

Building a mini Electrical Substation through Project based Learning and analysing data using ANOVA

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ABSTRACT: Project-based learning (PBL) is a student-centered pedagogy that involves a dynamic classroom approach, in which it believed that the students acquire a deeper knowledge through active exploration of real-world challenges and problems. For the same, with a set of prepared guidelines, third year B. Tech. Electrical Engineering students are asked to design a mini ‘**Electrical Substation**’. These designs presented and evaluated by the internal and external examiners. Students are further motivated for deep study in substations. Total 18 groups of students worked on substation design project with 18 parts of Electrical Substation. This activity not only improved the learning index of the students but also improved course attainment, which mapped with program outcomes.

Keywords: Mini Electrical Substation, CPI, CO-PO attainment, ANOVA, SPSS

1. INTRODUCTION

Millennial learners are very much active and eager to find new things. To feed their intellectual brain, the design problems proposed. Few students always avoid participating in such activities and do not take lead. It is necessary to create same platform to all the students to show their skills. Student lead conference gives such platform. The activity was well planned and discussed with the students prior to the semester. It is lengthy activity and needs preparation. All the students of T.Y. B. Tech Electrical Engineering program had participated in this activity under the course ‘Switchgear and Protection’. This course has wide scope for such competitions. Students are very much familiar with the electric failures, such as electric shock, short circuits, open circuits, overloading etc. They are also acquainted with fuse, MCB, energy meters, relays etc. This activity takes them from known to unknown and then finds the solutions [1]. Students are asked to form groups. These groups have done market survey for available equipments and their

cost. All groups have designed the single line diagram with available equipments. Students were very enthusiastic and creative in designing the scheme. One of the constraints is the scheme should not be similar within the groups. Rubrics formed by the course instructor for the evaluation of market survey and design schemes. Such as active participation, creativity, presentation, Q and A, idea, parameter selection etc. Student’s performance is measured and course attainment is calculated. Program outcomes mapped with it [1]

2. METHODOLOGY

The complete activity planned and divided in some stages.

Stage 1:- ‘Project based learning’, had discussed with the students with a set of guidelines. Students formed groups as per their choice. Heterogeneous 18 groups formed.

Group Formation: This course had offered to the students in third year B. Tech. Their average score of previous years in percentage calculated and arranged in ascending order. Group of 18 students formed. Strength of the class was 72 ($18 \times 4 = 72$). One student from each group (from 18 students) had selected sequentially and made another group of four students. Now, this group contains four students of different merit order possessing different skills. Such 18 groups formed. This is discussed in detail in fig no.1 showing the grades of the students, fig. no.2 showing the arrangement in ascending order and fig. no. 3 showing the group formation.

Stage 2:- These groups had selected their role and equipment or part of substation to be designed. It is shown in Fig. no.4. All were undergone market survey. Students searched for the electrical equipments required in substation in the market with its specifications and cost. For cost reduction, few

equipments have been designed by respective groups. Course contents haddelivered in the class in this duration.

Roll no	CPI	Roll	CPI	Roll	CPI	Roll	CPI
1508046	3.84	1608018	8.05	1608039	6.34	1608059	3.77
1508052	3.96	1608019	7.58	1608040	7.65	1608060	5.8
1601045	6.65	1608020	5.47	1608041	7.73	1608061	5.3
1608001	4.59	1608021	7.89	1608042	7.35	1608062	5.8
1608002	6.01	1608022	6.8	1608043	7.16	1608063	6.59
1608004	7.03	1608023	6.3	1608044	8.46	1758001	6.05
1608005	4.7	1608024	4.62	1608045	7.7	1758002	7.31
1608006	7.59	1608025	6.3	1608046	6.68	1758004	7.66
1608007	6.99	1608026	5.09	1608047	7.97	1758005	7.91
1608008	6.84	1608027	8.19	1608048	6.92	1758006	8.19
1608009	7.59	1608028	8.03	1608049	6.57	1758007	5.39
1608010	7.27	1608029	6.86	1608051	6.74	1758009	7.39
1608012	7.32	1608031	6.81	1608052	5.81	1758010	6.65
1608013	7.46	1608032	7.35	1608054	8.05	1758011	3.58
1608014	5.99	1608033	7.42	1608055	6.61	1758012	4.19
1608015	6.93	1608036	7.5	1608056	7.05	1758013	4.34
1608016	4.62	1608037	8.04	1608057	7.11	1758014	6.76
1608017	7.24	1608038	7.35	1608058	8.08	1758015	5.8

