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 witha 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*4= 72). One student from each group (from 18 students) had selected sequentially and made another group of four students. 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 had been delivered in the class in this duration.

| Roll no | CPI | Roll no | CPI |
|---------|-----|---------|-----|
| 1508046| 3.84| 1608039| 6.34|
| 1508052| 3.96| 1608040| 7.65|
| 1608020| 5.47| 1608041| 7.73|
| 1608001| 5.69| 1608042| 7.35|
| 1608002| 6.81| 1608043| 7.16|
| 1608004| 7.03| 1608044| 8.46|
| 1608005| 4.74| 1608045| 7.73|
| 1608006| 7.59| 1608046| 6.68|
| 1608007| 6.99| 1608047| 7.97|
| 1608008| 6.84| 1608048| 6.92|
| 1608009| 7.59| 1608049| 6.57|
| 1608010| 7.27| 1608050| 6.74|
| 1608012| 7.32| 1608051| 5.81|
| 1608013| 7.46| 1608052| 8.05|
| 1608014| 5.99| 1608053| 4.19|
| 1608015| 6.01| 1608054| 6.61|
| 1608016| 6.18| 1608055| 7.05|
| 1608017| 6.93| 1608056| 4.19|
| 1608018| 8.04| 1608057| 7.11|
| 1608019| 8.08| 1608058| 8.08|

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.

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 6.92 1608019 7.58
GROUP 2 1608059 1608002 1608015 6.93 1608006 7.59
GROUP 3 1508046 1608001 6.05 1608007 6.99 1608009 7.59
GROUP 4 1508052 1608023 6.3 1608004 7.03 1608040 7.65
GROUP 5 1758012 4.19 1608025 6.3 1608051 7.05 1758004 7.66
GROUP 6 1758013 4.34 1608039 6.34 1608057 7.11 1608045 7.7
GROUP 7 1608001 4.59 1608049 6.57 1608043 7.16 1608041 7.73
GROUP 8 1608016 4.62 1608053 6.59 1608017 7.24 1608021 7.89
GROUP 9 1608024 4.62 1608055 6.61 1608010 7.27 1758005 7.91
GROUP 10 1608005 4.7 1608045 6.65 1758002 7.31 1608047 7.97
GROUP 11 1608026 5.09 1758010 6.65 1608012 7.32 1608028 8.03
GROUP 12 1608061 5.3 1608046 6.68 1608032 7.35 1608037 8.04
GROUP 13 1758007 5.39 1608051 6.74 1608038 7.35 1608018 8.05
GROUP 14 1608020 5.47 1758014 6.76 1608042 7.35 1608054 8.05
GROUP 15 1608060 5.8 1608022 6.8 1608039 7.39 1608058 8.08
GROUP 16 1608062 5.8 1608031 6.81 1608033 7.42 1608027 8.19
GROUP 17 1758015 5.8 1608008 6.84 1608013 7.46 1758006 8.19
GROUP 18 1608052 5.81 1608029 6.86 1608036 7.50 1608044 8.46

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GROUP 4 1508052 1608004 1608009 7.59
GROUP 5 1758012 1608005 1608010 7.65
GROUP 6 1758013 1608040 1608051 7.73
GROUP 7 1608016 1608057 1608045 7.73
GROUP 8 1608024 1608010 1758005 7.91
GROUP 9 1608005 1608012 1608028 8.03
GROUP 10 1608061 1608032 1608037 8.04
GROUP 11 1758007 1608038 1608018 8.05
GROUP 12 1608020 1608042 1608054 8.05
GROUP 13 1608060 1608039 1608058 8.08
GROUP 14 1608062 1608033 1608027 8.19
GROUP 15 1758015 1608013 1758006 8.19
GROUP 16 1608052 1608036 1608044 8.46

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 2 Poles GROUP 3 Insulators GROUP 4 Earthing GROUP 5 Residential Load
GROUP 7 Current Transformer GROUP 8 Transformer GROUP 9 Circuit Breakers GROUP 10 Relays GROUP 11 Switches
GROUP 13 Agricultural Load GROUP 14 Lightning arrester GROUP 15 Capacitor Bank GROUP 16 Fencing GROUP 17 Panel board
GROUP 12 Distribution Transformer GROUP 18 Isolator

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.
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 tested, 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.

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.

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

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](image)

   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](image)

   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**

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

**Table No. 1 : Mapping of activities with course outcomes**

**Table No. 2 : Program outcomes of Electrical Engineering Department**

| a | b | c | d | e | f | g | h | i | j | k |
|---|---|---|---|---|---|---|---|---|---|---|
| a | b | c | d | e | f | g | h | i | j | k |

- 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.
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

| GROUP  | 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

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= T1^2/N_A +T2^2/N_B + T3^2/N_C + T4^2/N_D – CF = 30.875

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

Table No. 8: 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 |       | (α=0.05)Table No. 6: Table to find critical value |
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

| Learning_Type | Sum of Squares | df | Mean Square | F   | Sig |
|---------------|----------------|----|-------------|-----|-----|
| Between Groups| 503.810        | 3  | 10.273      | 2.704 | .047|
| Within Groups | 250.064        | 68 | 3.627       |      |     |
| Total         | 308.874        | 71 |             |      |     |

Table No. 8: Results for Post Hoc Tests

| Learning_Type | Tukey HSD | Multiple Comparisons |
|---------------|-----------|----------------------|
|               | Mean Difference ± SE | 95% Confidence Interval |
| A              | -7.02 ± .39 | -10.32 to -3.72 |
| B              | -1.44 ± .39 | .39 to -2.83 |
| C              | -2.22 ± .39 | -4.13 to -0.31 |

Group A compared with Group B, C, and D, and Group B compared with Group C, and Group D. Group C compared with Group D.

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.

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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7. REFERENCES

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