Course Outcomes, Specific Performance Indicators, Rubrics and Continuous Quality Improvement in a Core Undergraduate Electrical Engineering Course

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Abstract

This paper presents the course outcomes, specific performance indicators, rubrics and teaching / learning methodologies / strategies adopted related to the 'Signals and Systems' course taught to the bachelor's students of Electrical Engineering. It will discuss the mapping of course outcomes, and specific performance indicators with the ABET Student Outcomes, the rubrics used for the assessments and evaluations related to each specific performance indicator and how Continuous Quality Improvement (CQI) is implemented in the course of 'Signal and Systems' by modifying the course teaching / learning strategy in course delivery related to the failing course outcomes. And the impact of these teaching strategies on the performance of students is discussed in detail. And conclusions are drawn based on the teaching and learning methodologies adopted for improvement.

1. Introduction

Over a very long period, the main teaching and learning strategy has been the traditional Content-Based Education (CBE) which is a teacher-centred approach and mainly focuses on contents using textbooks and considers syllabus as rigid & non-negotiable. This approach sees students as passive learners, just listening and trying to absorb the given information. This approach provides such an environment to the students having very less focus on whether the students have ever learned the given material. The approach makes students exam oriented and CGPA driven. It emphasizes on what the teacher hopes to achieve. And the graduates produced through this strategy are not well-prepared for the requirements of the job market. It emphasizes very less focus on soft skills such as communication, interpersonal-, and analytical skills, etc. needed for different jobs.

Outcome-Based Education (OBE) is a paradigm shift in education. It is not what the teacher has taught; it's what the student has learned. It focuses on the desired end results and curriculum instruction and assessments are taken according to the exit outcomes It is a student-centered approach creating more calmness and composure between the teacher and the students [1-2]. Even though the teacher still has the final authority, but he/she is acting more as a facilitator, guiding the students and facilitating them in their learning process. It has more directed and coherent curriculum. OBE includes the modifications and amendments in curriculum, assessments and teaching strategies for reflecting the achievements of high order learnings and mastering it rather than just accumulating the course credits. This approach sees students as active learners. It enables the students to complete a task with flexible time frames. The assessment is a continuous process which involves the curriculum, instruction and assessment be taken according to the exit outcomes. Through OBE, the graduates will be more well-rounded graduates which make them more relevant to industry and other stakeholders. And one of the very significant benefits of OBE is that it has a Continuous Quality Improvement (CQI) in place which ensures the constant review of teaching and learning strategies based on outcomes. It connects the Vision and Mission of the institution, Program Educational Objectives (PEO), Students Outcomes (SO), and Course Outcomes (CO) as shown in the Figure 1.

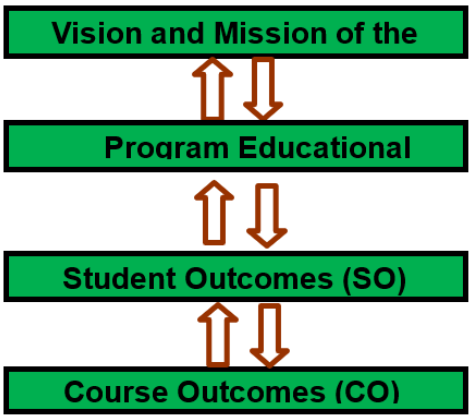

Figure 1. A Model Hierarchy of Outcomes

PEOs are comprehensive declarations that outline the expectations of the graduates to achieve within some certain years after the completion of the program. Program educational objectives depends on the requirements of the program's aspects and components [3-4]. Student Outcomes (SO) mentions the expectations for the students to learn and are able to perform heretofore the completion of that specific

program. It describes what students should know (cognitive), think (attitudinal) or do (behavioural) when they have completed a program. Each program needs to have documented SOs for making the graduates of achieving program educational objectives. We have applied ABET Student Outcomes which are 11 outcomes in total (SO-1 to SO-11) [5-6].

