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Evaluating the Effect of Study Habits on Academic Performance of Undergraduate Students Using Latin Square Design

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ABSTRACT

In educational experiments student's performance is not only influenced by their study methods or teaching methods but also by several other factors like time period, environment and time of day. These additional sources of variation may influence the results and make it difficult to determine the true impact of study or teaching methods. This problem leads to the need of a design of experiments that can control two sources of variation along with determining the effect of the primary factor which is Latin Square Design. The objective of this research was to determine the effect of four (4) study methods (i.e., watching online lectures, solving practice questions, making notes/summaries, and re-reading notes/ textbooks), times of day, and the length of study session on academic performance of undergraduate students. A 4×4 Latin Square Design was utilized in this study, the data for which was collected through an online survey. Semester Grade Point Average (SGPA) was used as the response variable and analysis of variance (ANOVA) technique was used for analysis. The study was conducted at 5%level of significance.

This study highlights the practical applicability of Latin Square Design in educational research and explains how its structured approach helps in managing multiple influencing factors simultaneously. The findings contribute to understanding how study-related variables influence the academic performance.

KEYWORDS

Latin Square Design (LSD), Factor, Analysis of Variance (ANOVA), Study Methods, Semester Grade Point Average (SGPA).

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1. Introduction

In higher studies, the academic performance is increasingly understood not as a result of individual intelligence but as a result of utilizing proper study techniques, routines and habits. The undergraduate students are expected to master a large amount of complex academic material within limited time span. Thus, their primary goal becomes retention- ability to keep the knowledge in one's mind for a long period of time so that it can be retrieved correctly at the time of assessments. There are several study methods nowadays but the main goal remains to find the best one that can lead to knowledge retention for a long time and give good academic results.

Instead of using specialized or technical tools, most of the students prefer to use some general methods like- re-reading their notes or textbooks, making notes every time they study for better understanding, solving as many questions as they can, highlighting main points or studying using online lectures. The passive methods like re-reading, online lectures and highlighting main points are quite popular because of their easiness, whereas they generally create an illusion of mastery without any deep understanding. Active methods such as making notes, solving questions require students to reorganize their mind and information which leads to higher retention and long term understanding of the topics.

However, along with the study methods used, some other factors like duration of the study session, surrounding environment, time of day and a student's own ability also affects the performance. The presence of several factors makes it difficult to study the effect of a single factor and determine whether it is responsible for the academic performance of students.

To address this problem and to study the effect of the main factor i.e., treatment while controlling two sources of variation a design of experiment known as Latin Square Design can be used. This Design is structured in a way that each treatment appears once in each row and each column, due to this structure it effectively controls the two sources of variation and thus gives unbiased and efficient result. The Latin squares were initially given by Leonhard Euler (a mathematician) in the 18^{th} century as "a square array of n rows and n columns filled with n

different symbols such that each symbol appears exactly once in each row and each column". He illustrated this concept using Latin letters as the symbols used in the array thus, giving it the name Latin squares. Later in 1920s, R.A. Fisher formally adapted Latin Squares in design of experiment and widely promoted the use of Latin squares in agricultural experimentation. By the late 20th century, applications of Latin squares expanded to industrial design, clinical studies and many other research fields where a systematic control over variations was needed.

In clinical studies Chilton (1955) demonstrated the use of Latin Square Design to test different types of drugs and their responses during treatment. This design has also been used in dietary related studies to determine preferences of diets and find most preferred as well as least preferred diets. A study was conducted where multiple Latin squares were used to study the preference of lambs for some cool season grasses by Borman et al. (1991). In agricultural researches LSD has been quite popular since the beginning and has been used by several researchers. Jones et al. (2015), applied Latin square design in agronomic field experiment to demonstrate how it offers a low risk, high reward option for controlling heterogeneity in fields and gives more precise and unbiased results as compared to other designs. Similarly Adamu et al. (2020) used LSD in agricultural experiment to analyze the effect of NPK and urea on yield of tomato. Charles K. Assuah (2019) in his paper "Using Latin Square Design to determine the best mathematics teaching method" used this design of experiment to study the effect of different teaching methods on performance of students in academics and determine which of the study methods is best for mathematics. Similarly, Sule.et.al in 2025 utilized it to determine the effect of different teaching methods on performance of students in their paper "Latin square design: a methodological innovation in educational research for improved teaching and learning". This design also enhances the efficiency of educational experiments by requiring fewer participants and resources while still maintaining accuracy and unbiasedness.

