Outcome-Based Education: A Learner-Centric Pedagogical Framework with Case Studies in Digital Communication and Signal Processing Courses

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***Abstract*— Outcome-based education (OBE) is the buzzword these days in the education field which boosts students' creativity through their active engagement in learning course contents. Their participatory learning in the OBE model is well supported by making them aware of learning goals and course outcomes. Due to this, the students develop themselves nicely in their working surroundings along with peers. This helps develop their interpersonal skills along with improving academic performance. This paper primarily outlines the implementation of a few key standards of OBE in teaching-learning of two fundamental courses in Electronics and Telecommunication Engineering. It then covers how OBE, and its consequences demand paradigm shifts in instructional design and evaluation practices. The discussion on OBE for courses on Digital Communication and Digital Signal Processing is explored with Program Outcomes (POs), Program-Specific Outcomes (PSOs), and Course Outcomes (COs). Analysis of PO and CO attainment for these two courses reflects the importance of the OBE framework. The inclusion of engineering pedagogy and active learning strategies in this framework leads to enhancing students' creativity leading to their growth in their professional careers.**

***Keywords*— Outcome-based evaluation (OBE), Course Outcomes (COs), Program Outcomes (POs), Program-Specific Outcomes (PSOs), Performance Indicators (PIs)**

***JEET Category*—Research, Practice**

I. INTRODUCTION

OUTCOME-BASED education (OBE) is an educational model that sets each aspect of an educational system around goals (outcomes). It is a process that involves the reorganization of curriculum, assessment, and practices in education to reflect the achievement of higher-order learning and mastery rather than the accumulation of course credits. OBE is a student-centered instruction model that focuses on measuring student performance through outcomes. OBE is about preparing students for life, along with getting them ready for employment. It is based on concepts, clarity of focus involving curriculum design, instructional delivery, assessment in line with the expected outcomes, expanded opportunity i.e., ways and number of times students get a chance to learn and demonstrate. Outcome-based methods have been adopted in education systems around the world. In an international effort to accept OBE, the Washington Accord was created in 1989. The Washington Accord countries recognize undergraduate engineering degrees that were obtained using OBE methods.

Engineering Education in India have been changing to align with the OBE model. Accreditation agencies like NAAC and NBA are promoting and setting up the frameworks to support this shift in engineering education to enhance the quality of education and to make the students globally competitive. The OBE approach has become one of the primary components for quality enhancement, sustainability, and accreditation across the globe, as desired by the statutory bodies.

II. OBE FRAMEWORK

As quoted by Covey (2004), "To begin with the end in mind means to start with a clear understanding of your destination. It means to know where you're going so that you better understand where you are now so that the steps you take are always in the right direction." It is rightly applicable to the outcome-based education and a teaching-learning processes under OBE.

Fig. 1 indicates the OBE strategy. It begins with Institute Vision and Institute Mission. "The vision statement is a concise articulation of what the institute stands for and what is its ultimate purpose. The mission statement is closely linked to the vision and provides clear and more detailed direction for the present and the future" (Covey, 2004). Department Vision and Mission statements are aligned with institute Vision and Mission.

After Vision and Mission, Program Education Objectives (PEOs) are required to be set for effective implementation of OBE. Objectives represent a "wish-list" that may not be directly assessed.

An OBE framework shown in Fig. 2 provides further detailing about each element in OBE. The curriculum, instruction and assessment are in principle need to be planned such that the specified broad objectives (in long-term) and outcomes as near short-term goals are achieved viably.

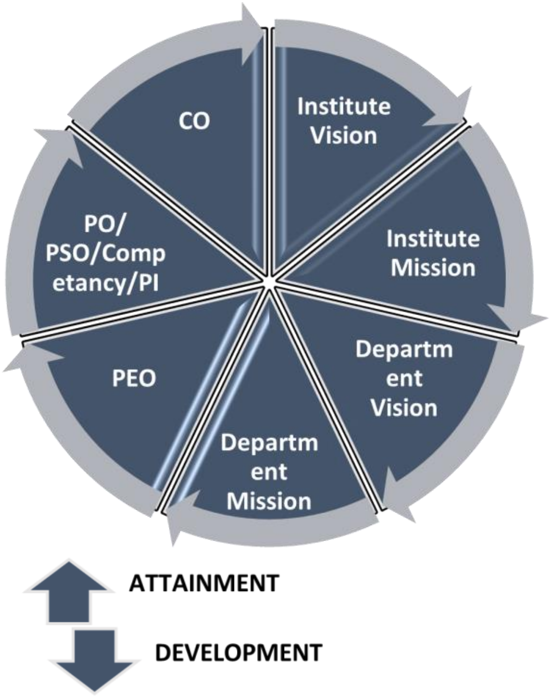


Fig. 1. OBE strategy

The PEOs are designed with inputs from Internal Stakeholders – Students, Faculty, and staff, and External Stakeholders including Employers, Industry, Academicians, Parents, and Alumni.