Fig. No.1- grades of the students

Above figure no. 1 shows the previous year CPI (Cumulative Performance Index) of the students of batch 2018-19.

1758011	3.58	1608014	5.99	1608048	6.92	1608019	7.58
1608059	3.77	1608002	6.01	1608015	6.93	1608006	7.59
1508046	3.84	1758001	6.05	1608007	6.99	1608009	7.59
1508052	3.96	1608023	6.3	1608004	7.03	1608040	7.65
1758012	4.19	1608025	6.3	1608056	7.05	1758004	7.66
1758013	4.34	1608039	6.34	1608057	7.11	1608045	7.7
1608001	4.59	1608049	6.57	1608043	7.16	1608041	7.73
1608016	4.62	1608063	6.59	1608017	7.24	1608021	7.89
1608024	4.62	1608055	6.61	1608010	7.27	1758005	7.91
1608005	4.7	1601045	6.65	1758002	7.31	1608047	7.97
1608026	5.09	1758010	6.65	1608012	7.32	1608028	8.03
1608061	5.3	1608046	6.68	1608032	7.35	1608037	8.04
1758007	5.39	1608051	6.74	1608038	7.35	1608018	8.05
1608020	5.47	1758014	6.76	1608042	7.35	1608054	8.05
1608060	5.8	1608022	6.8	1758009	7.39	1608058	8.08
1608062	5.8	1608031	6.81	1608033	7.42	1608027	8.19
1758015	5.8	1608008	6.84	1608013	7.46	1758006	8.19
1608052	5.81	1608029	6.86	1608036	7.50	1608044	8.46

Fig No. 2- showing ascending order of CPI

Above figure no.2 shows an ascending order of CPI. This distribution is shown by using different color codes. Further, one student from each column is picked to form "Group".

GROUP 1	1758011	1608014	1608048	1608019
GROUP 2	1608059	1608002	1608015	1608006
GROUP 3	1508046	1758001	1608007	1608009
GROUP 4	1508052	1608023	1608004	1608040
GROUP 5	1758012	1608025	1608056	1758004
GROUP 6	1758013	1608039	1608057	1608045
GROUP 7	1608001	1608049	1608043	1608041
GROUP 8	1608016	1608063	1608017	1608021
GROUP 9	1608024	1608055	1608010	1758005
GROUP 10	1608005	1601045	1758002	1608047
GROUP 11	1608026	1758010	1608012	1608028
GROUP 12	1608061	1608046	1608032	1608037
GROUP 13	1758007	1608051	1608038	1608018
GROUP 14	1608020	1758014	1608042	1608054
GROUP 15	1608060	1608022	1758009	1608058
GROUP 16	1608062	1608031	1608033	1608027
GROUP 17	1758015	1608008	1608013	1758006
GROUP 18	1608052	1608029	1608036	1608044

Fig. No.3-"Group Formation"

Above figure no.3 shows the group formation.

All groups have selected equipment to be designed in their group.

GROUP 1	Bus bar	GROUP 7	Current Transformer	GROUP 13	Agricultural load
GROUP 2	Poles	GROUP 8	voltage Transformer	GROUP 14	Lightening arrester
GROUP 3	insulators	GROUP 9	Circuit breakers	GROUP 15	capacitor bank
GROUP 4	earthing	GROUP 10	Relays	GROUP 16	Fencing
GROUP 5	Residential load	GROUP 11	Switches	GROUP 17	Panel board
GROUP 6	Distribution Transformer	GROUP 12	Fuses	GROUP 18	isolator

Fig No.4- Distribution of equipments

Stage 3:- Fig no.5 shows that students visited nearby substation (33kV/11kV). They observed the substation and studied the same for their own substation design. As the students were designing for real solution, all the ratings must be dropped down. All groups designed the required specifications for substation. 440V/230V substation specifications were fixed.



