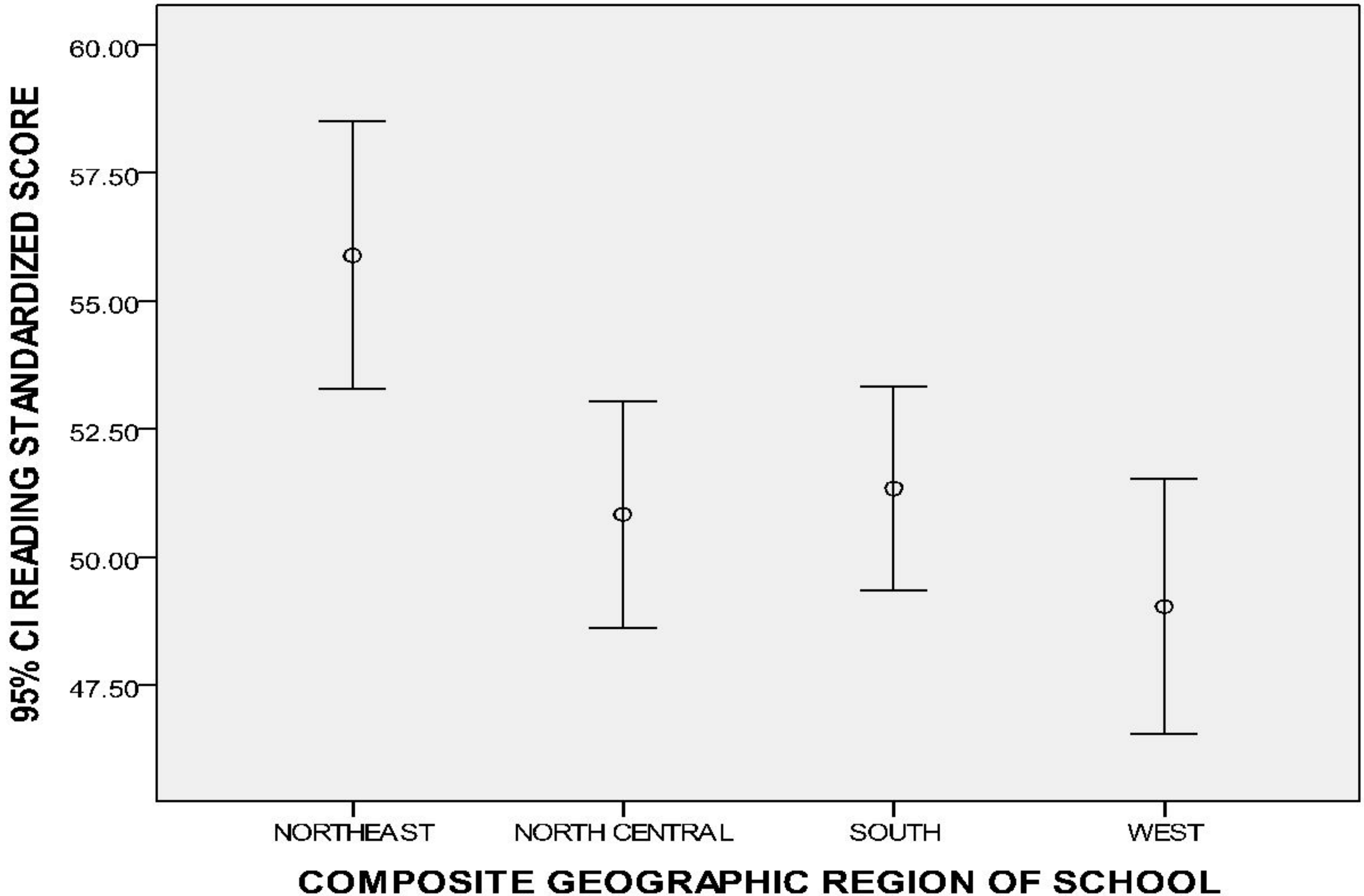
Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct an exploratory analysis

Why?

a) Examine descriptive statistics
b) Check for outliers
c) Check that the normality assumption is met
d) Verify that there are mean differences between groups to justify ANOVA

Error Bar graph



95% CI READING STANDARDIZED SCORE
60.00
57.50
55.00
52.50
50.00
47.50
NORTHEAST
NORTH CENTRAL
SOUTH
WEST
COMPOSITE GEOGRAPHIC REGION OF SCHOOL

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct an exploratory analysis

Why?

a) Examine descriptive statistics
b) Check for outliers
c) Check that the normality assumption is met
d) Verify that there are mean differences between groups to justify ANOVA