Then comes the Curriculum Planning and Instruction Planning. Curriculum planning is an important first step towards implementing OBE. This involves writing Course Outcomes (COs), mapping COs to Program Outcomes (POs)/Program Specific Outcomes (PSOs)/Competency/ Performance Indicators (PIs), and planning assessments to measure performance in COs. The instructors need to take a "top-down" approach where mappings between COs to POs/PSOs are first established they are also required to develop a strategy to gather COs performance data and use it for quantifying performance at the POs/PSOs level.

The mapping of outcomes to PIs is essential since OBE is

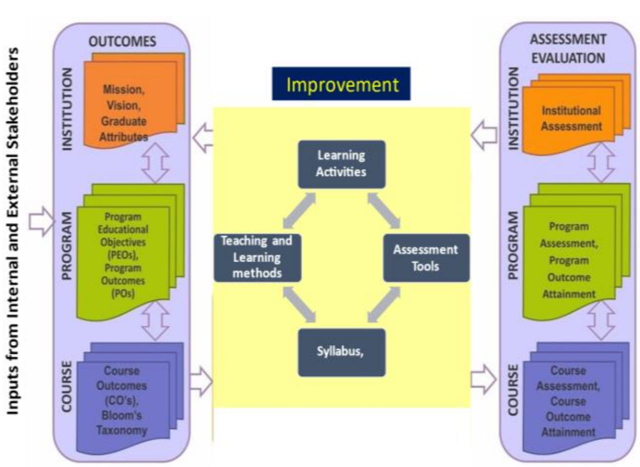


Fig. 2. OBE Framework

outcome-based. It is important to have a mechanism that can determine the extent of the success of the educational process in ensuring the attainment of the POs/PSOs. To assess the attainment of the POs, one common approach is to have measurable PIs that are evaluated to measure the attainment of POs. PIs are comparable to the concept of "leading indicators" used in economics, which is used to "identify specific characteristics of the economy that are significant indicators of the current state and predict future trends (ABET, 2016)."

Rao (2013) deliberated learning outcomes, that came out of the Organization for Economic Co-operation and Development (OECD) project. These are classified into five categories as- "General Learning outcomes, Basic Engineering Sciences, Engineering Analysis, Engineering Design and engineering Practice". The skills set of engineers required by the employers can be characterized by skills factors like employability, communication, and professional skills, covering cognitive skills related to the engineering professions. These skills build ability to apply engineering knowledge, design and conduct the experiments, analyzing data, and interpreting the results.

Sahasrabudhe, A. (2015) emphasized significance of OBE in NBA accreditation. One of the important deliberations in this document is, "OBE is directing teaching and other academic processes to facilitate students to do what they are expected to do". Thus, it is realized that if the teaching-learning process is framed using active learning techniques, students' participation will increase where the teacher facilitates and ensures that the learning objectives are fulfilled.

A global international perspective on OBE accreditation standards, practices, and attitudes as a geographically dispersed set of academics from United Kingdom, United States of America, Malaysia, Saudi Arabia is presented by Qadir (2020). OBE context ties Bloom-Anderson (Anderson & Krathwohl, 2001; Bloom et al., 1956) taxonomy of learning for curriculum design and to uphold the quality of teaching and learning. It establishes a connect between the course outcomes with the learning outcomes which the students will attain after successful completion (Hager & Holland, 2006) of the course and further the Programme.

Significance of OBE in higher education institutions to enhance the quality of teaching learning and its articulation through the curriculum alignment with the requirements of OBE is outlined in (Gurukkal, 2020).

Masni-Azian et al., (2014) and N. Guruprasad, (2015) discussed CO and PO attainment in the Product design and development and Data structures courses as case studies. Whether the implementation of OBE has taken place successfully or not can be examined through direct and indirect assessment and CO-PO-PSO attainment.

