

# Promoting Engineering Education Through Visible Learning and Formative Assessment Strategies

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**Abstract:** The assessment and teaching strategies are chief indicators of comprehended learning in the field of education. They are the critical moves in the learning process, specifically when related to engineering and science. The mediocre content delivery and inferior assessment affect several educational spheres, such as faculty development, student scores, placement, and life-long experience. These two factors considerably regulate the program-specific outcomes (PSOs) and course outcomes (COs). The present work focuses on analyzing the effects of learning and assessment methods to achieve the designated PSOs and COs through visible learning. The analysis has been carried out with Hattie's effect size that influences the program and course achievement. The process was monitored for two subjects offered to the limited population of undergraduate students of Electrical Engineering. The statistics have been derived in the effect size affected by the source of influence, aspect, and factor. Further, the possibilities of incorporating formative evaluation and visible learning in Indian engineering education is framed in the discussion.

**Keywords:** Effect size, formative assessment, statistics, visible learning.

## 1. Introduction

Engineering is a domain connecting inventions, development, and applications of technologies and infrastructures. Engineering links up society through natural sciences and human sciences [1]. As a career option, engineering education has been a trend in India due to sturdy industrial growth for the past two decades. Also, the field opens a variety of career paths after the graduation. The concerns of the engineering education have also been a matter of discussion in other parts [2-8] of the world in terms of higher education [9] and transforming engineering education [10-11]. But it is imperative to discuss about the engineering education in India as one of the fastest developing countries in the recent times. The changes required in engineering education have been suggested to improve competitiveness and productivity [12]. All of the above, it becomes necessary to achieve the output of the education and training systems [12].

The efforts were put to alter the perception towards engineering education [13-14]. But no result has been seen in teaching and assessment strategies. It is essential to educate students through a deep understanding of engineering sciences and evidence-based learning exercises, and formative assessment [15-22]. This approach makes it significantly easier to achieve PSOs of the program- B.Tech. (Electrical

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Engineering) and COs of the courses- High Voltage Engineering (EL613) and Electrical Power Utilization and Traction (EL516) as these subjects were offered by the instructor. It has been aimed to see the impact of visible learning on PSOs first rather POs as this work is progressive to observe a significant effect in a long time. These two factors provide preliminary statistics to construct better-organized decisions to elevate students' productivity and program output.

In the study, it has been attempted to promote visible learning strategies and formative assessment so as to meet PSOs and COs of the course. In regard to the visible learning methods, John Hattie's effect size [23-24], the source of influence on student learning and achievement, aspect and factor are encompassed. The effect size is a straightforward measure for computing the difference between two groups or the same group over a period of time [24]. It is mandatory to include the students who appear in all the examinations to compute the effect size [24]. The study has been carried out for two engineering subjects offered to the appeared 25 undergraduates of Electrical engineering: Electrical Power Utilization and Traction (EL516) and High Voltage Engineering (EL613). Throughout the study, the student learning and achievement have been observed by using formative assessment along with visible learning strategies. Here, the formative assessment should be referred to the use of a couple of assessment methods that were promoted in evaluations of students' performance during classes and practical sessions. However, it should be noted that the presented work is still progressive to justify the COs and PSOs for the different subjects offered to the students. The paper discusses the effect of visible learning and formative assessment over conventional learning systems. Moreover, the effect size has been derived to show the performance of students. The COs and PSOs have been mapped from the attained results.

The paper is structured as- section 2 describes various learning strategies and formative assessment involved in the study. In reference to these, effect size has been calculated. In section 3, the attainment of COs and PSOs are discussed. In the study, the intelligent quotient (IQ) of individual students and psychological stresses are not considered. Section 4 discusses the probable factors that affect the results of the attempt subjected to the relevant statistics.

## 2. A case study: Visible Learning and Formative Assessment

Visible learning is a process of seeing learning through the eyes of students [24]. It also an exchange of learning between instructors and students. In an effective classroom, both teaching and learning are evident. It is also essential for the instructors to identify their wide dimensions to seek out more shreds of evidence of learning. Moreover, compared to summative assessment, formative assessment plays a vital role in the achievements of students. Formative assessment continuously monitors the performance of students, learning needs, and styles. It also allows instructors to practice various influential activities and take feedback on the progress of a student. The source of influence, aspect, and factor should be referred to from Table 1.