This study uses the Latin Square Design to determine the effect of different study methods on the academic performance of undergraduate students. In this study a 4×4 Latin Square Design has been used, where the two factors namely- Time of day and Length of study session were controlled. The primary factor i.e., treatments used are the different study methods namely- watching online lectures, solving practice questions, making notes/summaries, and re-reading notes/ textbooks. The data has been collected through an online survey and the obtained data has

been properly organized as per LSD structure ensuring that each treatment appears once and only once in each row and column.

The purpose of this study is to evaluate the effect of different study methods on student's SGPA using a controlled and structured experimental design, and explain how it gives valid, unbiased and precise result for a study.

2. Methodology

2.1 Research Design

The present study utilized a 4×4 Latin Square Design. The design ensures that each treatment appears exactly once in each row and each column, thus maintaining balance and reducing the influence of extraneous variation.

For this study, responses from 64 students have been used to construct LSD; all 64 students have been distributed evenly across all experimental units. Hence, each experimental unit consists 4 students.

The structured arrangement of the data within the Latin Square framework helps in systematic evaluation of effects of study methods while controlling the other two factors. Therefore, the design provides an efficient way to analyze the effect of study related variables on academic performance.

2.2 Factors of the Study

This study aims to study effect of study methods on students' academic performance. The factors involved in study are as follows:

Study method is taken as the primary factor in this study and serves as the treatment factor. It represents the different methods students use to study such as Watching online lectures, Solving practice questions, Making notes/summaries, or Re-reading notes/textbooks. The objective is to study if variations in study methods affect the academic performance.

Time of day is taken as one of the blocking factor and is assigned as the row factor in the Latin Square Design. It refers to the period during which students prefer to study such as morning, afternoon, evening or night.

Length of study session is taken as the second blocking factor and is assigned as column factor in Latin Square Design. It refers to the duration of study sessions which is categorized into different time intervals.

The response variable considered in the study is **Semester Grade Point Average (SGPA)**, which serves as a measure of students' academic performance.

Table 1: Layout of constructed Latin Square Design

	Length of Study Session				
Time Of Day		**About 1 hour**	**About 2 hours**	**About 3 hours**	**4 or more hours**
	Morning	Watching online lectures	Solving practice questions	Making notes/summaries	Re-reading notes/textbooks
	Afternoon	Solving practice questions	Making notes/summaries	Re-reading notes/textbooks	Watching online lectures
	Evening	Making notes/summaries	Re-reading notes/textbooks	Watching online lectures	Solving practice questions
	Night	Re-reading notes/textbooks	Watching online lectures	Solving practice questions	Making notes/summaries

Table 2: Constructed Latin Square Design

	About 1 hour	**About 2 hours**	**About 3 hours**	**4 or more hours**
Morning	7.50	7.98	7.33	8.71
Afternoon	7.05	7.68	7.12	8.58
Evening	7.31	7.69	7.84	7.88
Night	7.41	7.50	8.52	8.66

The arrangement of the factors in a Latin Square Design structure is shown in table 1 and after substituting the response variables in all experimental units, the final LSD has been shown in table 2.

2.3 Statistical Model

The statistical model for Latin square design is an additive effect model as it represents the observation as a sum of overall mean effect, effects of different factors and random error due to unexplained reasons. The statistical model used in the study is as follows:

$$y_{ijk} = \mu + \alpha_i + \beta_j + \tau_k + \varepsilon_{ijk} \quad , i = 1,2,3,4 \; ; j = 1,2,3,4; \; k = 1,2,3,4 \tag{1.1}$$

Where;

y_{ijk} is the observed student performance score(SGPA) corresponding to the i^{th} row j^{th} column, and k^{th} treatment

μ is the overall mean student performance

α_i is the effect of i^{th} row blocking factor (Time of day)

β_j is the effect of j^{th} column blocking factor (Length of study session)

τ_k is the effect of k^{th} treatment (study method)

ε_{ijk} is the random error

error terms are assumed to be independently and normally distributed with mean 0 and constant variance $N(0, \sigma^2)$.