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

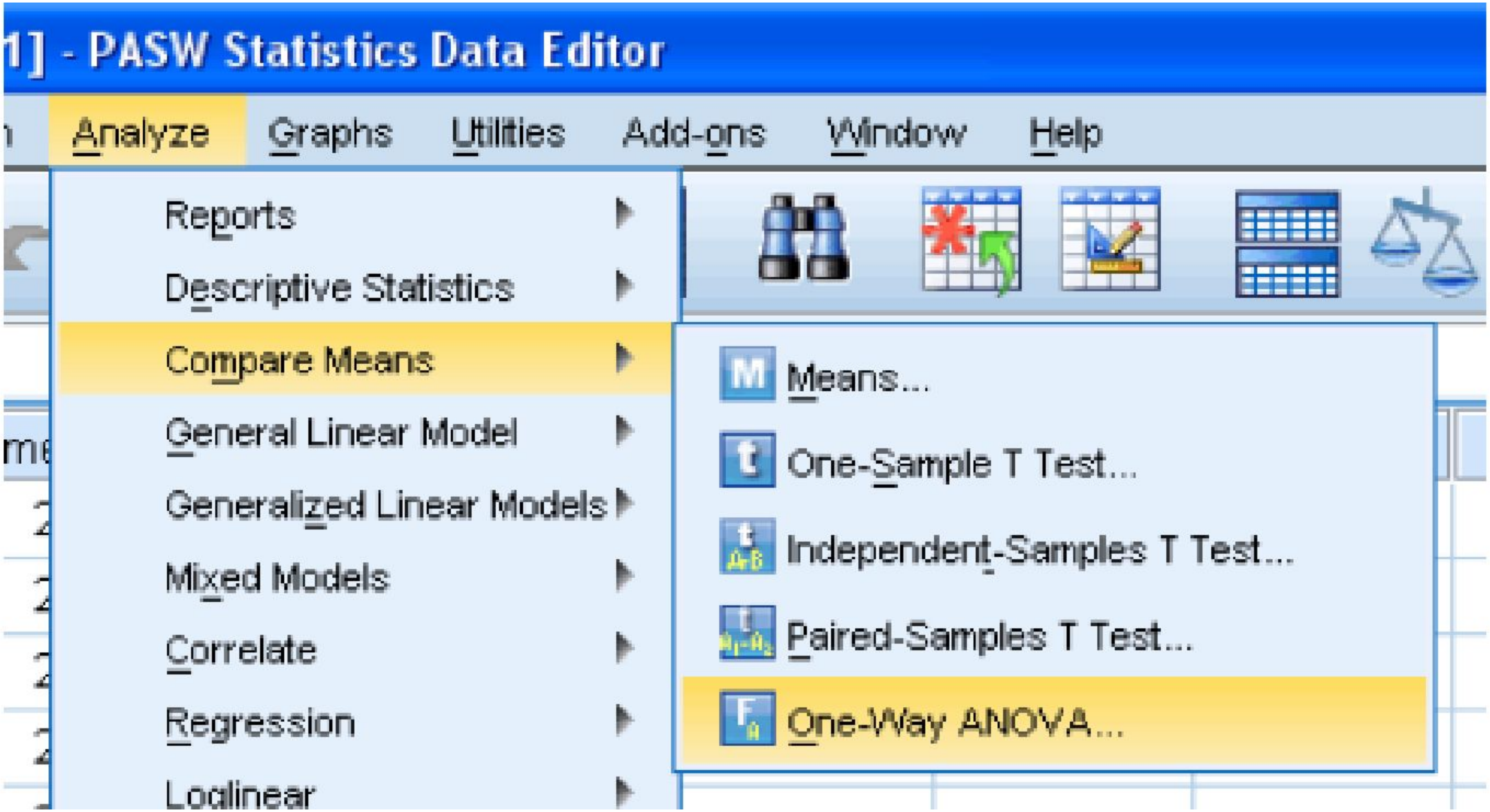
Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct One Way ANOVA

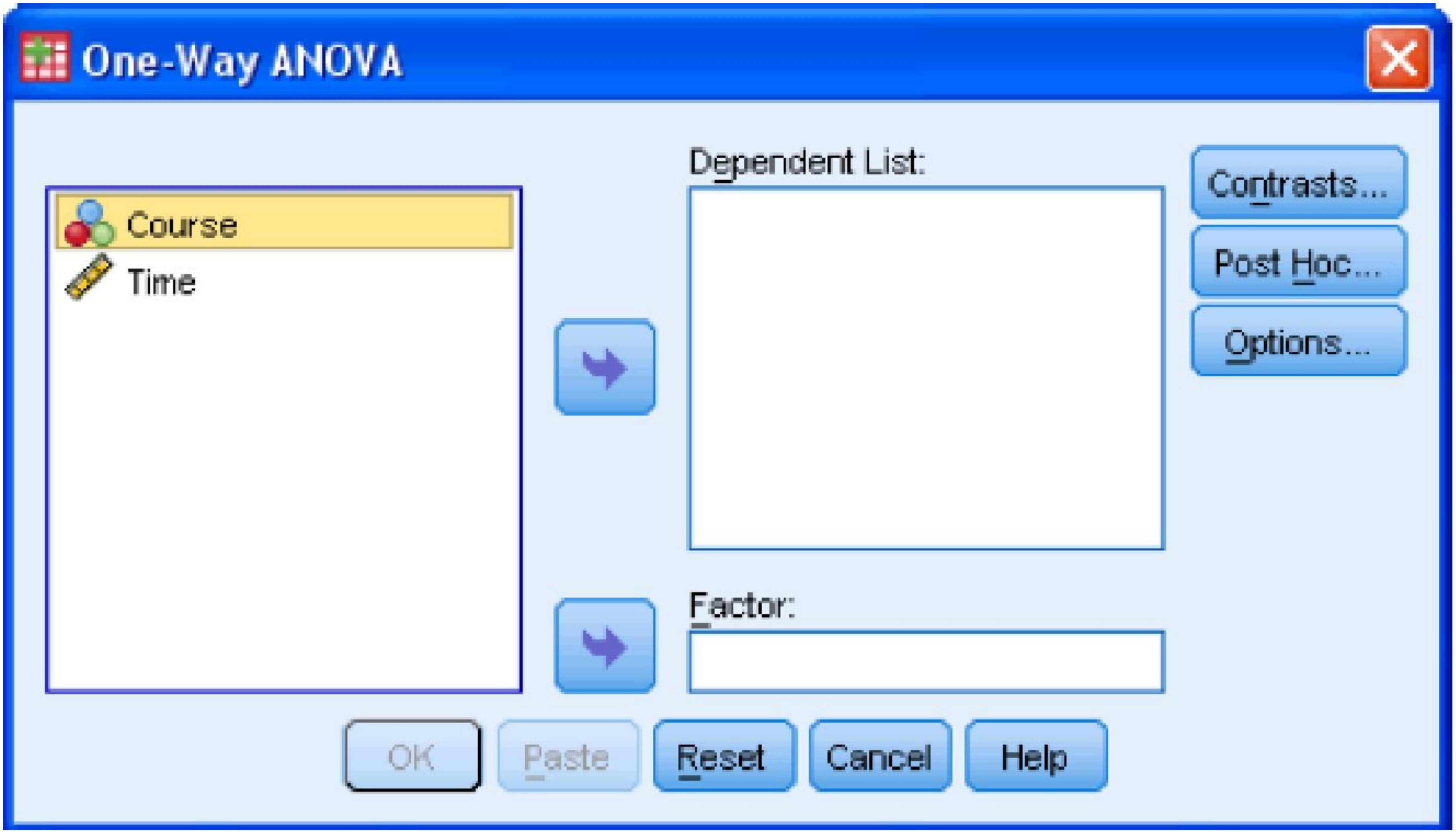
Why?