III. OBE and Student-centric Learning Approach

OBE promotes a student-centric learning approach. In OBE framework, a teacher's role very crucial, it is shown in Figure 3. A teacher is involved in various activities such as plan, develop and implement an outcome-based curriculum. In order

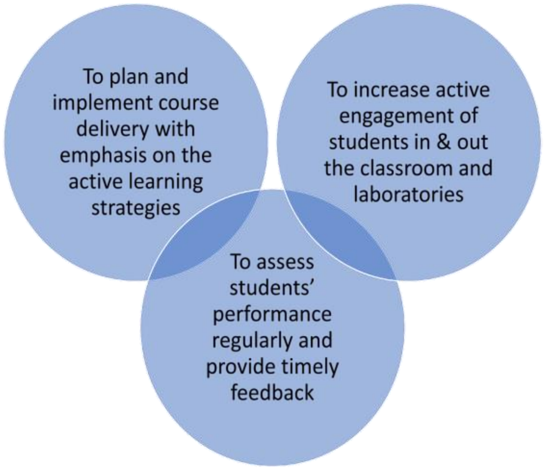


Fig. 3. Teacher's role in student-centric learning

to increase the engagement of students involve them into different active learning techniques. Simultaneously assess their performance regularly and give them timely feedback for improvement.

The overall curriculum of E&TC program for undergraduate students is preparing students for strengthening their fundamental knowledge and skills in the form of core courses such as Communication, Signal Processing, VLSI and Embedded Systems and advanced courses as program electives. The course outcomes for all courses are mapped with the program outcomes. At the end of course students' learning is evaluated based on their continuous internal evaluation (CIE) and semester end evaluation (SEE). Further the CO-PO-PSO attainment is calculated to analyze students' CO-wise attainment and its mapping to PO and PSO. In this paper a case study of two core courses under the OBE framework is explained in detail in the next section.

IV. Case Study of Implementing OBE in Engineering Courses

With the process of the OBE framework, a case study is presented for two engineering courses in Third Year 5th semester Digital Communication (DC) and Third Year 6th semester Digital Signal Processing (DSP).

The COs are drafted considering satisfying the four checks as given in Table I.

TABLE I
4-POINT CHECK FOR DRAFTING CO QUESTIONS

Check	Question
1	"Are they written using action verbs to specify definite, observable behaviors?"
2	"Does the language describe students' rather than teachers' behavior?"
3	"Do the outcomes clearly describe and define the expected abilities, knowledge, values, and attitude of students of the course?"
4	"Is it possible to collect accurate and reliable data for each outcome?"

The mapping of Course Outcome (COs) with Blooms Level, Program Outcome POs, Program Specific Outcomes POSs, Competence, and Performance Indicators PIs are indicated. The AICTE examination reform policy interprets PO, Competence, and Performance Indicators PIs (AICTE Examination Reforms Policy, India).

The PSOs of the ETC department referred are as-

Students will be able to:

1. *"Develop Electronic Systems using knowledge of Signal processing, Embedded, VLSI, Automation, and Artificial Intelligence domains."*

2. *"Analyze, Design, and Build Mobile Communication, Microwave and Fiber Optic Communication Systems."*

The CO attainment of students is measured for three academic years 2018-19, 2019-20, and 2020-21. The IONCUDOS software is used to measure the outcome across these years.

The CO attainment has improved by incorporating active learner-centric pedagogies like project-based learning, flipped classroom, Think-Pair-Share, Simulation-based learning, assessment with ICT tools - Crossword, word search, MCQs after completion of each unit.

A. Course 1: Digital Communication

CO statements of Digital Communication course are as follows:

- **CO1**: Describe waveform coding technique and evaluate bitrate, bandwidth and signal-to-noise ratio
- **CO2**: Describe and interpret data formats, multiplexing, synchronization and Inter-symbol Interference for reliable baseband Transmission
- **CO3**: Classify random processes in terms of mean, variance and autocorrelation
- **CO4**: Describe and analyze bandpass modulation techniques along with their performance measure - bit period, bandwidth, signal space representation and Euclidian distance
- **CO5**: Analyze the error probability of digital modulation techniques with matched filter and correlator
- **CO6:** Illustrate the concept of Direct sequence and