**Table 1 : The Parameters influencing student achievement**

Source of Influence	Aspect	Factor
Teaching: Teaching/Instru ction Strategies	Strategies emphasizing learning intentions, teaching strategies	Problem solving teaching, prior knowledge

Formative assessment has been carried out to fulfill the requirement of the curriculum for 3 different theoretical examinations: Theory Continuous Internal Examination (TCIE-1 and 2) and Theory Semester End Examination (TSEE). The effect size has not been calculated differently in both assessment methods, but the impact of the assessment method has been observed in overall performance. The pre-test was assessed before implementing the visible learning techniques. The examination structure of both the subjects.

**Table 2 : Examination structure with maximum marks**

Subject	TCIE		TSEE
	TCIE-1	TCIE-2	
Subject-1: High Voltage Engineering (EL613)	Conventional written exam: 40 marks maximum	Poster presentation: 40 marks maximum	Conventional written exam: 100 marks maximum
Subject-2: Electrical Power Utilization and Traction (EL516)	Conventional written exam: 40 marks maximum	Conventional written exam: 40 marks maximum	Conventional written exam: 100

**Table 3: Analogy: Scientific concept and Source domain**

Subject	Scientific concept	Source domain
Subject-1: High Voltage Engineering (EL613)	Ionization process	Vehicle traffic
	<i>Similarities</i>	
	Collision	Road traffic
	Primary electrons	Scooters, autos, cars
	Secondary electrons	Buses, Trucks, SUVs
	Electron avalanche	Green signals are shown
	Electrical breakdown	All the vehicle can transport from one end to another end.
	<i>Dissimilarities</i>	
	The energy is lost or gained depending on the type of collision, and primary and secondary ionization factors.	Vehicles are in a que; they do not lose or gain any sort of energy.
Subject-2: Electrical Power Utilization and Traction (EL516)	Electric Lamp	The Sun
	<i>Similarities</i>	
	Limited photon energy	Unlimited photon energy
	Depreciation factor: the luminaries are covered by dust particles.	Depreciation factor: The Sun is covered by clouds, mist or fog.
	Direct light scheme as per the design	When the Sun is at 12:00 noon
	Light emission: ion collision	Light emission: Nuclear Fusion and Fission process
	<i>Dissimilarities</i>	
	Constant and limited illumination	Constant illumination except the position of the earth and the distance between the earth and the Sun

should be referred from Table 2. It is interesting to consider that along with effect size, the source of influence, aspect, and factor, a few analogies that teach the nature of science were included to help understand the engineering concepts [16-17] [25-26]. During the semester for both the subjects, a number of analogies were developed to help students grasp hard contents easily; for the sake of brevity, only one analogy has been cited for each subject and Table 3 depicts the features of the analog and the science concept. For the sake of brevity only a few of them have been mentioned. During the evaluation, it was observed the impact of the mode of examination on students' performance. It means conventional written examination or innovative examination, e.g., poster presentation; the students had to select a topic from the syllabus contents to demonstrate.

The effect size [11] has been calculated for TCIE-1 and TCIE-2 examinations from equation (1) as-

$$Effect\ Size = \frac{\frac{Average\ of\ Post-assessment - Average\ of\ Pre-assessment}{Average\ Standard\ Deviation}}{(1)}$$

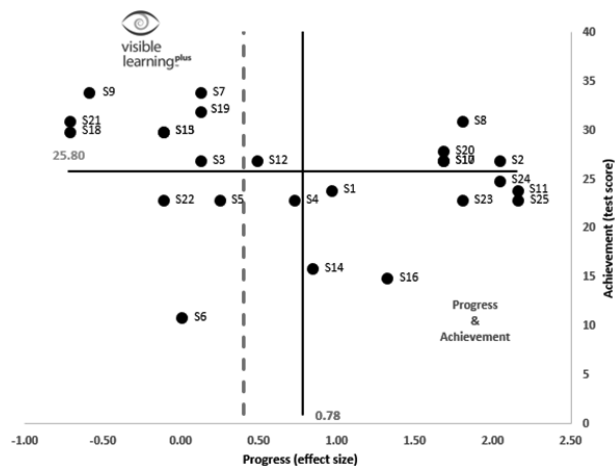
The pre-assessment is the impact before implementing innovative learning methods, and the post-assessment is conducted after the change in learning methods in students' learning. For the sake of conciseness, all the test results, a brief result analysis has been shown in Table 4. Overall, as compared to TCIE-1, during TCIE-2, the students performed remarkably in both the subjects. The results have been compared in terms of the average of marks and standard deviation. For each student, the progress and achievement have been derived using a coded tool of visible learning plus [27]. The tool displays achieved effect size along with the performance of students after post-assessment.