1. Determine whether group means are different form one another (warranting post hoc comparison tests)

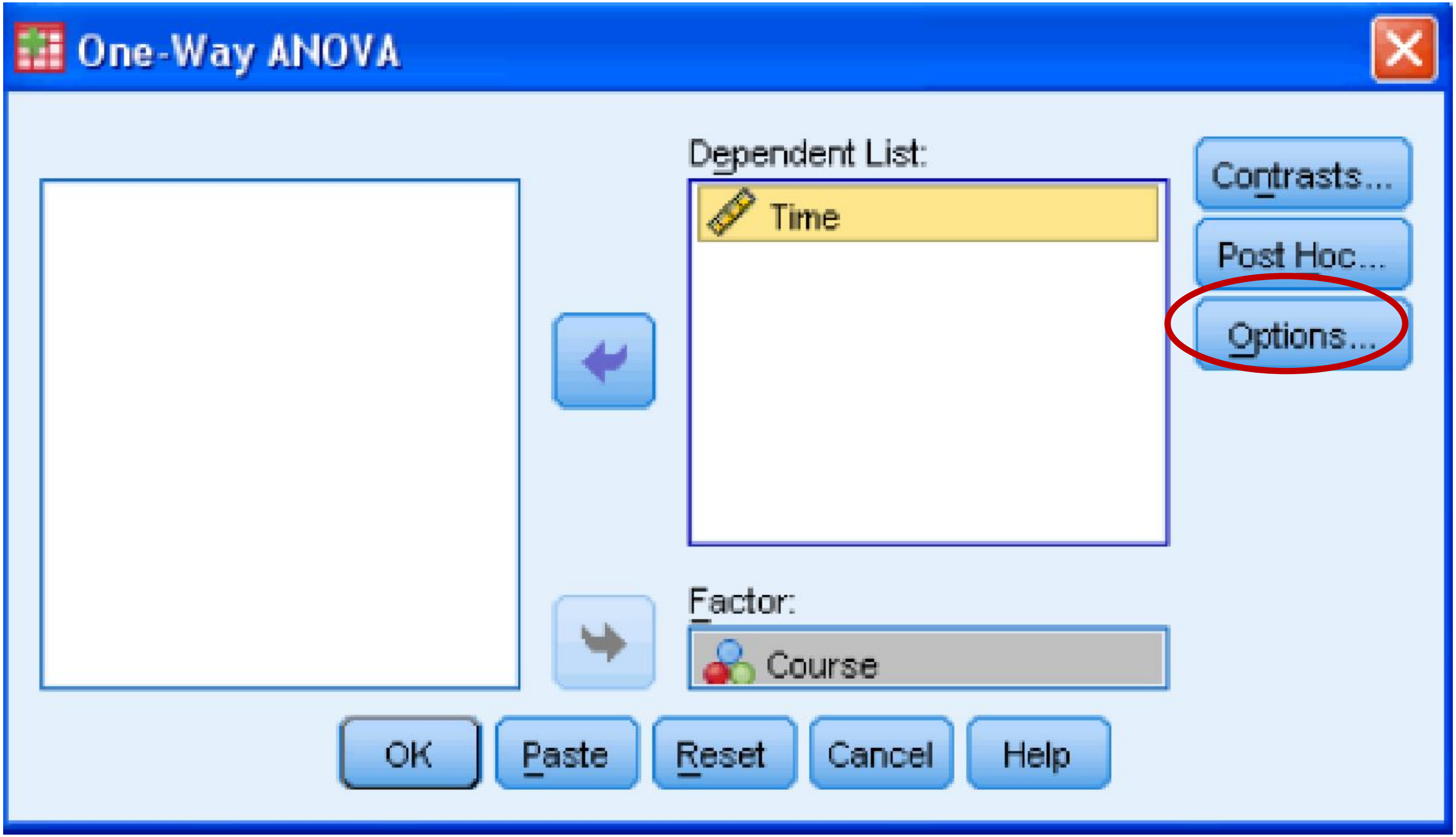
2. Check that the homogeneity of variance assumption is met