TABLE II
DC COURSE CO-RBL-PO-PSO-PI MAPPING

COURSE OUTCOMES	REVISED BLOOMS LEVEL	PO	PSO	COMPETENCE	PERFORI INDICAT
CO - 1	L2, L3	PO1	PSO2	1.4	1.4.1
CO - 2	L2, L3	PO1, PO2	PSO2	1.4	1.4.1, 2.:
CO - 3	L3, L4	PO1	PSO2	1.4	1.4.1
CO - 4	L2, L3, L4	PO1, PO2	PSO2	1.4	1.4.1
CO - 5	L3, L4	PO1, PO2	PSO2	2.2	2.2.2
CO - 6	L3, L4	PO1, PO2, PO3	PSO2	1.4	1.4.1

Frequency hopped spread spectrum

Table II shows mapping COs to Blooms Level, Program Outcomes, Program Specific Outcomes, Competence and Performance Indicators.

Fig. 4 shows the CO attainment for the 3 years based on the direct assessment of students based on their performance.

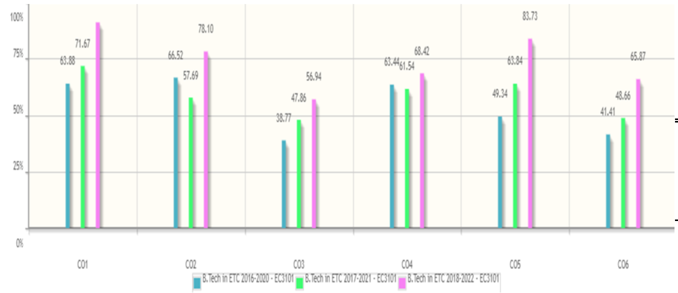


Fig. 4. CO Attainment for Digital Communication academic year 2018-19, 2019-20 and 2020-21

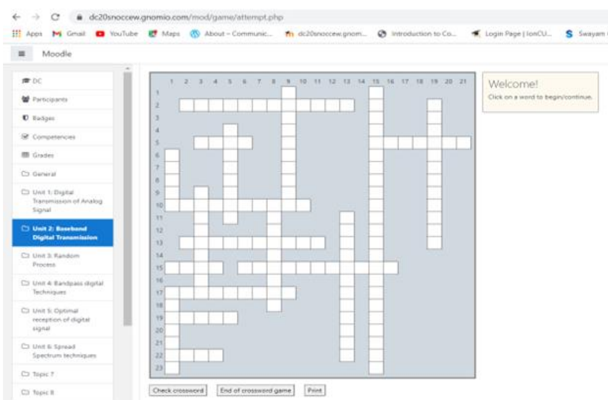


Fig. 5. Crossword

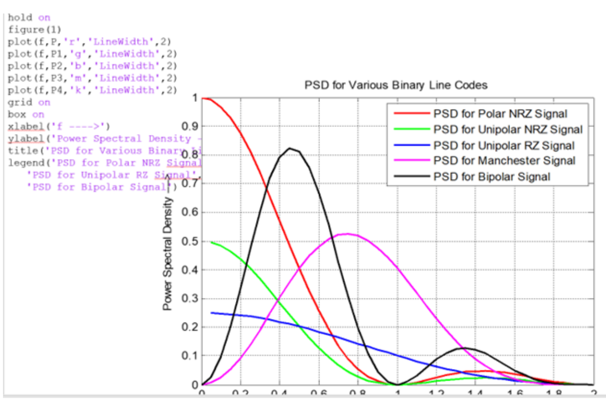
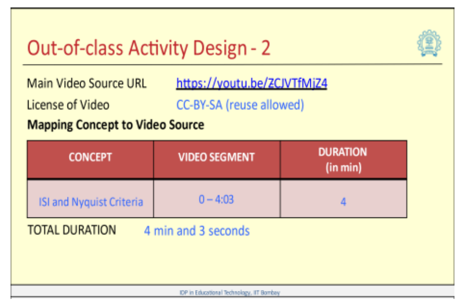


Fig. 6. Simulation Assignment

Fig. 5 and 6 shows an example of a crossword and simulation-based assignment used in the course of DC for teaching learning process.