The Course Outcomes (CO) are soft or technical skills which every student needs to attain before completing that specific course [7]. The COs should be made in such a way that they are measurable and can be linked to the SOs and PEOs [8]. The Performance Indicators (PI) are specific, measurable statements identifying the performance(s) required to meet the outcomes, confirmable through evidence. Performance Indicator describes student outcomes in "measurable" terms provide a basis for teaching/learning strategies and data collection. Performance Indicators (PI) are concrete, measurable statements indicating the specific characteristics students need to show for the demonstration of required achievement of the student outcome. The characteristics of PIs include the use of action verbs which highlight the depth to which students need to demonstrate the performance. It is content referent and is free of terms that express the value (e.g. effectively, accurately, completely, etc.). Those express values with a scale and descriptions in the form of a rubric. Assessment is one or more processes that indicate, gather, and prepare data for evaluating the achievement of student outcomes. Evaluation is the process of determining the degree of achievement of desired student outcomes.

For ensuring that the SO and PEO are suitable, employable and in accordance with the job requirements of the modern era, continuous assessment and evaluation of these sets of outcomes needs to be done periodically. Therefore, continuous quality improvement (CQI) is a significant constituent in OBE [7]. The inputs such as the program delivery and assessment methods are modified as per requirement for ensuring that student performances match the desired SO. This needs a systematic approach of measuring SOs attainment from student assessments [9-11].

This paper represents the course learning outcomes, and specific performance indicators related to the course 'Signals and Systems' in the degree plan of Bachelor of Science in Electrical Engineering. And for the implementation of Continuous Quality Improvement (CQI) the modifications performed in teaching and learning strategies/methodologies in the course delivery related to the failing course learning outcomes and discussing the effects of these teaching strategies on the performance of students.

2. Signals and Systems Course

2.1. Course Outcomes (CO)

The measurable course outcomes developed for and used in the course 'Signals and Systems' are the following with the action verbs used are highlighted in bold:

1. Perform the transformation of the independent variable (amplitude and time domain) operations on Continuous-Time (CT) and Discrete-Time (DT) signals.
2. Draw the continuous-time and discrete-time complex exponential and sinusoidal signals.
3. Classify systems in terms of continuous-time or discrete-time, linear or non-linear, time-invariant or time-varying, and causal or noncausal.
4. Determine LTI system response by applying the convolution sum and convolution integral techniques.
5. Evaluate the properties of Linear Time Invariant (LTI) systems using their impulse response.
6. Characterize LTI systems by representing their differential and difference equations using block diagrams.
7. Apply the Fourier series for analyzing the frequency spectrum of periodic signals.
8. Apply continuous-time and discrete-time Fourier transform for analyzing the frequency spectrum of periodic and aperiodic signals.
9. Conduct research to study and examine the real-life applications of convolution techniques, Fourier series and Fourier transform.
10. Apply Z-transform, inverse Z-Transform and its properties for the analysis of LTI systems.

2.2. Specific Performance Indicators

A big database of measureable specific Performance Indicators (PI) is developed for use in an undergraduate program of Electrical Engineering [12]. The specific PIs are classified in terms of Bloom's 3 learning domains (Cognitive, Affective, Psychomotor) with the respective learning levels. The specific PIs developed and used for the course 'Signals and Systems' for identifying the student performances for obtaining the corresponding CO and SOs are as follows.

[CO-1_SO-1_PI-59] Cognitive: Applying Perform various amplitude domain operations such as amplitude Scaling, multiplication, addition, subtraction and time domain operations such as Time shifting, Time reversal and Time scaling etc. on continuous-time and discrete-time signals.

[CO-2_SO-1_PI-80] Psychomotor: Complex overt response Represent diagrammatically the complex exponential and sinusoidal continuous- and discrete-

time signals; Properly label the diagram; find the fundamental period.
[CO-3_SO-1_PI-58] Cognitive: Understanding Explain or justify the classifications of system and/or signals as being continuous-time or discrete-time, linear or non-linear, time varying or time-invariant, periodic or aperiodic, stable or unstable, and causal or non-causal.
[CO-4_SO-11_PI-40] Cognitive: Analyzing Determine LTI system response by performing convolution sum and convolution integral techniques based upon the type of input signal.
[CO-5_SO-11_PI-38] Cognitive: Evaluating Analyze LTI systems based on their impulse response; find the various characteristics of LTI systems such as causal/non-causal, memory less/with memory, stability etc.