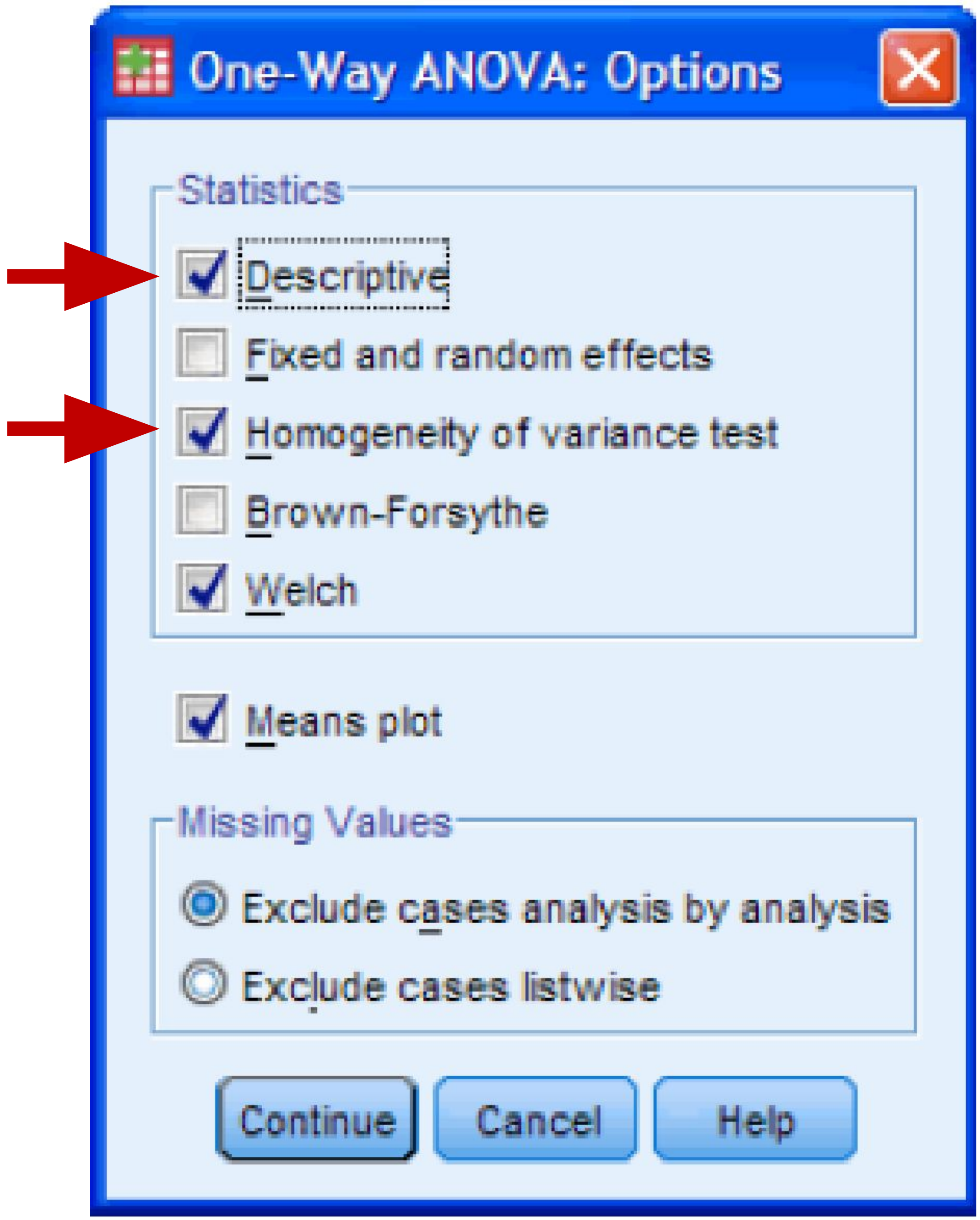
1] - PASW Statistics Data Editor
Analyze
Graphs
Utilities
Add-ons
Window
Help
Reports
Descriptive Statistics
Compare Means
General Linear Model
Generalized Linear Models
Mixed Models
Correlate
Regression
Loglinear
Means...
One-Sample T Test...
Independent-Samples T Test...
Paired-Samples T Test...
One-Way ANOVA...



One-Way ANOVA
Course
Time
Dependent List:
Factor:
Contrasts...
Post Hoc...
Options...
OK
Paste
Reset
Cancel
Help



One-Way ANOVA
Dependent List:
Time
Contrasts...
Post Hoc...
Options...
Factor:
Course
OK
Paste
Reset
Cancel
Help


One-Way ANOVA: Options
Statistics
Descriptive
Fixed and random effects
Homogeneity of variance test
Brown-Forsythe
Welch
Means plot
Missing Values
Exclude cases analysis by analysis
Exclude cases listwise
Continue
Cancel
Help

Descriptives

Time

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Beginner	10	27.2000	3.04777	.96379	25.0198	29.3802	22.00	33.00
Intermediate	10	23.6000	3.30656	1.04563	21.2346	25.9654	18.00	29.00
Advanced	10	23.4000	3.23866	1.02415	21.0832	25.7168	18.00	29.00
Total	30	24.7333	3.56161	.65026	23.4034	26.0633	18.00	33.00

Test of Homogeneity of Variances

Time

Levene Statistic	df1	df2	Sig.
.105	2	27	.901

ANOVA

Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	91.467	2	45.733	4.467	.021
Within Groups	276.400	27	10.237		
Total	367.867	29			

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct One Way ANOVA

Why?