The effect of size for the subjects has been illustrated in Fig. 1 and Fig. 2, respectively. In Fig. 1 and Fig. 2, the horizontal axis represents the effect size. The vertical axis represents achievement (score of 40 marks). The dotted lines indicate the effect size of 0.40- a hinge point defined by Hattie. an effect size at which the attempt offers greater than an average influence on attainment [24]. The distribution of individual effect size is shown by black spots for both subjects, respectively.

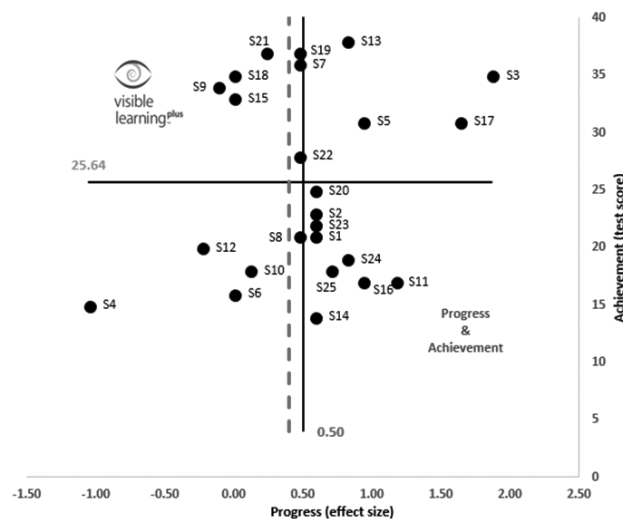
**Table 4 : Result analysis**

Performance indicators	Subject-1: High Voltage Engineering (EL613)		Subject-2: Electrical Power Utilization and Traction (EL516)	
	TCIE-1	TCIE-2	TCIE-1	TCIE-2
Average of marks	19.28	25.80	21.32	25.6
Standard deviation	11.05	5.66	8.88	8.24
Average of Standard Deviation	8.36		8.56	

It is evident from the analysis that there is an increase in progress and achievement after implementing visible learning strategies (see Table 1) and formative assessment. From Table 4, it is inferred that for subject 1, the average of marks ranged from almost 19 to 26 from TCIE-1 and TCIE-2 orderly. In Fig. 1, S9 gained 39 and stood first in subject-1 during TCIE-1 whereas, S25 showed the poorest performance with only 5-marks in the same category.



**Fig. 1 : Progress (effect size) and achievement (test score) for High Voltage Engineering (EL613)**



**Fig. 2 : Progress (effect size) and achievement (test score) for Electrical Power Utilization and Traction (EL516)**

During TCIE-1, students S9, S18 and S21 scored 35 marks- the highest score amongst all the appeared students. In contrast, in Fig. 2, S11 scored 7 marks-a lowest performance in subject-2. On the other side, S13 was the top scorer, while S14 stood the lowest scorer with 14 marks in TCIE-2. It is interesting to note that the average deviation remained almost 8.5 in both subjects. From the graphical illustrations (Fig. 1 and Fig. 2), it is depicted that the effect size is computed as much as high as 0.78 in subject-1 and 0.50 in subject-2. In Fig. 1, for subject-1, the effect size is observed to be negative in reference to students S4, S9, and S12, and the effect sizes are -1.05, -0.12, and -0.23 respectively. This is also true in subject-2 but, students S9, S15, S18, S21, and S22 remarkably

exhibited a declined performance; the trend can be observed in Fig. 2.

In the formative assessment, it is essential to find the impact of mode of examination, i.e., conventional and innovative (here, poster presentation in TCIE-2, subject-2). It is crucial to identify the responsible parameters to check the feasibility of such modes of examination, probable causes of the declined trend, and the same has been discussed in section 4. In general, it is apparent from the statistics that students performed better in the subject with an effect size more than the hinge point-0.4 that shows the influence of visible learning and achievement.

### 3. Attainment of COs and PSOs

In the National Assessment and Accreditation Council (NAAC), India certification, the program design, and program development are firmly associated measures with the description of learning outcomes [28]. The learning outcomes are the specific intentions composed in clear terms are the statements describing the ability that the students will be able to get after completing the course [28]. In higher education, it is vital to attaining both COs and PSOs to endorse the educational practices. These practices are in tune with indigenous, national, and global changes occurring [15]. The COs and PSOs are the key indicators to evaluate the educational practices with objectivity and transparency. Here, an attempt has been made to map COs and PSOs with 25 undergraduate electrical engineering students for subject-1 and subject-2. Table 5 displays various grades secured by students S1 to S25 in both subjects. The overall score is decided as per the norms of the institutions. The indicators- Exemplary (P), Accomplished (Q), Approaching (R), Needs improvement (S) signify the CO attainment. The CO attainment indicators can be referred to from Table 6.