Fig no. 5- 33kV/11kV distribution substation visit

Stage 4:- All 18 groups had drawn single line diagram for substation. One single line diagram is commonly approved. Each group designed respective part of substation and tasted the system. Once all designs are verified and tasted, the actual building of substation is started.

Stage 5:- Students along with the course instructor selected one place, free space near to RIT college power house. The necessary, major cost equipments are provided by Electrical maintenance department and electrical engineering department. Fig no. 5 shows that the students are taking measurements for substation design



Fig. No. 5-Taking measurements for substation building

Stage 6:- Students marks are collected from examiners and course attainment is calculated. Program outcomes are also calculated and mapped. Fig.6 Shows the market survey for miniature circuit breaker. Students hold a poster on which construction, manufacturer (Siemens, L&T, ABB, Havell's), specifications and cost are the four columns drawn.



Fig.no.6 Market survey for miniature circuit breaker

Following fig.no.7 shows that the students are demonstrating and explaining the substation to examiners



Fig. No. 7- Demonstration and Explanation

For the evaluation, rubrics were made and was given to the Examiners. Rubrics are also discussed with the students so students were too much enthusiastic

3. RESULTS

After successfully completed these activity students are

1. acquainted with the electrical protection equipments used in the markets with its specifications and cost under 'Market Survey' activity and aware of the existing society related electrical problems
2. able to apply their knowledge to create solution scheme and implement skills to design protection scheme
3. improved their confidence, presentation and communication skills and ready to face next model competition
4. Course outcomes: - At the end of this course students will be able to
 1. Explain fundamentals of different power system components
 2. Classify and explain the operation of circuit breakers and relays
 3. Discuss distance protection schemes
 4. Determine the causes, effects and protective schemes for over-voltage and over-current relay.
 5. Describe different faults and devise protection schemes for generator and transformer
5. These course outcomes are mapped with activities conducted throughout the semester for switchgear and protection subject

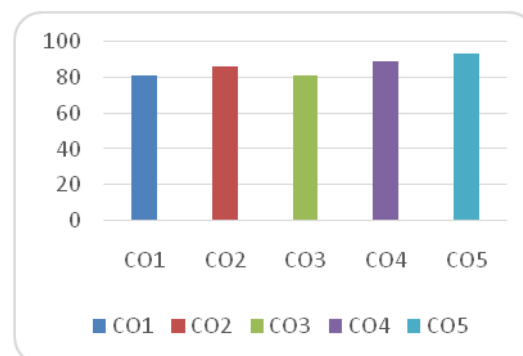
Table No.1 : Mapping of activities with course outcomes

Activities	CO1	CO2	CO3	CO4	CO5
Group formation and teamwork		√	√		
Market survey	√	√	√	√	
Poster Presentation		√	√	√	√
Design solution	√	√	√	√	√
Final competition	√	√	√	√	√

6. Attainments are calculated

Attainments are calculated by direct and indirect method. Direct method – Students marks from In-Semester Evaluation and final demonstration. [2]

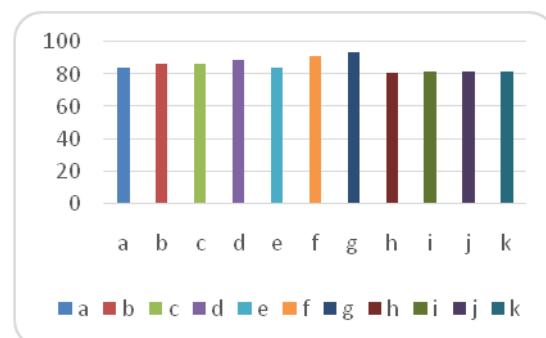
Indirect Method- Student's Feedback[2]



Graph No. 1: Attainment of course outcomes in percentage

From the above results it is seen that the CO5 is mapped excellently which is about designing the protection scheme.