1. Determine whether group means are different form one another (warranting post hoc comparison tests)

2. Check that the homogeneity of variance assumption is met

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

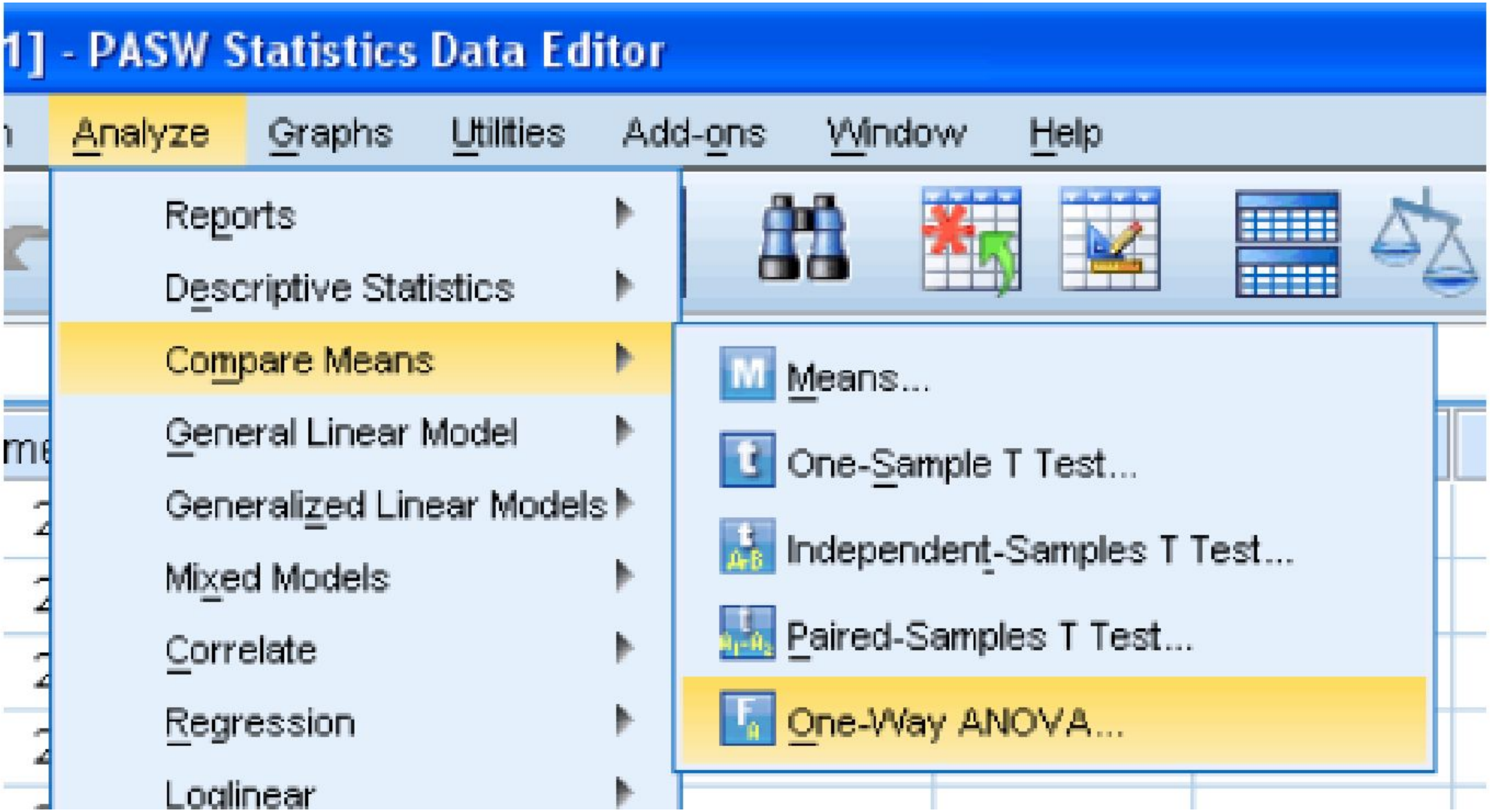
One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

