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Assessment and Evaluation of the Course Outcomes of Semiconductor Devices Course for the BSc in EEE Program

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Abstract

The main challenge of present-day engineering educators is to develop higher-order complex engineering skills among the undergraduate students of engineering disciplines. However, it is a very daunting task to perform the proper assessment and evaluation of these skills through various course works. Students take several courses during their undergraduate engineering studies. Different courses have different objectives that are to be accommodated in the curriculum. The semiconductor devices course is one such core course in the Bachelor of Science in Electrical and Electronic Engineering (BSc in EEE) program. This is one of the important courses of BSc in EEE curriculum and its course outcomes are mapped to some of the program outcomes. So, proper initiatives must be taken to assess and evaluate the outcomes of the semiconductor device course and hence its contribution to the outcomes of BSc in EEE program. In this paper, such assessment and evaluation procedures are described for this course of the BSc in EEE program which follows the Outcome-Based Education (OBE) approach. The working methods, course contents, course outcomes (COs) and their mapping with the program outcomes (POs), assessment plan, course, and program outcome assessment data and its statistical analysis are presented for a particular student cohort of semiconductor device course conducted in Fall 2019 Semester at the EEE Department of Southeast University (SEU). It has been observed that the benchmark set by the course instructor was attained by all students through CO-PO analysis. Finally, some recommendations were made as part of the continuous quality improvement (CQI) process.

Keywords: OBE, Course Outcome, Assessment, Evaluation, COI, Semiconductor Device Course.

I. Introduction

Engineering programs are being accredited by the Board of Accreditation for Engineering and Technical Education (BAETE) under the umbrella of the Institution of Engineers Bangladesh (IEB), which is one of the largest professional societies in Bangladesh (BAETE, 2019). If a program is not accredited, the graduates of that program can't apply to obtain the IEB membership. However, an engineer needs to approve engineering design, but to do that in most cases, the IEB membership certificate is necessary. As such, every engineering program leader seeks accreditation so that his/her graduates can find suitable engineering jobs. However, to get an engineering program accredited by the BAETE, one has to revisit the curriculum to convert it into an Outcome-Based Curriculum (OBC) and also follow the Outcome-Based Teaching-Learning (OBTL) process. As a result, the EEE department of SEU has updated its curriculum to an outcome-based curriculum with effect from the Spring 2019 Semester (M. H. Bhuyan and A. Tamir, 2020; EEE-PO, 2020) as per BAETE OBE Manual (BAETE, 2019). The department of EEE wishes to apply based on the second version of the manual in December 2021 (BAETE, 2019).

The number of universities and hence engineering programs are increasing every year in Bangladesh (UGC, 2020). So, there is a huge competition among the universities to admit quality students. Thus every university is trying to highlight its strengths as well as to obtain recognition from various agencies. For engineering programs, getting accreditation from BAETE is very important. At present, BAETE provides program accreditation based on an outcome-based engineering curriculum. Due to the new policy of Outcome-Based Accreditation (OBA), many engineering programs in Bangladesh

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are gradually switching to the outcome-based curriculum and thus applying to the BAETE for OBA (BAETE, 2020).

The EEE Department of SEU started to implement the OBE-based curriculum from the Spring 2019 semester. All the core courses of the curriculum have been selected initially for the course outcome preparation and mapping it to the program outcomes as well as assessing and evaluating these outcomes through a systematic and well-defined plan. The course outcomes will be evaluated through a direct assessment technique (EEE-PO, 2020).

This paper reports on how to assess and evaluate the course outcomes of the semiconductor device course. Besides, the mappings of the course outcomes (COs) to the corresponding program outcomes (POs) have been calculated based on their corresponding weights and linking methods. BSc in EEE program has included 12 Program Outcomes (POs) provided by the BAETE in its curriculum (BAETE, 2019).

II. Literature Review

The fundamental requirement of accreditation for any engineering degree program is to achieve a set of well-defined attributes/program outcomes at the point of degree completion through different course outcomes (BAETE, 2019). The course outcomes primarily emphasize students' learning activities and progress during a particular semester. Students need to demonstrate the course outcomes attainments through any one or all of the three domains of Bloom's taxonomy, viz. knowledge, skills, and attitudes upon successful completion of a specific course in the curriculum at the end of that semester (C. Asheim *et al*., 2017; H. A. M. Abdeljaber and S. Ahmad, 2017). Course outcomes data have a direct influence on the curriculum improvement of engineering programs to ensure quality and further development (N. A. Mustaffa *et al*., 2019).