2.4 Assumptions

The application of Latin Square Design is based on certain assumptions. These assumptions ensure the validity of analysis and the reliability of results. Those are as follows:

1. There is no interaction between treatments and the blocking factors.
2. The effects of rows, columns, and treatments are additive in nature.
3. The error terms are assumed to be independently and normally distributed with mean zero and variance constant.

2.5 Hypotheses of the Study

For each of the factors hypotheses have been formulated, which later help to determine whether the factors have significant effect on the response variable or not.

For study method (treatment factor):

Null hypothesis (H_{0t}) : study method has no significant effect on students' SGPA.

Alternate hypothesis (H_{1t}) : study method has a significant effect on students' SGPA.

Similarly hypotheses for row and column factors can be formulated.

2.6 Optimality Measures of the Latin Square Design

To understand the statistical properties and quality of constructed Latin Square Design, the optimality measures of the design were calculated. These evaluate the performance of the experimental design in terms of parameter estimation and information content. The values calculated were A-optimality, E-optimality, G-optimality and I-optimality. The values obtained are as shown in Table 3.

Table 3: Optimality values of the design

Optimality	Value
A-Optimality	5.1250
E-Optimality	0.6307
G-Optimality	0.6250
I-Optimality	0.6250

A-optimality is related to the average variance of the parameter estimates. E-optimality considers the minimum eigen value of the information matrix. G-optimality is associated with the maximum prediction variance. I-optimality is associated with the average prediction variance over the design region. These values help evaluate the statistical suitability of the design used in the study.

2.7 Statistical Analysis

This section presents a detailed analysis of the data obtained using statistical method. The data are analyzed using the Analysis of Variance (ANOVA) framework. It provides a systematic way to divide the total variation into components like variation due to treatments, row, column and random error. In this case ANOVA partitioned the total variations occurring in student performance into components like, variation due to time of the day, variation due to length of study session, variation due to the study method used and random error.

The analysis is initially carried out manually in order to illustrate the analytical procedure and later to verify the results, analysis has also been performed using R Software.

Manual Calculations

All the necessary calculations are performed for each source of variation. The step-by- step calculations are presented below:

Y_{ijk} represents the observation (student performance) where i represents the time of day, j represents the length of study session and k represents the study methods used.

The Total no. of observations is $N = 16$

The Order of the Latin Square is $p = 4$.

The grand total of all observations is $G = 124.76$

The sum of squares of all observations is $\sum {Y_{ijk}}^2$ =977.3954

For each of the rows, columns and treatments, their totals were calculated as shown:

Sum of observations for each row factors (time of the day) are:

$$R_1(morning) = 31.52,$$

$$R_2(afternoon) = 30.43,$$

$$R_3(evening) = 30.72,$$

$$R_4(night) = 32.09,$$

The sum of observations for each of the column factors (length of study session) are:

$$C_1(about\ 1\ hour) = 29.27,$$

$$C_2(about\ 2\ hours) = 30.85,$$

$$C_3(about\ 3\ hours) = 30.81,$$

$$C_4(4\ or\ more\ hours) = 33.83$$

The sum of observations for each of the treatment factors (study method) are:

$$T_A(watching\ online\ lectures) = 31.42,$$

$$T_B(solving\ practice\ questions) = 31.43,$$

$$T_C(making\ notes\ /summeries) = 30.98,$$

$$T_D(re - reading\ notes/\ textbooks) = 30.93$$

The sum of squares for each of the sources of variation are calculates as shown below:

Total sum of squares is:

$$TSS = \sum_{i=1}^{P}\sum_{j=1}^{P} {Y_{ijk}}^2 - \frac{G^2}{p^2}$$

$$TSS = 977.3954 - \frac{124.76^2}{16}$$

$$TSS = 977.3954 - 972.8161$$

$$TSS = 4.5793$$

Sum of squares for row factors (time of day):

$$SSR = \frac{\sum_{i=1}^{p} R_i^{\,2}}{p} - \frac{G^2}{p^2}$$

$$SSR = \frac{31.52^2 + 30.43^2 + 30.72^2 + 32.72^2}{4} - 972.8161$$

$$SSR = \frac{3892.982}{4} - 972.8161$$

$$SSR = 973.2455 - 972.8161$$

$$SSR = 0.4294$$

Sum of squares for column factors (length of study session):

$$SSC = \frac{\sum_{j=1}^{p} C_J^{\,2}}{p} - \frac{G^2}{p^2}$$

$$SSC = \frac{29.27^2 + 30.85^2 + 30.81^2 + 33.83^2}{4} - 972.8161$$

$$SSC = \frac{3902.1804}{4} - 972.8161$$

$$SSC = 975.5451 - 972.8161$$

$$SSC = 2.7290$$

Sum of squares for treatment factors (study methods):

$$SST = \frac{\sum_{k=1}^{p} T_k^{\,2}}{p} - \frac{G^2}{p^2}$$

$$SST = \frac{31.42^2 + 31.43^2 + 30.98^2 + 30.93^2}{4} - 972.8161$$

$$SST = \frac{3891.4866}{4} - 972.8161$$

$$SST = 972.8717 - 972.8161$$

$$SST = 0.0556$$

Then the error sum of squares is computed as shown:

$$SSE = TSS - SSR - SSC - SST$$

$$SSE = 4.5793 - 0.4294 - 2.7290 - 0.0556$$

$$SSE = 1.3654$$

The degrees of freedom for each of the sources of variation are as shown:

Total $df = p^2 - 1 = 16 - 1 = 15$

Time of day $df = p - 1 = 4 - 1 = 3$

Length of study session $df = p - 1 = 4 - 1 = 3$

Study method $df = p - 1 = 4 - 1 = 3$

Error $df = (p - 1)(P - 2) = (4 - 1)(4 - 2) = 6$

The mean squares for row, column, treatments as well as error are calculated as follows;

$$MSR = \frac{SSR}{p - 1} = \frac{0.4294}{3} = 0.1431$$

$$MSC = \frac{SSC}{p - 1} = \frac{2.7290}{3} = 0.9097$$

$$MST = \frac{SST}{p - 1} = \frac{0.0556}{3} = 0.0185$$

$$MSE = \frac{SSE}{(p-1)(P-2)} = \frac{1.3654}{6} = 0.2276$$

In order to test the significance of effects due to different factors, F-ratios are computed by dividing the mean square of that factor by mean square of error as follows:

The F-ratio for row factors is:

$$F_{rows} = \frac{MSR}{MSE} = \frac{0.1431}{0.2276} = 0.6290$$

The F-ratio for column factors is:

$$F_{columns} = \frac{MSC}{MSE} = \frac{0.9097}{0.2276} = 3.9974$$

The F-ratio for treatments are:

$$F_{treatments} = \frac{MST}{MSE} = \frac{0.0185}{0.2276} = 0.0814$$

All the calculated values are presented in ANOVA table below (Table 4);

Table 4: ANOVA table for the Latin Square Design involved.

Sources of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-ratio
Rows(Time of day)	3	0.4294	0.1431	0.6290
Columns(Length of study session	3	2.7290	0.9097	3.9974
Treatments(Study method)	3	0.0556	0.0185	0.0814

Error	6	1.3654	0.2276	
Total	15	4.5793		

Using R Software

To verify the results obtained from manual calculations, ANOVA was performed on R software using appropriate functions the resulting ANOVA table has been shown as table 5:

Table 5: ANOVA results from R Software for Latin Square Design

Sources of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-ratio	P(>F)
Rows(Time of day)	3	0.4294	0.1431	0.629	0.6225
Columns(Length of study session	3	2.7290	0.9097	3.997	0.0702
Treatments(Study method)	3	0.0556	0.0185	0.081	0.9677
Error	6	1.3654	0.2276		
Total	15	4.5793			

3. RESULTS AND INTERPRETATION

The ANOVA results that are obtained from both manual computation and using R software can be interpreted by comparing the calculated and tabulated F-values. The results and their

interpretations determining the significance of factors based on F-values and significance levels are discussed below:

For Treatments (Study Method)

The F- value calculated for study methods is 0.081. As this value is smaller than the tabulated F-value (4.757), we failed to reject the null hypothesis. If we consider the p-values, the p-value for study methods is 0.997, this value is greater than the chosen level of significance. This again means that we failed to reject the null hypothesis. These comparison show that there is no significant effect of the study methods on the academic performance (SGPA) of students and there is no statistically significant difference among the treatment means.