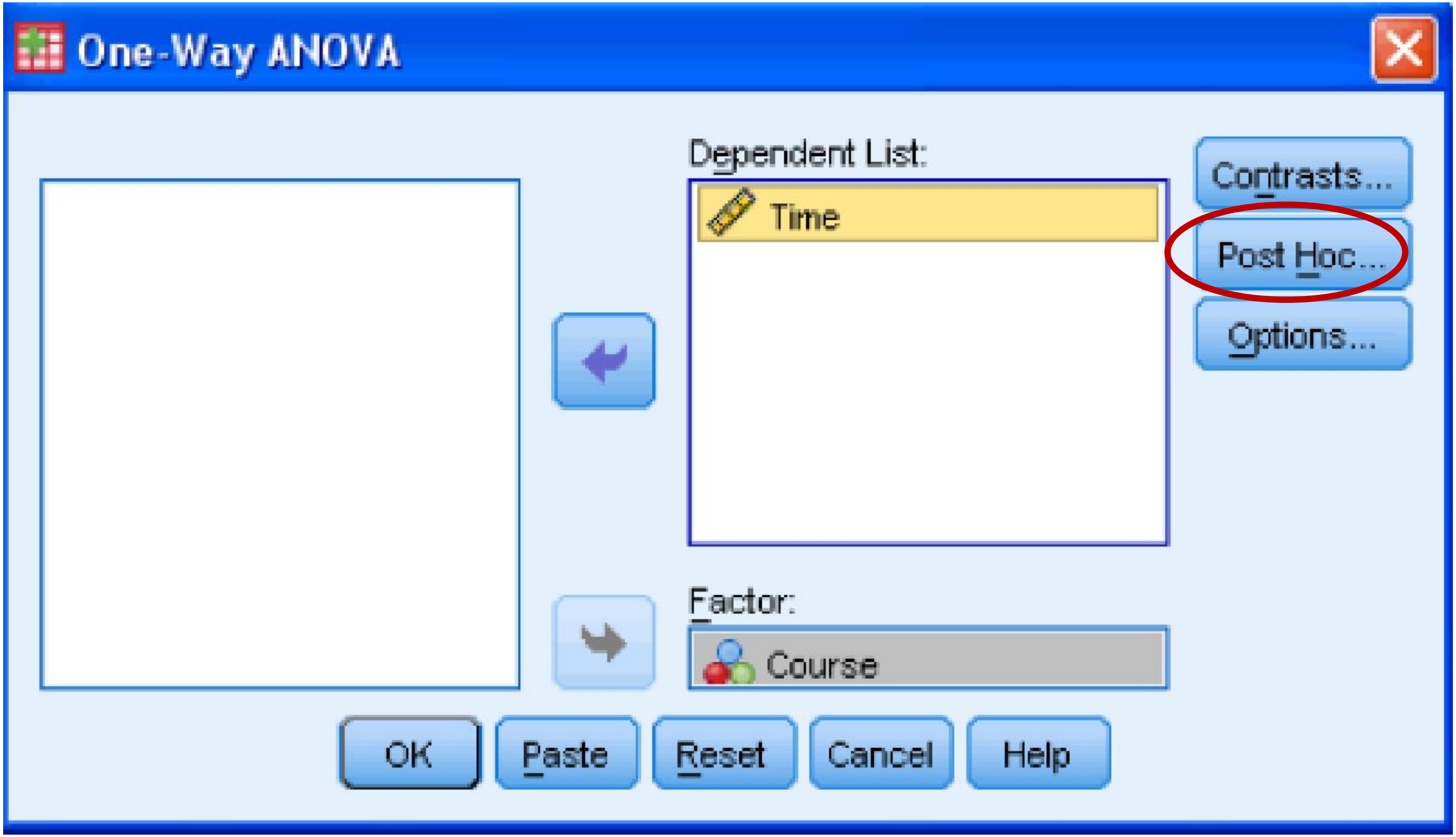
Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