Assessment and evaluation of various course outcomes (COs) are indispensable to check the student attainment of the program outcomes (POs) in an engineering program that follows the outcome-based curriculum and seeks accreditation as per the Washington Accord (WA) (M. H. Bhuyan and S. S. A. Khan, 2020; M. H. Bhuyan and A. Tamir, 2020). Course outcomes are measured after the successful completion of a course taught to a specific cohort of students in a definite semester. Through this measurement process, one can have a clear portrait of the course learning outcomes of those students in a specific cohort and as a result, the corresponding POs of those students (M. H. Bhuyan and S. S. A. Khan, 2020). This is also required to suggest and implement the continuous quality improvement process of the program (T. Sikander *et al*., 2017).

Since through assessment, we try to identify and collect students' attainment data to calculate their accomplishment of course learning outcome and hence the program outcomes, a sustainable assessment method was developed to take corrective measures for the improvement of the learning outcome and thus ensuring the quality of the undergraduate engineering education (R. Mahadevan *et al*., 2013),. It has been suggested that an effective assessment plan can provide quantitative and qualitative as well as direct and indirect measurements aptly (ABET, 2010).

Though there are various types of assessment patterns to quantify the course and hence program outcomes, direct and indirect assessment patterns are the most common among them (R. Terry *et al*., 2007; P. Jayarekha and M. Dakshayini, 2014). However, direct assessment schemes are mostly used for the course learning outcome assessment (J. Shaeiwitz and D. Briedis, 2007). This process facilitates a program to reveal how a particular PO is achieved by the students of an electrical and electronic engineering curriculum.

Direct assessment is performed based on an effective course assessment plan and evidence of course learning outcomes. The pieces of evidence provide the gradation of relationship about the mastery of a specific subject area by a particular student. This assessment technique is primarily applied to define the course or program level outcome. There are several constituents for the direct assessment method. One such method is the examination questions at various stages such as quizzes, class tests, midterm or final examinations, etc. (H. A. Harvey *et al*., 2010; M. H. Bhuyan and S. S. A. Khan, 2020).

Another method suggested for the direct assessment is to measure the course outcomes

(COs) and the program outcomes (POs) based on a defined set of performance indicators that have a strong correlation with the taught courses (H. Gurocak, 2008; L. Alzubaidi, 2017). These performance indicators were some measurable attributes that were unique to meet the required POs (G. Rogers, 2003).

Semiconductor Device course is a core course in the undergraduate Electrical and Electronic Engineering curriculum. This course is also known as the Solid State Device course. Since this is an advanced-level electronics course, students find it difficult to obtain good grades and attain the required course outcomes. As such, for many years, various attempts were taken to make the theories and models fathomable to the students. In this context, e-learning was found as a proven technique to overcome such difficulties. The researchers mainly employed web and applet-based e-resources and online lecture videos on semiconductor devices to help the students to achieve their course learning outcomes (G. K. Singh, 2011). However, to tackle the challenges to attain the course outcomes, sometimes, motivation from the faculty is crucial and was found effective (M. H. Bhuyan and S. S. A. Khan, 2018).

In another research paper, it was found that a new approach called *Integration of Knowledge* is effective in terms of student satisfaction and self-assessment of the students' course outcomes of the semiconductor device course using the SUPREM software package. They used this software to teach the students how to design three and four-terminal semiconductor devices (M. E. Rizkalla and C. F. Yokomoto, 2001).

III. Objectives of the Work

The main objective of this work is to find a suitable method to assess and evaluate the course learning outcomes of semiconductor device courses and use its weighted contribution to calculate the attainment of the program outcomes of the BSc in EEE program. However, the other purposes of this work are to-

i. Survey several works on the OBE-based assessment and evaluation processes of the semiconductor device and other such courses
ii. Prepare an assessment plan for calculating the attainment of the course outcomes of the semiconductor device course
iii. Provide some knowledge and skills of device design relevant to complex electrical and electronic engineering problems.
iv. Assess and evaluate the attainment of each student of the semiconductor device course.
v. Assess and evaluate the attainment of program outcomes mapped to the course outcomes of the semiconductor device course.
vi. Determine the strong and weak areas of the course and suggest remedial actions to be undertaken by the program chair for continuous quality improvement (CQI).