[CO-6_SO-11_PI-37] Cognitive: Analyzing Use given differential (continuous time) and difference equations (discrete time) to obtain the block diagram representation of a LTI system; solve these equations using given parameters to find the explicit relationship between input and output.

[CO-7_SO-11_PI-53] Cognitive: Analyzing Analyze the frequency spectrum of periodic CT/DT signals by applying Fourier series and obtain the coefficients of constituent signals; or use given coefficients of harmonically related constituent basic signals to reconstruct the periodic signal.

[CO-8_SO-11_PI-54] Cognitive: Analyzing Analyze the frequency spectrum of periodic and aperiodic CT/DT signals by applying Fourier transform; convert given signal in frequency domain to time domain using inverse Fourier transform.

[CO-9_SO-9_PI-12] Affective: Internalizing values Perform literature survey on given engineering problem/application; Locate requested technical information using the internet, company provided or external resources; provide professional research citations for technical information relevant to the topic of research; assimilate technical information in an organized format for presenting the practicality of application of engineering solutions to existing problems.

[CO-10_SO-11_PI-61] Cognitive: Analyzing Analyze LTI systems by applying Z-transform, inverse Z-transform and its properties; obtain Z-transform of the given signal; draw the region of convergence; find its poles and zeros; or use inverse Z-transform to obtain the time domain signal.

Where CO-X is the corresponding course outcome of the course, SO-X is the corresponding ABET Student Outcome mapped to the CO and PI-XX is specific performance indicator with the related number from the data base.

A pie chart showing the corresponding percentages of the revised Bloom's three learning domains covered in this course is shown in Figure 2.

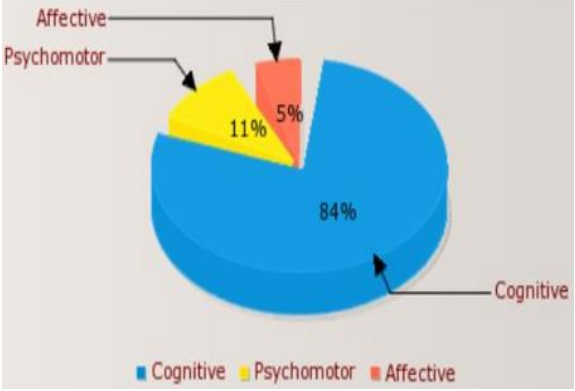

Figure 2. Percentage distribution of assessment activities in Bloom's three learning domains

It is evident that it mainly covers Cognitive domain (84%) with a small fraction of Affective and Psychomotor domains. The learning levels in each learning domain are categorised into three skills levels i.e. Elementary, Intermediate and Mastery [13] (see Table 1). The percentage skill levels covered by this course are shown in Figure 3. It is clear that it is covering mainly the 'Intermediate skills' i.e. 68%, followed by 'Advanced Skills' of 21% and 'Elementary Skills' of 11%.

Table 1. Three-levels skills categorization of revised Bloom's three learning domains [13]

Skills Level	Cognitive Domain	Affective Domain	Psychomotor Domain
Elementary	1. Knowledge 2. Comprehension	1. Receiving phenomena 2. Responding to phenomena	1. Perception 2. Set 3. Guided response
Intermediate	3. Application 4. Analysis	3. Valuing	4. Mechanism 5. Complex overt response
Advanced	5. Evaluation 6. Creation	4. Organizing values into problems 5. Internalizing	6. Adaptation 7. Origination