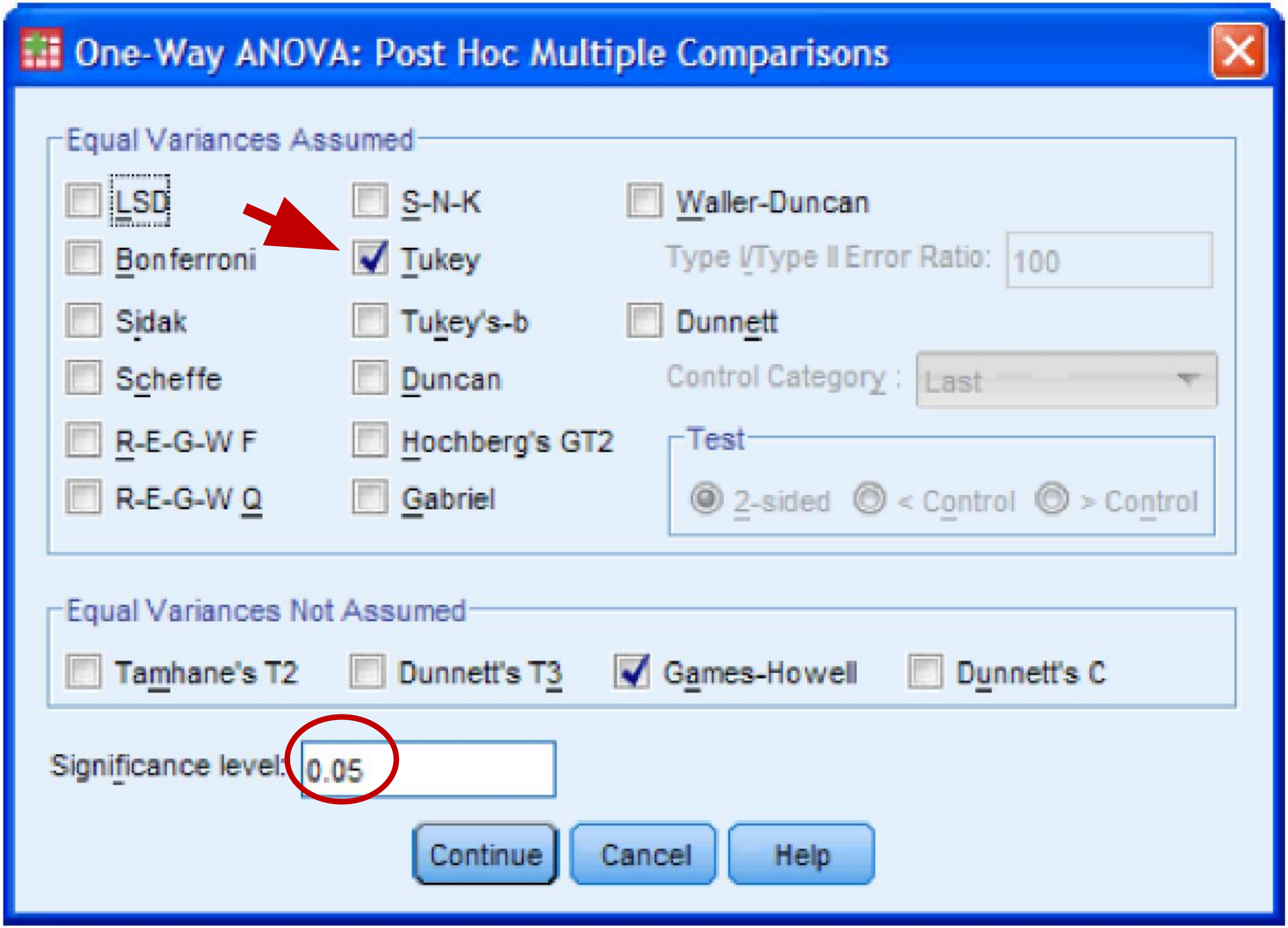
Conduct Post hoc comparison test

Why?

To confirm where the differences occurred between groups


1] - PASW Statistics Data Editor
Analyze
Graphs
Utilities
Add-ons
Window
Help
Reports
Descriptive Statistics
Compare Means
General Linear Model
Generalized Linear Models
Mixed Models
Correlate
Regression
Loglinear
Means...
One-Sample T Test...
Independent-Samples T Test...
Paired-Samples T Test...
One-Way ANOVA...


One-Way ANOVA
Dependent List:
Time
Factor:
Course
Contrasts...
Post Hoc...
Options...
OK
Paste
Reset
Cancel
Help


One-Way ANOVA: Post Hoc Multiple Comparisons
Equal Variances Assumed
LSD
S-N-K
Waller-Duncan
Bonferroni
Tukey
Type I/Type II Error Ratio:
100
Sidak
Tukey's-b
Dunnett
Scheffe
Duncan
Control Category :
Last
R-E-G-W F
Hochberg's GT2
Test
R-E-G-W Q
Gabriel
2-sided
< Control
> Control
Equal Variances Not Assumed
Tamhane's T2
Dunnett's T3
Games-Howell
Dunnett's C
Significance level:
0.05
Continue
Cancel
Help

Multiple Comparisons

Dependent Variable:Time

	(I) Course	(J) Course	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Beginner	Intermediate	3.60000*	1.43088	.046	.0523	7.1477
		Advanced	3.80000*	1.43088	.034	.2523	7.3477
	Intermediate	Beginner	-3.60000*	1.43088	.046	-7.1477	-.0523
		Advanced	.20000	1.43088	.989	-3.3477	3.7477
	Advanced	Beginner	-3.80000*	1.43088	.034	-7.3477	-.2523
		Intermediate	-.20000	1.43088	.989	-3.7477	3.3477

Multiple Comparisons

READING STANDARDIZED SCORE
Tukey HSD

(I) COMPOSITE GEOGRAPHIC REGION OF SCHOOL	(J) COMPOSITE GEOGRAPHIC REGION OF SCHOOL	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
NORTHEAST	NORTH CENTRAL	5.05891*	1.71890	.018	.6178	9.5000
	SOUTH	4.55355*	1.65008	.031	.2903	8.8168
	WEST	6.86063*	1.82445	.001	2.1468	11.5744
NORTH CENTRAL	NORTHEAST	-5.05891*	1.71890	.018	-9.5000	-.6178
	SOUTH	-.50536	1.48624	.986	-4.3453	3.3346
	WEST	1.80171	1.67773	.706	-2.5330	6.1364
SOUTH	NORTHEAST	-4.55355*	1.65008	.031	-8.8168	-.2903
	NORTH CENTRAL	.50536	1.48624	.986	-3.3346	4.3453
	WEST	2.30707	1.60714	.478	-1.8453	6.4594
WEST	NORTHEAST	-6.86063*	1.82445	.001	-11.5744	-2.1468
	NORTH CENTRAL	-1.80171	1.67773	.706	-6.1364	2.5330
	SOUTH	-2.30707	1.60714	.478	-6.4594	1.8453

*. The mean difference is significant at the 0.05 level.

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Conduct Post hoc comparison test

Why?

To confirm where the differences occurred between groups

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Return to Exercise (16)

ANOVA

READING STANDARDIZED SCORE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1513.532	3	504.511	5.104	.002
Within Groups	29260.128	296	98.852		
Total	30773.660	299			

Multiple Comparisons

READING STANDARDIZED SCORE
Tukey HSD

(I) COMPOSITE GEOGRAPHIC REGION OF SCHOOL	(J) COMPOSITE GEOGRAPHIC REGION OF SCHOOL	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
NORTHEAST	NORTH CENTRAL	5.05891*	1.71890	.018	.6178	9.5000
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WEST	NORTHEAST	-6.86063*	1.82445	.001	-11.5744	-2.1468
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	SOUTH	-2.30707	1.60714	.478	-6.4594	1.8453

*. The mean difference is significant at the 0.05 level.