IV. Methods

At SEU, one of the most demanding and student attractions grasping engineering program is its BSc in Electrical and Electronic Engineering (EEE) program. However, admission seekers want to know the status of its accreditation. Therefore, the program leader also finds it very interesting that the program should be made accredited as soon as possible. The main objective of this bold step is to get the required financial and physical resources to grow the program as one of the quality-ensuring tertiary-grade engineering programs in the university and the country. But now the accreditation is provided only if the program outcome attainment by the student cohort can be ensured through the outcome-based curriculum, teaching-learning, and assessment. In this regard, the EEE department needs to find the crucial performance indicators to measure the Course Outcomes (COs) and hence the Program Outcomes (POs) (M. H. Bhuyan and A. Tamir, 2020). Consequently, the EEE Department had developed an OBE-based curriculum with effect from the Spring 2019 Semester and formulated OBE-based teaching-learning and assessment-evaluation guidelines. Based on these guidelines, a model was adopted to figure out the achievement of the Program Outcomes (POs) through several direct assessment tools. Because of that, each of the semiconductor device COs was linked to any one of twelve POs of the BSc in EEE program. This is done by the subject-specific course teacher. After that, each course teacher is to devise an assessment plan to figure out the course outcomes attained by the students of that particular course. While preparing this plan for each CO, the course teacher needs to set questions according to the action verbs used to write COs and their corresponding mapping with the POs and Bloom's taxonomy domain of learning. Then the assessment data of COs are used to compute the POs linked to the COs. PO evaluation is done for each student based on the data collected from the course results of the faculty members of various courses. Then the accuracy of the results is examined and finalized for contribution to the POs (R. Mehdi and M. A. Naaj, 2013).

A. Course Contents

The course contents provide us a broad picture of a particular course in the curriculum of any program. Therefore, it is necessary to design it in such a way that the faculty members and students of that program can have an idea of the broader aspect of a course and can understand what knowledge and skills the faculty members are going to deliver to their students and the same are going to be developed by the students who undertake that course. However, an amalgamation of excessive issues in the course contents may hinder the course objectives and hence the course outcomes. As such, the prime contents of the semiconductor device course are given as follows:

"*Semiconductors in equilibrium: Energy bands, intrinsic and extrinsic semiconductors, Fermi levels, electron and hole concentrations, the temperature dependence of carrier concentrations and invariance of Fermi level. Carrier transport processes and excess carriers: Drift and diffusion, generation and recombination of excess carriers, built-in-field, Einstein relations, continuity and diffusion equations for holes and electrons and quasi-Fermi level. PN junction: Basic structure, equilibrium conditions, contact potential, equilibrium Fermi level, space charge, non-equilibrium condition, forward and reverse bias, carrier injection, minority and majority carrier currents, transient and AC conditions, the time variation of stored charge, reverse recovery transient and capacitance. Bipolar Junction Transistor: Basic principle of pnp and npn transistors, emitter efficiency, base transport factor and current gain, diffusion equation in the base, terminal currents, coupled-diode model and charge control analysis, Ebers-Moll equations, and circuit synthesis. Metal-semiconductor junction: Energy band diagram of metal-semiconductor junctions, rectifying and ohmic contacts. MOS structure: MOS capacitor, energy band diagrams and flat band voltage, threshold voltage and control of threshold voltage, static C-V characteristics, qualitative theory of MOSFET operation, body effect, and current-voltage relationship of a MOSFET. Junction Field-Effect-Transistor: Introduction, qualitative theory of operation, pinch-off voltage and current-voltage relationship*" (EEE-CC, 2020).

B. Course Outcomes

A Course Learning Outcome (CLO) or simply the Course Outcome is one of the fundamental components of any engineering course's curriculum. It articulates to the students, faculty members, employers, parents, and other stakeholders that upon the successful completion of a particular course, what the students will be able to do through an appropriate measurement. As such, a Course Outcome (CO) is measurable, observable, and specific when stated. It indicates explicitly what knowledge a student should have and what abilities or skills he/she should develop as a result of the teaching-learning process.