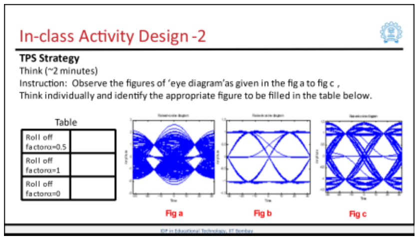
The flipped classroom model, often known as "inverted learning," is a pedagogical approach in which the teacher provides students with digital materials outside of the classroom using an LMS platform, followed by an outside-of-class activity Active, group-based, and interactive problem-solving exercises and consolidation techniques are used in class. Thus, students are more active in the class. For both Digital Communication and Digital Signal Processing courses a flipped classroom activity is implemented. The implementation steps of flipped classroom are discussed in Table III and IV. In both tables starting from topic selection till step-by-step implementation along with an example is given.

TABLE III
FLIPPED CLASSROOM EXAMPLE IN DIGITAL COMMUNICATION

Steps implemented during flipped classroom	Course: Digital Communication
Step I: Plan *Decide the topic you want to flip.*	• Topic: Intersymbol interference (ISI)
Step II: Invert classroom teaching	• Instead of teaching this Topic in-person, prepare and share a video. • The video is recorded using Active presenter tool and shared via Google classroom.
Step III: Design OUT-CLASS ACTIVITY *Students solve questionary (lower cognitive level) based on shared video/ material.*	

Learning Objective	Assessment Strategy	Expected duration (in min)
Understand the Intersymbol interference and Nyquist criteria	1. Sampling Theorem in time and frequency domain 2. Study of Aliasing effect 3. Draw the sampled signal for fs> 2fm, fs<2fm and fs=2fm.	15 min

Step IV: Design IN-CLASS ACTIVITY
Students perform a with higher cognitive level.



Step IV: Design IN-CLASS ACTIVITY
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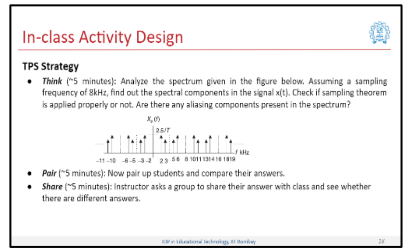
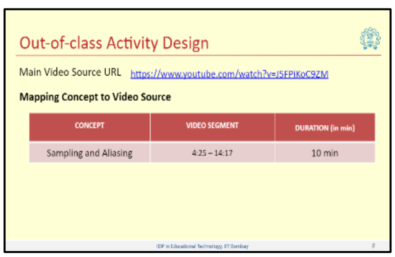


TABLE IV
FLIPPED CLASSROOM EXAMPLE IN DIGITAL SIGNAL PROCESSING

Steps implemented during flipped classroom	Course: Digital Signal Processing
Step I: Plan *Decide the topic you want to flip.*	• Topic: Sampling and Aliasing
Step II: Invert classroom teaching	• Instead of teaching this Topic in-person, prepare and share a video. • The video is recorded using Active presenter tool and shared via Google classroom.

Step III: Design OUT-CLASS ACTIVITY
Students solve questionary (lower cognitive level) based on shared video/ material.



Learning Objective	Assessment Strategy	Expected duration (in min)
Explain how to convert continuous time signal into discrete time signal and the aliasing effect	1.Given x(t)=2cos(1000∏t), obtain DT signal x(n) 2. The effect caused by under sampling is called.... a) smoothing b) sharpening c) summation d) aliasing	8 Minutes

B. Course 2: Digital Signal Processing

Course Outcomes for the Digital Signal Processing (DSP) course are as follows:

- **CO1**: Explain the basic building blocks of a DSP system.
- **CO2**: Apply sampling theorem and convert signals from continuous time (CT) to discrete time (DT).
- **CO3**: Apply transformation techniques such as DFT, FFT, Z-Transform on DT signals.

TABLE V
DSP COURSE CO-RBL-PO-PSO-PI MAPPING

COURSE OUTCOMES	REVISED BLOOMS LEVEL	PO	PSO	COMPETENCE	PERFORMANCE INDICATORS
CO - 1	L2, L6	PO1	PSO1	1.4	1.4.1
CO - 2	L3	PO1, PO2	PSO1, PSO2	1.4, 2.2	1.4.1, 2.2.1
CO - 3	L3	PO1, PO2	PSO1, PSO2	1.1, 2.2	1.1.2, 2.2.1
CO - 4	L4	PO1, PO2	PSO1	1.4, 2.3	1.4.1, 2.3.3
CO - 5	L3, L4	PO1, PO2,	PSO1, PSO2	1.1, 2.3, 3.1	1.1.2, 2.3.3, 3.1.3
CO - 6	L2, L5	PO3	PSO1, PSO2	1.4, 2.1	1.4.1, 2.1.1

- **CO4**: Analyze the spectral representation of the signals.
- **CO5**: Design and build Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) digital filters.
- **CO6**: Explain the real-life applications of Digital Signal Processing.