For Row Factors (Time of Day)

The calculated F- value for time of day is smaller than the F-value tabulated (4.757) and P-value is greater than the significance level chosen. Both these comparison means that the null hypothesis is not rejected and there is no significant effect of time of day on the SGPA obtained by the students and there is no significant difference between means due to different times of day.

For Column Factors (Length of Study Session)

The F-value calculated for length of study session is 3.997, it is smaller than the F-value tabulated (4.757). The P-value for this factor is 0.702 which is greater than the level of significance (0.05) chosen. This means that the null hypothesis is not rejected and the length of study session has no significant effect on SGPA obtained by students.

Thus, it can be concluded that none of the factors –time of day, length of study session and study methods have a statistically significant effect on the academic performance of students. This may mean that the variability in data is random or unexplained, not attributable to treatments or blocking factors.

4. Graphical Representation

This section provides a visual understanding of the results obtained from the above analysis of Latin Square Design ,with the help of graphical representation of the treatment, row and column factors with their respective mean values obtained (mean SGPA) using Bar graph.

Figure 1 presents the mean SGPA obtained by students under different study methods. The mean values are quite close to each other, indicating only minor variations among the treatments. The observations here are consistent with the ANOVA findings.

Figure 2 shows the mean SGPA obtained by students studying at different times of day using bar graph. The mean values are relatively close to each other, indicating only minor variations among the times of day, thus supporting the non-significant effect of row factors(time of day) obtained using ANOVA previously.

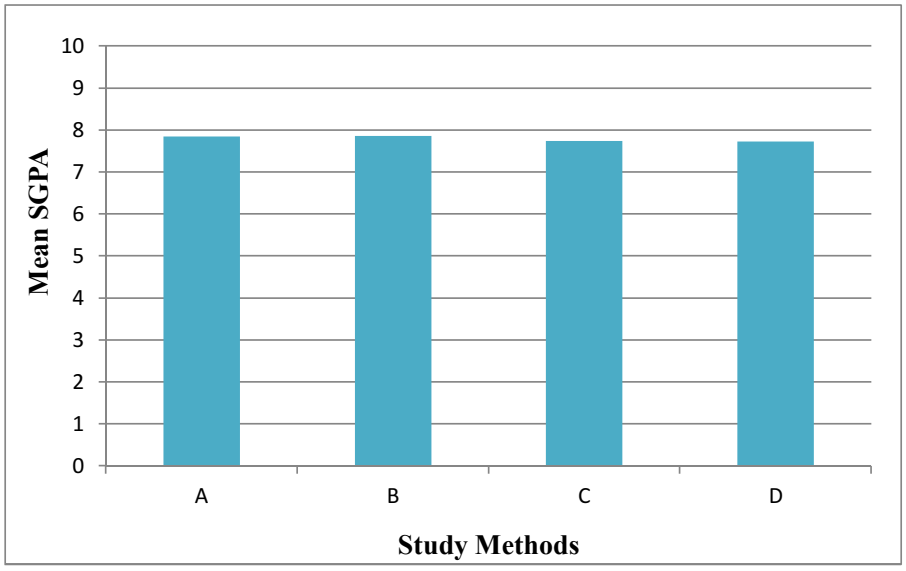

Figure 1 Mean SGPA obtained under different study methods.