**Table 5 : Grade wise student count**

Grades	Subject-1	Subject-2
A+	0	0
A	5	6
B+	2	2
B	5	3
C+	9	4
C	3	6
D	0	4
F	1	0
X	0	0

**Table 6 : CO attainment indicators**

Group-wise student count: CO attainment indicators	Subject-1	Subject-2
Exemplary (P) (P = (A+) + (A)) grades)	5	6
Accomplished (Q) (Q = (B+) + (B) + (C+) grades)	16	13
Approaching (R) (R = (C) + (D) grades)	3	6
Needs improvement (S) (S = (F) + (X) grades)	1	0

The group-wise- 'P' to 'S' percentage (%) students can be determined by equation (2).

$$\text{Group wise \% students} = \frac{P \text{ or } Q \text{ or } R \text{ or } S}{P + Q + R + S} \times 100 \quad (2)$$

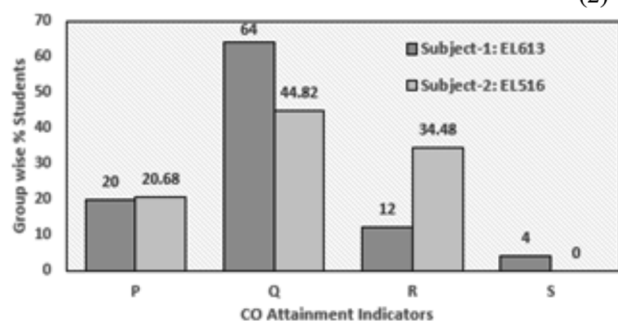
**Fig. 3 : CO attainment indicators Vs Group wise % students**

Fig. 3 provides an analysis of overall CO attainment indicators including group-wise % students. As the study has been taken up for only two offered subjects, the analysis has been restricted to those subjects only. The rationale of comparing two subjects (as offered in the semester) is to observe the impact of formative assessment methods and visible learning. The COs can surely be different from each other as the subject contents and requirements are distinct and different.

In the graph, the indicator 'Q' is the striking feature showing a remarkable difference of almost 20 % between two subjects in reference to group-wise % students. Besides, 'R' is significant in subject-2 compared to subject-1 whereas 'P' and 'Q' make a subtle change in the category.

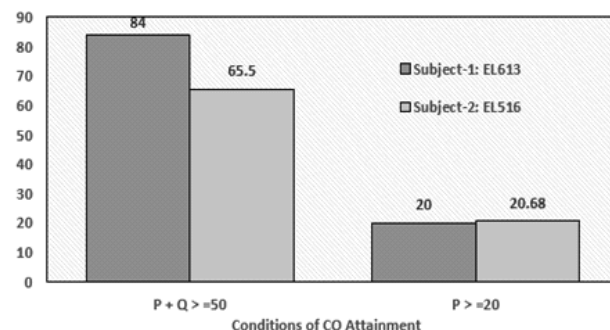
After this analysis, by applying necessary conditions of CO attainment (as per Table 7), CO attainments are examined. It is appealing to note that the conditions of CO attainment result in the indicator-

'Exemplary- P' i.e., the proposed study serves a desirable model. However, it is not limited, it can be executed for a greater number of students.

**Table 7 : Conditions of CO attainment**

CO attainment indicators	Conditions
Exemplary (P)	$P + Q \geq 50, P \geq 20$
Accomplished (Q)	$P + Q \geq 50, P < 20$
Approaching (R)	$P + Q + R \geq 50$
Needs improvement (S)	$P + Q + R < 50$

The CO attainment is displayed in Fig. 4. Taking this into the consideration, the COs of both the subjects (refer Table 7) have been mapped with the PSOs of the program (refer Table 7) and the same can be referred from Table 9.

**Fig. 4 : The attainment of COs**

The statistics show that a club of visible learning and formative assessment have had an effect on progress and achievement in the courses. The statements of PSOs for both the subjects should be referred to from Table 8. The PSOs comprise of different subjects offered during the program. The Table 9 depicts the mapping of the CO attainment indicator(s) and the PSOs.

It is concluded that subject-1 secures 'P'-the CO attainment indicator and it fulfills the PSO2, whereas, subject-2 also secures 'P' that matches the PSO4 of the department.