Table V indicates the CO to PO, PSO, RBL mapping and competency levels with respect to the POs and PI indicators. Mapping as shown in Table 2 and 3 is referred at the time of drafting the questions for CIE and ESE assessment.

Fig. 7 shows the course assessment strategy and the active learning techniques implemented in the course. Techniques such as case study presentations, flipped classroom, simulation-based learning, and project-based learning (PBL) are profoundly use in the course delivery. For assessment purposes MCQs, crosswords, and presentations under PBL activity are considered.

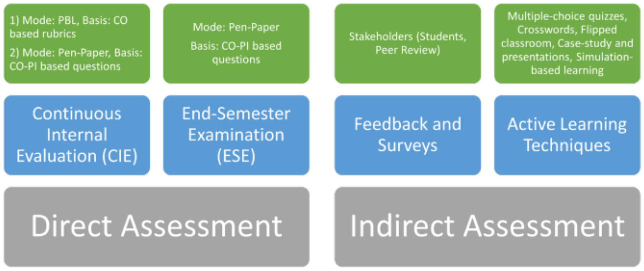


Fig. 7. Course assessment and learning activities

The calculation for CO attainment based on direct assessment is done as follows:

- For each CO, target is set as 60%
- Attainment Level 3: If 60% students achieve marks, >=60%
- Attainment Level 2: If students achieve marks, 50-59%
- Attainment Level 1: If students achieve marks, 40-49%

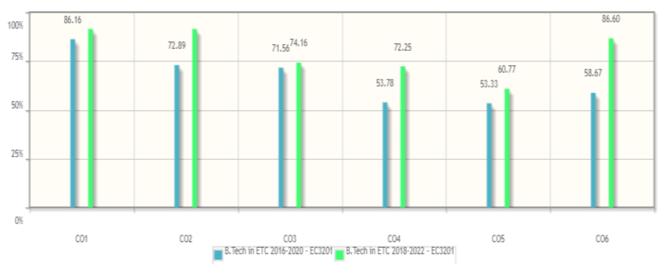


Fig. 8. CO attainment with direct assessment in DSP course for Year 2018-19 (in blue) and 2020-21 (in green)

A plot in Fig. 8 indicates that the CO attainment has been improved in Year 2020-21 where the Project-based Learning (PBL) is included in the teaching and evaluation of the course. It helped developing many skills and knowledge and reflected in terms of students' satisfaction level of CO attainment.

Fig. 9 and Fig. 10 illustrate the students' feedback collected on course survey as an indirect assessment for each CO. The total attainment is considered as the sum of 95% of direct attainment and 5% of indirect assessment.

Fig. 9. Students' responses on Course Outcomes Evaluation

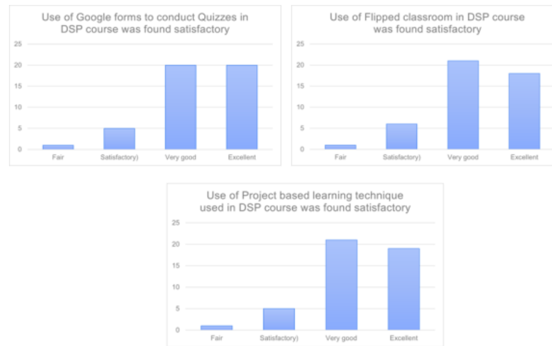


Fig. 10. Students' responses on use of active learning techniques

IV. CONCLUSION

In this paper an OBE framework and its successful dissemination for the two E&TC engineering courses Digital Communication and Digital Signal Processing are presented. OBE framework and active learning strategies together provides wide range of learning opportunities and experiences to students. Hence the student's engagement in learning is increased which gets reflected in improving the CO attainment. OBE and its implementation necessitate a paradigm shift in instructional design and evaluation practices. It can be planned well by the course teacher while drafting the curriculum and implemented during course delivery and assessment processes.

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