Well-articulated Course Outcomes (COs) of a particular course consists of the following components (V. K. Chandna, 2015):

i. Action verb as per Bloom's taxonomy
ii. The subject of the course
iii. Level of achievement for a specific task by the students
iv. Condition of performance for a task at a specific context by the students (optional)

In an OBE-based curriculum, there may be further lower-level and higher-level course outcomes from the first year to the final year, but the semiconductor device course is a very important core course in the undergraduate curriculum of the electrical and electronic engineering program. Thus, the understanding of this course is also very important, because the knowledge of this course is required for the next higher level core and elective courses as well. Therefore, the course outcomes of the semiconductor device course should be designed in such a way so that the students can develop their deep understanding of this course. Various theorems and laws related to semiconductor device physics are taught to the students in a 3-credit theory course. Besides, models of semiconductor device designs are explained for circuit simulation.

As a result, the course outcomes were prepared accordingly for this course. To prepare the course outcomes, we used appropriate action verbs for each CO. Then we wrote five-course outcomes for the semiconductor device course with a starting phrase as follows-

After the successful completion of this course, the students will be able to-

[CO1] Explain the physical phenomena and principles that govern the semiconductor behavior properly

[CO2] Draw the energy band diagrams of various devices to explain their behavior under various biasing conditions

[CO3] Derive semiconductor device equations for modeling their dynamic behavior

[CO4] Compute the operational and performance parameters for various semiconductor devices

[CO5] Determine the semiconductor device parameters from their characteristic curves

C. *Program Outcomes*

Program Outcomes (POs) of an engineering academic program are defined as the knowledge, skills, and attitudes that a graduate should be able to demonstrate right after the degree completion. These outcomes describe the graduate of an academic program. Program outcomes connote broad declarations about engineering graduates integrating wide areas of inter-related knowledge, skills, and attitudes developed during the study period in a particular engineering program through a wide range of theory courses and laboratory and other practical experiences. While the course outcomes reveal the constituents that frame the entire program through knowledge, skills, and attitudes, the program outcomes characterize the whole from those constituents through the integration of them. So, it demonstrates the students' cumulative learning from all the courses upon the completion of the program.

The OBE-based curriculum of the Bachelor of Science in Electrical and Electronic Engineering program is designed with a total minimum of 153 credits (of which 72 credits are core courses) according to the UGC, Bangladesh (UGC, 2018), and BAETE, Bangladesh strategies (BAETE, 2019). Twelve program outcomes for the engineering programs in the BAETE Manual are adopted in the curriculum of the BSc in EEE program directly just by using the appropriate modifiers when necessary. So, the graduates of this program are expected to attain twelve POs at the point of their graduation (EEE-PO, 2020). Since five COs of the semiconductor device course are mapped to three POs (PO1, PO2, and PO4) of the BSc in EEE program, therefore, these three POs are described as per BAETE manual as follows (BAETE, 2019):

[PO1] **Engineering Knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex electrical and electronic engineering problems;

[PO2] **Problem Analysis**: Identify, formulate, research the literature and analyze complex electrical and electronic engineering problems and reach substantiated conclusions using first principles of mathematics, the natural sciences, and the engineering sciences;

[PO4] **Investigation**: Conduct investigations of complex electrical and electronic engineering problems, considering the design of experiments, analysis, and interpretation of data, and synthesis of the information to provide valid conclusions;

D. *CO-PO Mapping and Performance Assessment*

Performance Indicators (PI) or Key Performance Indicators (KPIs) are some of the key pointers that focus on the most important parameters to be measured to quantify the level of achievement of the course outcomes by the students of their program (ABET, 2010). Choosing the right KPIs is an important factor to attain the course outcomes appropriately. In semiconductor device course, direct measurement techniques are used to get the knowledge levels against each course outcome to have an insight into their CO attainment. It is expected that the faculty member of each course preserves the records of each semester. Upon successful completion of each course in a particular semester, the student gets letter grades CO attainment in percentage demonstrating their PO achievement through the COs (H. Gurocak, 2008; EEE-PO, 2020).