Table 8. Program Specific Outcomes (PSOs) and Course Outcomes (COs) PSOsProgram Specific Outcomes (PSOs)PSO1To analyse different electrical machines, their designs, verify control topologies though experiments and interpret suitable applications in the electrical power system.PSO2To investigate various dielectric materials and their

**Table 8 : Program Specific Outcomes (PSOs) and Course Outcomes (COs)**

PSOs	Program Specific Outcomes (PSOs)	
PSO1	To analyse different electrical machines, their designs, verify control topologies through experiments and interpret suitable applications in the electrical power system.	
PSO2	To investigate various dielectric materials and their properties through testing to design high voltage insulation systems.	
PSO3	To design and model power systems with advanced technology and protection schemes for a reliable operation of generation, transmission and distribution sectors.	
PSO4	To identify the most efficient renewable system and draw out the feasibility of the system for the sustainable environment.	
PSO5	To design, develop and carry out an innovative project work by applying conceptual knowledge of multidiscipline, tools and the research methods.	
	Course Outcomes (COs)	
COs	Subject-1 High Voltage Engineering (EL613)	Subject-2 Electrical Power Utilization and Traction (EL516)
CO1	To recall the importance of high voltage technology	To understand applications and effective utilization of electric energy
CO2	To discuss breakdown phenomena in different dielectrics	To design an effective illumination system
CO3	To demonstrate generation and measurement of high voltages	To apply the utility of electric heating
CO4	To examine testing methods used for different HV apparatus	To realize the working of electric traction system
CO5	To evaluate insulation coordination among different HV apparatus	---
CO6	To plan high voltage laboratory layout	---

properties through testing to design high voltage insulation systems. PSO3 To design and model power systems with advanced technology and protection schemes for a reliable operation of generation, transmission and distribution sectors. PSO4 To identify the most efficient renewable system and draw out the feasibility of the system for the sustainable environment. PSO5 To design, develop and carry out an innovative project work by applying conceptual knowledge of multidiscipline, tools and the research methods.

Course Outcomes (COs) COs Subject-1 High Voltage Engineering (EL613) Subject-2 Electrical Power Utilization and Traction (EL516) CO1 To recall the importance of high voltage technology To understand applications and effective utilization of electric energy CO2 To discuss breakdown phenomena in different dielectrics To design an effective illumination system CO3 To demonstrate generation and measurement of high voltages To apply the utility of electric heating CO4 To examine testing methods used for different HV apparatus To realize the working of electric traction system CO5 To evaluate insulation coordination among different HV apparatus --- CO6 To plan high voltage laboratory layout

Apart from it, the factors affecting the effect size of subject-1 should be discussed as it is observed that implementation of the innovative examination reduces the effect size of a number of students and the

same has been discussed with other influencing factors in section 4.

**Table 9 : Mapping of COs with PSOs**

Course/Subject	PSOs				
	PSO1	PSO2	PSO3	PSO4	PSO5
Subject-1: High Voltage Engineering (EL613)		P			
Subject-2: Electrical Power Utilization and Traction (EL516)				P	

#### 4. Discussion on influential factors of the attainment of COs and PSOs

The formative assessment is a continuous assessment and may involve various pedagogies to instruct and assess students and periodic feedback from students and instructors. It is observed that the individual student performance (compare-Figures 1 and 2) has decreased when evaluated by the poster presentation. In the poster presentation, students were to prepare and present on a topic only. The rubrics of the evaluation were genuine enough to assess and have not been cited for the sake of brevity. It makes a considerable difference between the modes of examination. A conventional written examination comprises a variety of questions to check the ability of students. On the other side, poster presentation

narrows down the reach out of the evaluation. In contrast, it may offer diversity to examine representation skills. However, it is predicted that this divergence in the examination modes might have affected the effect size in subject-1. The students may not have the required demonstrating skills.

Apart from it, the instructors and students must be availed of the necessary academic and research infrastructures to make it more well-organized, and ancillary staff support [19] [29-30] to make it more well-organized. Exposure to cutting-edge practice in engineering and science [30] is also equally essential. In parallel, the support from instructors and students to each other can bring a considerable change in the results.

## 5. Conclusion

From the attainment indicators, it is apparent that promoting visible learning and formative assessment can enhance the learning process in the engineering domain. It is necessary to keep the effect size 0.4 or above to realize a difference in a learning environment, and it is realized in the presented study. However, the present study is underway to observe long-term results in this domain. An instructor may invent and apply new strategies to evolve the learning and the evaluation process. It is expected to produce long-lasting experience and alter the prevailing gaps in the engineering education system.

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