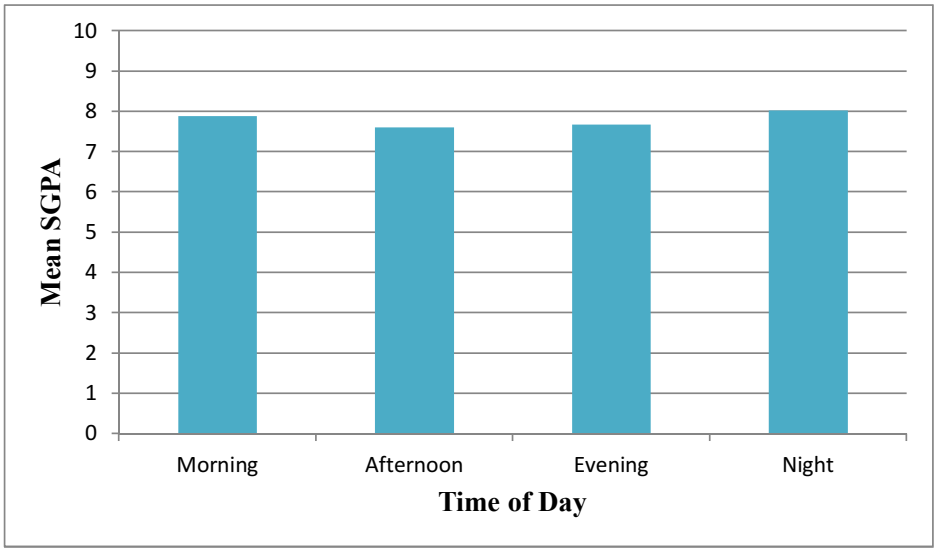

Figure 2: Mean SGPA obtained under different times of the day.

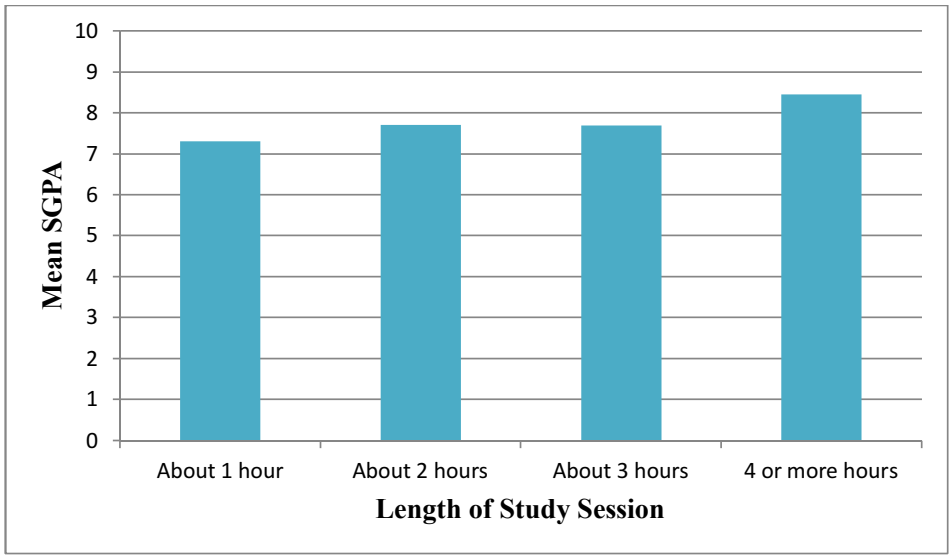

Figure 3: Mean SGPA obtained under different lengths of study session.

Figure 3 here shows the mean SGPA obtained by students after studying for different lengths of study session. It can be seen that the mean values are relatively close to each other, indicating

only minor differences among the different lengths of study session. It supports the non-significant effect of column factor (length of study session) obtained using ANOVA.

5. CONCLUSION

The dataset involved in this educational research was analyzed using the Analysis of Variance framework under Latin Square Design. The results show that none of the factors- study methods, time of the day and length of study session- have any significant effect on student's academic performance. It suggests that the study habits involved in this study have no significant effect on academic performance of student. Hence, the variations in it might be due to their individual differences, environment or due to some unexplained factors. The application of Latin Square Design in educational research proved methodologically appropriate, as it allows systematic control over the two sources of variation and its ability of increasing precision and validity of results due to its structure makes it a reliable experimental design. This showed the usefulness of this design in structuring experiments in an efficient way, even in cases where no significant effects are detected.

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