Knowledge, skills, and attitudes are the key elements to attain any program outcome through various course outcomes. The faculty members need to define various performance indicating parameters with the corresponding teaching-learning domains and levels under Bloom's Taxonomy (BT), and appropriate teaching-learning strategies, and assessment kits for the semiconductor device course. To deliver proper knowledge of this course and transform the students with the necessary skills at various levels of the cognitive domain, appropriate teaching-learning strategies should also be devised. However, for various undergraduate electrical and electronic engineering courses, it has been witnessed that the various levels of the cognitive domain under Bloom's taxonomy is effective than the old-fashioned methods of teaching-learning strategies in several articles (M. H. Bhuyan, 2014; M. H. Bhuyan and S. S. A. Khan, 2014; M. H. Bhuyan *et al*., 2014; M. H. Bhuyan *et al*., 2018).

Table 1 shows CO-PO mapping, and levels of the teaching-learning in cognitive domains of BT, teaching-learning delivery methods, and various direct assessment parts for CO measurement.

Table 1: CO-PO mapping, taxonomy domain, teaching-learning strategy, and assessment tools of the semiconductor device course

Course Outcome		PO	Taxonomy Domain/Level	Teaching-Learning Strategy	Assessment Strategy
[CO1]	Explain the physical phenomena and principles that govern the semiconductor behavior properly	PO1	Cognitive/ Understand	Lectures Discussion with the students Question and answer session	Class Test Assignment
[CO2]	Draw the energy band diagrams of various devices to explain their behavior under various biasing conditions	PO1	Cognitive/ Apply	Lectures Discussion with the students Question and answer session Problems solving in the class	Class Test Assignment Midterm Exam
[CO3]	Derive semiconductor device equations for modeling their dynamic behavior	PO2	Cognitive/ Understand and Apply	Lectures Question and answer session Problems solving in the class	Class Test Midterm Exam
[CO4]	Compute the operational and performance parameters for various semiconductor devices	PO4	Cognitive/ Apply and Analyze	Practical demonstration Problems solving in the class Question and answer session	Class Test Assignment Final Exam
[CO5]	Determine the semiconductor device parameters from their characteristic curves	PO4	Cognitive/ Analyze and Evaluate	Problems solving in the class Discussion with the students Question and answer session	Class Test Assignment Final Exam

Table 2: Assessment Plan of Semiconductor Device Course

Assessment Tool				Mapping with Course Outcome				
Item	**Q#**	**Cognitive Level**	**Allotted Marks**	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Class Test1	Q2	C2: Understand	3.0	√				
Class Test2	Q3	C3: Apply	3.0		√			
Class Test3	Q3	C3: Apply	3.0		√			
Midterm Examination	Q1(a)	C2: Understand	3.0			√		
	Q1(b)	C3: Apply	4.0			√		
	Q2(c)	C3: Apply	4.0		√			
	Q3(a)	C2: Understand	5.0	√				
	Q4(a)	C4: Analyze	4.0				√	
	Q4(b)	C3: Apply	3.0			√		
Final Examination	Q1(a)	C2: Understand	3.0			√		
	Q2(a)	C3: Apply	5.0				√	
	Q2(b)	C5: Evaluate	5.0					√
	Q3(a)	C4: Analyze	3.0					√
	Q4(a)	C3: Apply	3.0				√	
	Q5(b)	C5: Evaluate	4.0					√
Total	**15**	**-**	**55.0**					

Table 3: Percentage distribution of questions as per levels of Bloom's taxonomy in the cognitive domain

Cognitive Levels		Questions			
Level #	Level Name	Number of Questions		Marks of Questions	
		In Count	In %	In Number	In %
C2	Understand	4	26.7%	14	25.5%
C3	Apply	7	46.7%	25	45.5%
C4	Analyze	2	13.3%	7	12.7%
C5	Evaluate	2	13.3%	9	16.4%
	Total	**15**	**100.0%**	**55**	**100.0%**

Table 2 shows the itemization of each of these parts through which CO attainment of semiconductor device course was done. These tools comprise several certain questions of class tests (continuous or formative assessment tool), midterm, and final examinations (summative assessment tool), etc. In SEU, 30% marks are allotted for continuous assessment, 30% are for the midterm, and 40% are for the final examinations. Table 2 also shows the corresponding question number of an examination, marks allotted to each of these questions, cognitive domain level, etc. Straightforward relationships among COs and POs are assumed for the semiconductor device course (M. H. Bhuyan and A. Tamir, 2020).