7. Program outcomes are mapped



Graph No. 2: Attainment of program outcomes in percentage

It is also observed that the PO(g) is achieved excellently from this course, which helps them in technical interviews with raised confidence

PROGRAM OUTCOMES OF ELECTRICAL ENGINEERING DEPARTMENT

Table No. 2 : Program outcomes of Electrical Engineering Department

a	Apply knowledge of mathematics, science, and electrical engineering.
b	Design and conduct experiments, as well as to analyze and interpret data.
c	Design a system, components or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical,

	health and safety, manufacturability and sustainability
d	Function on multidisciplinary teams.
e	Identify, formulate, and solve electrical engineering problems
f	Demonstrate professional and ethical responsibility
g	Communicate effectively at work.
h	Understand the impact of electrical engineering solutions in global, economic, environmental, and societal context
i	Engage in life-long learning
j	Use the techniques, skills, and modern engineering tools necessary for engineering practice.
k	Apply the knowledge to evaluate contemporary issues with project and finance management skills.

4. DISCUSSION

For ANOVA test case, the group is divided in 4 columns. Group A, Group B, Group C and Group D

Each group has undergone separate task with its own learning activity. Group A was considering the students scored higher in previous exams. These students are asked to design the selected object with their respective team under conventional teaching learning. Group B had selected the suitable equipment for substation (Brainstorming). Group C had done the market survey for the cost effective elements with proper specification (Group Discussion). Group D decided to visit the site for optimal placement of the equipments (PBL).

Table No. 3 : Groups formation for ANOVA

	A	B	C	D
GROUP 1	1758011	1608014	1608048	1608019
GROUP 2	1608059	1608002	1608015	1608006
GROUP 3	1508046	1758001	1608007	1608009
GROUP 4	1508052	1608023	1608004	1608040
GROUP 5	1758012	1608025	1608056	1758004
GROUP 6	1758013	1608039	1608057	1608045
GROUP 7	1608001	1608049	1608043	1608041
GROUP 8	1608016	1608063	1608017	1608021
GROUP 9	1608024	1608055	1608010	1758005
GROUP 10	1608005	1601045	1758002	1608047
GROUP 11	1608026	1758010	1608012	1608028
GROUP 12	1608061	1608046	1608032	1608037
GROUP 13	1758007	1608051	1608038	1608018
GROUP 14	1608020	1758014	1608042	1608054
GROUP 15	1608060	1608022	1758009	1608058
GROUP 16	1608062	1608031	1608033	1608027
GROUP 17	1758015	1608008	1608013	1758006
GROUP 18	1608052	1608029	1608036	1608044

'Teamwork' and 'coordination' are the most essential part of building a substation.

Null Hypothesis: All activities are equally good.

Alternative Hypothesis: At least two are not equally good

Let's define $N = \sum N_i$ where $N_i = N_A, N_B, N_C, N_D$, (specimen). $N_A = N_B = N_C = N_D = 18$. $N = \sum N_i = 72$

Calculations: Df = Degree of freedom

$Df_{\text{between}} = \text{No. of conditions (k=4)} - 1 = 3$; $Df_{\text{within}} = \text{Total No. of observations (N=72)} - (k=4) = 68$; $Df_{\text{total}} = 68 + 3 = 71$;

Evaluation of PBL-ISE-Marks (Max =20)

Table No. 4: Marks of students

	A	B	C	D	
GROUP 1	12	14	20	16	
GROUP 2	14	17	18	17	
GROUP 3	15	17	14	19	
GROUP 4	14	17	18	15	
GROUP 5	17	18	18	19	
GROUP 6	13	14	15	17	
GROUP 7	17	17	17	17	
GROUP 8	15	15	19	16	
GROUP 9	13	16	17	19	
GROUP 10	13	15	17	19	
GROUP 11	18	12	17	14	
GROUP 12	15	14	14	19	
GROUP 13	17	18	12	15	
GROUP 14	18	17	17	14	
GROUP 15	19	16	19	17	
GROUP 16	16	16	16	18	
GROUP 17	17	18	16	16	
GROUP 18	13	18	18	19	
Total(T1,T2,T3,T4)	276	289	302	306	G=1173
Square	76176	83521	91204	93636	