Report

READING STANDARDIZED SCORE

COMPOSITE GEOGRAPHIC REGI...	Mean	N	Std. Deviation	Variance	Skewness	Std. Error of Skewness
NORTHEAST	55.8918	100	9.86641	97.346	-.486	.316
NORTH CENTRAL	50.8328	100	10.01432	100.287	.224	.267
SOUTH	51.3382	100	10.00440	100.088	.246	.241
WEST	49.0311	100	9.81560	96.346	.502	.304
Total	51.5901	400	10.14505	102.922	.152	.141

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

IV. Make your Decision regarding Research Hypotheses

ANOVA

READING STANDARDIZED SCORE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1513.532	3	504.511	5.104	.002
Within Groups	29260.128	296	98.852		
Total	30773.660	299			

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

IV. Make your Decision regarding Research Hypotheses

Reject Null Hypothesis H_0

p-value of F statistic = 0.002

P-value < α

0.002 < 0.05

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

V. Report a conclusion

Multiple Comparisons

READING STANDARDIZED SCORE
Tukey HSD

(I) COMPOSITE GEOGRAPHIC REGION OF SCHOOL	(J) COMPOSITE GEOGRAPHIC REGION OF SCHOOL	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
NORTHEAST	NORTH CENTRAL	5.05891*	1.71890	$\boxed{.018}$	.6178	9.5000
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	NORTH CENTRAL	-1.80171	1.67773	.706	-6.1364	2.5330
	SOUTH	-2.30707	1.60714	.478	-6.4594	1.8453

*. The mean difference is significant at the 0.05 level.

Report

READING STANDARDIZED SCORE

COMPOSITE GEOGRAPHIC REGI...	Mean	N	Std. Deviation	Variance	Skewness	Std. Error of Skewness
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SOUTH	51.3382	100	10.00440	100.088	.246	.241
WEST	49.0311	100	9.81560	96.346	.502	.304
Total	51.5901	400	10.14505	102.922	.152	.141

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

V. Report a conclusion

The mean score of medical students at North-East University was significantly higher (55.89±9.86) than the mean score of students at North-Central, West, and South Universities (50.83 ±10.01, 49.03±10.00, 51.33±9.8 respectively).

Return to Exercise (17)

ANOVA

Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	91.467	2	45.733	4.467	.021
Within Groups	276.400	27	10.237		
Total	367.867	29			

Multiple Comparisons

Dependent Variable:Time

	(I) Course	(J) Course	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Beginner	Intermediate	3.60000*	1.43088	.046	.0523	7.1477
		Advanced	3.80000*	1.43088	.034	.2523	7.3477
	Intermediate	Beginner	-3.60000*	1.43088	.046	-7.1477	-.0523
		Advanced	.20000	1.43088	.989	-3.3477	3.7477
	Advanced	Beginner	-3.80000*	1.43088	.034	-7.3477	-.2523
		Intermediate	-.20000	1.43088	.989	-3.7477	3.3477

Descriptives

Time

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Beginner	10	27.2000	3.04777	.96379	25.0198	29.3802	22.00	33.00
Intermediate	10	23.6000	3.30656	1.04563	21.2346	25.9654	18.00	29.00
Advanced	10	23.4000	3.23866	1.02415	21.0832	25.7168	18.00	29.00
Total	30	24.7333	3.56161	.65026	23.4034	26.0633	18.00	33.00

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

IV. Make your Decision regarding Research Hypotheses

ANOVA

Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	91.467	2	45.733	4.467	.021
Within Groups	276.400	27	10.237		
Total	367.867	29			

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

IV. Make your Decision regarding Research Hypotheses

Reject Null Hypothesis H_0

p-value of F statistic = 0.021

P-value < α

0.021 < 0.05

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

V. Report a conclusion

Multiple Comparisons

Dependent Variable:Time

	(I) Course	(J) Course	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Beginner	Intermediate	3.60000*	1.43088	.046	.0523	7.1477
		Advanced	3.80000*	1.43088	.034	.2523	7.3477
	Intermediate	Beginner	-3.60000*	1.43088	.046	-7.1477	-.0523
		Advanced	.20000	1.43088	.989	-3.3477	3.7477
	Advanced	Beginner	-3.80000*	1.43088	.034	-7.3477	-.2523
		Intermediate	-.20000	1.43088	.989	-3.7477	3.3477

Descriptives

Time

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
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Total	30	24.7333	3.56161	.65026	23.4034	26.0633	18.00	33.00

One Factor ANOVA model - One Way ANOVA

Comparing means from more than two Independent Populations

V. Report a conclusion

Pharmacists who attended the Beginner course spent significantly longer duration of time to formulate the drug (27.20±3.04 hours) compared with Pharmacists who attended the Intermediate and the Advanced courses (23.60±3.30 hours, and 23.40±3.23 hours respectively).

One Factor ANOVA model - One Way ANOVA
Comparing means from more than two Independent Populations

Run a One Way ANOVA (SPPS's One Way ANOVA Procedure)

Comp
(Parar
One P

Two P
Indep

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Analy

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Thank you