The COs of this course are calculated according to the formula of equation (1).

$$CO_i = \frac{\sum_{j=0}^{j=N} OM_j}{\sum_{j=0}^{j=N} AM_j} \times 100\% \tag{1}$$

,where N is the total number of questions to be considered from various types of direct assessment type examinations for a particular course outcome (CO_i), OM_j is the obtained marks by a student against an examination question for a particular course outcome (CO_i) and AM_j is the allotted marks in a question considered for the i^{th} CO.

The POs are computed using equation (2). However, this is a partial contribution towards a particular PO. The final PO values are calculated from all COs of various courses of the curriculum.

$$PO_k = \frac{\sum_{i=0}^{i=n} TOMCO_i}{\sum_{j=0}^{j=n} TAMCO_i} \times 100\% \tag{2}$$

,where n is the total number of course outcomes considered for a particular program outcome (PO_k), $TOMCO_i$ is the total obtained marks by a student from different examinations for a particular course outcome (CO_i) and $TAMCO_i$ is the total allotted marks of different questions considered for the i^{th} CO.

Table 3 shows the percentage of question distribution in the assessment plan of Table 2 as per various levels of the cognitive domain under Bloom's taxonomy in terms of the number of questions and amount of allotted marks for each question (M. H. Bhuyan and S. S. A. Khan, 2020).

The attainment level measuring scale to be used is shown in Table 4. This is simply based on the percentage of marks contributed to each CO from diverse direct assessment tools as shown in Table 2. To begin with, the CO attainment target was fixed at 50%. This was the minimum benchmark in the early stage of CO assessment as the minimum passing CGPA at SEU is 2.5 on a scale of 4.00 that is equivalent to 50% marks. If the minimum benchmark level is 50% then 50% of the students of the semiconductor device course must be at or above this level, and this level corresponds to the satisfactory/benchmark level, highlighted in Table 4 (M. H. Bhuyan and S. S. A. Khan, 2020).

Table 4: Performance scale based on the percentage of marks obtained

Performance Level		Numerical Scale
Excellent	Achieved	80% and Above
Very Good		70-79%
Good		60-69%
Satisfactory		50-59%
Developing	Not achieved	40-49%
Unsatisfactory		Below 40%

E. PO Assessment

To gauge the attainment status of POs for each student of the semiconductor device course, each CO of this course has been mapped to anyone PO as shown in Table 1. The accomplishment of each PO is counted according to the following procedures (M. H. Bhuyan and A. Tamir, 2020):

i. Each CO will contribute to anyone PO only.
ii. As per Table 1, CO1 and CO2 jointly

contribute to accomplishing PO1, CO3 alone helps to achieve PO2, and finally, CO4 and CO5 together assist to attain PO4.

iii. The percentage of combined scores is calculated and is used to calculate the corresponding PO for each student.

iv. A program outcome is said to be attained if the combined number of students in the 'Excellent', 'Very Good', 'Good', and 'Satisfactory' levels in percentage is equal to or greater than 50%.

v. The PO standing is computed as per the following criteria-

a. Score < 50% → not achieved

a.i. Score < 40% → unachieved and in the unsatisfactory stage and require retaking the course for COs and POs attainment.

a.ii. Score ≥ 40% but < 50% → unachieved and in the developing stage and require additional care for the attainment of COs and POs.

b. Score ≥ 50% → achieved

b.i. Score ≥ 50% but < 60% → marginally achieved

b.ii. Score ≥ 60% but < 70% → achieved but need improvements in knowledge and skills.

b.iii. Score ≥ 70% but < 80% → achieved with very good status but still need improvements in a few areas of knowledge and skills.

b.iv. Score ≥ 80% → achieved with an excellent rank

F. Data Collection

Data of CO and PO assessments were collected from the semiconductor device course offered in the Fall 2019 Semester. Since the EEE Department started to implement the OBE-based curriculum from the Spring 2019 Semester thus to practice the OBE method, some courses of the old curriculum were also used to calculate the CO-PO attainment to check the method's validity. Semiconductor device course is usually offered in the third year's second semester. In the Fall 2019 Semester, 34 students of the old curriculum took this course. We used all the direct assessment data as per the assessment plan of Table 2 for the CO calculation and hence its contribution towards PO. No indirect assessment tool was used.