Raw S. S. = 19391 ; Correction factor(CF) = $G^2/n = (1173)^2/72 = 19110.125$; Total S S = $RSS - CF = 19391 - 19110 = 281$; S.S. due to treatments = $T_1^2/N_A + T_2^2/N_B + T_3^2/N_C + T_4^2/N_D - CF = 30.875$

Error SS = Total S S – S S due to treatment = 250.125

Table No. 5: Finding Variance

Source of Variation	S. S.	d.f.	MSS	Variance Ratio
Treatments	30.875	4-1 = 3	10.29	F= 2.797
Error	250.125	71-3 = 68	3.678	
Total	281	72-1 = 71		

($\alpha=0.05$) Table No. 6 : Table to find critical value

65	3.99	3.14	2.75	2.51
66	3.99	3.14	2.74	2.51
67	3.98	3.13	2.74	2.51
68	3.98	3.13	2.74	2.51
69	3.98	3.13	2.74	2.51
70	3.98	3.13	2.74	2.50
71	3.98	3.13	2.73	2.50
72	3.97	3.12	2.73	2.50

The calculated value of $F = 2.79$ is more than the tabulated value of $F = 2.74$. (This result through SPSS is shown in table no.7). Hence, we reject null hypothesis and conclude that not all methods are equally good. An alternative hypothesis accepted which says that there is difference in learning types. To find the best method, the mean of all groups are calculated.

Group A = 15.33; Group B = 16.05; Group C = 16.77 ; Group D = 17. The mean of Group 'D' is more. It indicates that the students working on site learnt more.(Result through SPSS is shown in table no. 9)

Table No. 7: ANOVA results in SPSS

ANOVA					
Learning_Type	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	30.819	3	10.273	2.794	.047
Within Groups	250.056	68	3.677		
Total	280.875	71			

Table No. 8: Results for Post Hoc Tests
Post Hoc Tests

Multiple Comparisons						
Dependent Variable: Learning_Type						
Tukey HSD						
(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
A	B	-.722	.639	.672	-2.41	.96
	C	-1.444	.639	.118	-3.13	.24
	D	-1.667	.639	.053	-3.35	.02
B	A	.722	.639	.672	-.96	2.41
	C	-.722	.639	.672	-2.41	.96
	D	-.944	.639	.457	-2.63	.74
C	A	1.444	.639	.118	-.24	3.13
	B	.722	.639	.672	-.96	2.41
	D	-.222	.639	.985	-1.91	1.46
D	A	1.667	.639	.053	-.02	3.35
	B	.944	.639	.457	-.74	2.63
	C	.222	.639	.985	-1.46	1.91

Above table, no.8 shows the results of Post Hoc Tests. Each group (I) compared with the remaining groups (J). Mean difference for first case is calculated as Mean of Group A 15.33 – Mean of Group B 16.05 = -0.72. This column gives all positive values in last comparison. This comparison shows that Group D has better results than A, B and C. Similarly, other values calculated for other groups.

Table No. 9: Results for Homogeneous Test
Homogeneous Subsets

Learning_Type			
Tukey HSD ^a			
Group	N	Subset for alpha = 0.05	
A	18	1	15.33
B	18	1	16.06
C	18	1	16.78
D	18	1	17.00
Sig.			.053

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean
Sample Size = 18.000.

5. CONCLUSION

The main objective of this activity is satisfied. All the students have participated with the same interest and enthusiasm. They got the platform to demonstrate their skills and creativity. Students developed simulation model for high ratings and hardware models for lower ratings. This shows their improved creativity and design ability. All the students have learnt from each other as every group developed a different protection scheme. Groups A,B,C,D differentiated by the student previous score. **Group D with fewer score performed better through PBL and secured good marks in exam.** ANOVA test is helpful for analysing this data. This data analysis verified and compared through IBM SPSS tool.

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