V. Data, Analysis, and Discussions

A. CO-PO Evaluation

Tables 5 and 6 summarize the attainment status of the course and program outcomes respectively in terms of the number of students for CO and PO. Tables 5 and 6 show the required engineering knowledge by gathering information on semiconductor device physics, materials, equations, laws, and theorems, etc. It is observed that the minimum satisfaction level was achieved by all the 24 students who participated in the class. Since it is above the benchmark level (minimum 50%) set by the program hence we can infer that the course and program outcomes were accomplished by the students through the semiconductor device course. The fact that all students could achieve the entire COs and hence POs is due to the special care taken by the course teacher as this course was an experimental course for the EEE department.

Based on assessment data, two figures have been plotted and are presented in Figures 1 and 2 to reveal the CO and PO attainment. Since the attainment benchmark was fixed at 50% for this course, it is observed that all the students could achieve all COs and hence could contribute towards their respective POs from this course. However, it needs further refinement.

Table 5: Number of students achieving the performance levels for all COs of the semiconductor device course of the EEE Department at SEU

Course Outcome	Excellent	Very Good	Good	Satisfactory	Developing	Un-satisfactory
CO1	12	10	2	0	0	0
CO2	11	8	5	0	0	0
CO3	15	5	3	1	0	0
CO4	14	6	3	1	0	0
CO5	13	9	1	1	0	0

Table 6: Number of students achieving the performance levels for various POs through the semiconductor device course only at the EEE Department

Course Outcome	Excellent	Very Good	Good	Satisfactory	Developing	Un-satisfactory
PO1	14	7	3	0	0	0
PO2	15	5	3	1	0	0
PO4	12	9	3	0	0	0

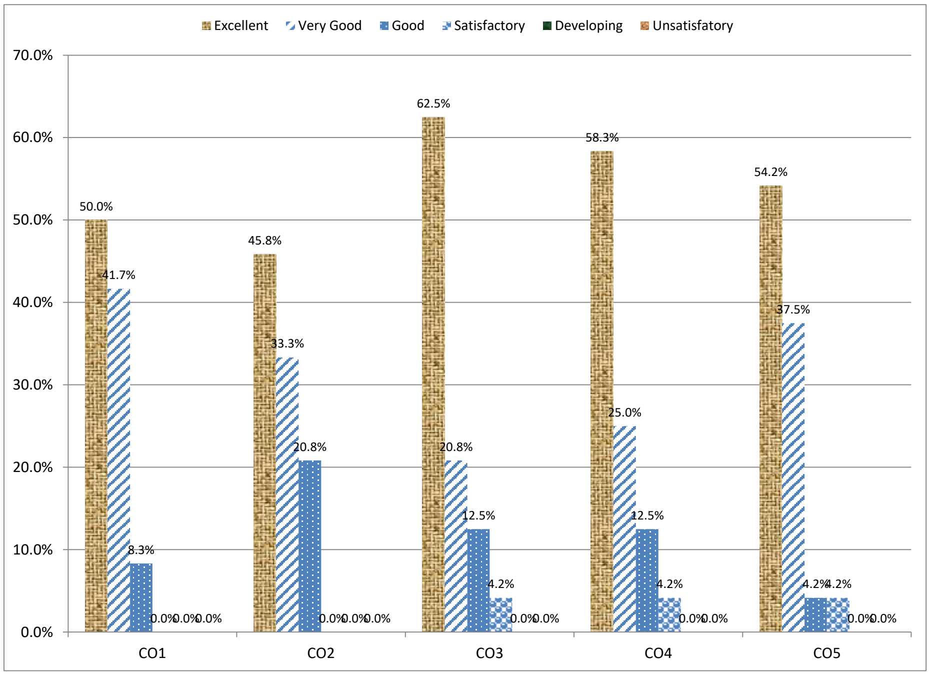

Figure 1: Summary of CO attainment chart

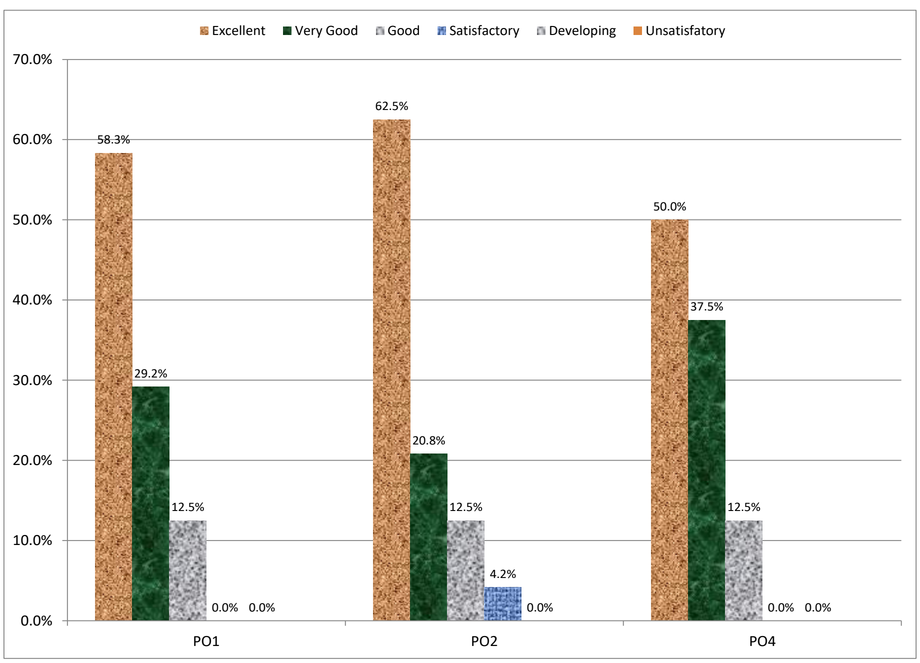

Figure 2: Summary of PO attainment chart

B. Suggestions for Improvement

To improve the attainment levels further, a list of possible but operative measures has been prepared. Of them, most of these measures may be initiated by the individual faculty member assigned for a particular course for continuous quality improvement of an individual student or sometimes for the content modernization of that course. However, an individual faculty member is not usually limited to the suggested measures, that is, there is scope for improvisation in one or more corrective practices to assist the students to improve their attainment status. A few suggested curative actions deemed fit for semiconductor device course are stated as follows:

a. Giving more home works and assignments to the students on numerical problems and derivations of semiconductor devices;
b. Engaging students in the class with more individual and group works to achieve a related CO of semiconductor device course;
c. Increasing time for tutorial classes for the weaker students if developments are needed;
d. Following sufficient number of text and reference books to teach the semiconductor device course;
e. Adopting an appropriate teaching-learning strategy to address issues of the lower number of CO attainment;
f. Designing the lecture slides and notes to make them fathomable to the students;
g. Showing real-life device design problems and using practical or experimental data to solve the numerical problems based on semiconductor device physics to develop students' interests in the course;
h. Involving students with research works on physics-based semiconductor device design, modeling, and simulation.

The EEE Department has one expert faculty member to conduct research works on physics-based semiconductor device design, modeling, and simulation. Therefore, more senior faculty members need to be recruited to carry on this work and also to prepare documentation of all actions of CO-PO achievement of semiconductor device course after the end of a particular semester. If any significant improvements on the achievement levels of CO-PO are found as a result of the above curative processes suggested by the course teacher of the previous semester then those are continued when the semiconductor device course is offered to the students in the subsequent semester.

VI. Conclusions

This paper reports a simple method to assess and evaluate the course outcomes (COs) of the semiconductor device course and hence its contribution towards three program outcomes (POs). This method is utilized as a part of the accreditation process of BSc in EEE program through its OBE curriculum and teaching-learning procedures. This simple model depends on several direct assessment tools to figure out the CO attainment level.

Several performance indicators are developed to determine the cognitive knowledge of the students at the point of their successful completion of the semiconductor device course.

The evaluation of the course outcomes should be done by the concerned course teacher through an appropriate assessment plan. To achieve/attain the course outcomes through the OBE process, the questions should be set at the higher levels of the cognitive domain (that is, from *Apply* to *Create* levels). Therefore, the question-setting strategies have also been described. On the whole, the assessment and evaluation data and recommendations can effectively be utilized by the university management and the concerned academic program leader for the continuous improvement of the program in terms of quality and future student intake quantity by developing strategic frameworks for the viable growth of the program and hence the university. Not only that, it will provide the EEE graduates of SEU with better pathways for their future career build-up and thus contribute to the national development.

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