2.2 Rubrics

2.2.1. Rubrics for [CO-1_SO-1_PI-59]

Course Outcome	CO-1: Perform the transformation of the independent variable (amplitude and time domain) operations on Continuous-Time (CT) and Discrete-Time (DT) signals.
ABET Student Outcome	SO-1: an ability to apply knowledge of mathematics, science, and engineering
Performance Indicator	P1-59: Perform various amplitude domain operations such as amplitude Scaling, multiplication, addition, subtraction and time domain operations such as Time shifting, Time reversal and Time scaling etc. on continuous-time and discrete-time signals.
Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. Write all the mathematical steps correctly of performing the required amplitude/time domain operations on the given continuous time and/or discrete time signals 2. The output signal is drawn correctly and properly labelled with respect to amplitude and time-axis.

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
50%	Accurately write all mathematical steps for performing required amplitude/time domain operations on the given continuous time and/or discrete time signals	Accurately write all mathematical steps for performing required amplitude/time domain operations on the given continuous time and/or discrete time signals	Minor errors to accurately write all mathematical steps for performing required amplitude/time domain operations on the given continuous time and/or discrete time signals	Major errors to accurately write all mathematical steps for performing required amplitude/time domain operations on the given continuous time and/or discrete time signals
50%	Accurately draw properly labelled output signal with respect to amplitude and time-axis.	Minor errors to accurately draw properly labelled output signal with respect to amplitude and time-axis.	Minor errors to accurately draw properly labelled output signal with respect to amplitude and time-axis.	Major errors to accurately draw properly labelled output signal with respect to amplitude and time-axis.

2.2.2. Rubrics for [CO-2_SO-1_PI-80]

Course Outcome	CO-2: Draw the continuous-time and discrete-time complex exponential and sinusoidal signals.
ABET Student Outcome	SO-1: an ability to apply knowledge of mathematics, science, and engineering
Performance Indicator	P1-80: Represent diagrammatically the complex exponential and sinusoidal continuous- and discrete-time signals; Properly label the diagram; find the fundamental period.
Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. Write all the mathematical steps correctly of finding the amplitude and time-axis values for the given complex exponential or sinusoidal form of continuous-time and/or discrete-time signals. 2. The output signal is drawn correctly and properly labelled with respect to amplitude and time-axis.

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)

40%	Accurately write all the mathematical steps of finding the amplitude and time-axis values for the given complex exponential or sinusoidal form of continuous-time and/or discrete-time signals.	Accurately write all the mathematical steps of finding the amplitude and time-axis values for the given complex exponential or sinusoidal form of continuous-time and/or discrete-time signals.	Minor errors to accurately write all the mathematical steps of finding the amplitude and time-axis values for the given complex exponential or sinusoidal form of continuous-time and/or discrete-time signals.	Major errors to accurately write all the mathematical steps of finding the amplitude and time-axis values for the given complex exponential or sinusoidal form of continuous-time and/or discrete-time signals.
60%	Accurately draw properly labelled output signal with respect to amplitude and time-axis.	Minor errors to accurately draw properly labelled output signal with respect to amplitude and time-axis.	Minor errors to accurately draw properly labelled output signal with respect to amplitude and time-axis.	Major errors to accurately draw properly labelled output signal with respect to amplitude and time-axis.

2.2.3. Rubrics for [CO-3_SO-1_PI-58]

Course Outcome	CO-3: Classify systems in terms of continuous-time or discrete-time, linear or non-linear, time-invariant or time-varying, and causal or noncausal.
ABET Student Outcome	SO-1: an ability to apply knowledge of mathematics, science, and engineering
Performance Indicator	P1-58: Explain or justify the classifications of system and/or signals as being continuous-time or discrete-time, linear or non-linear, time varying or time-invariant, periodic or aperiodic, stable or unstable, and causal or non-causal.
Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. Identify the characteristics of the given system/signal 2. Based on the characteristics, classify the system/signal as continuous- or discrete-time, linear or nonlinear, time-invariant or time-varying, digital or analog, periodic or aperiodic, deterministic or probabilistic, causal or non-causal and energy or power using logical reasoning and mathematical expressions.

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
40%	Identify all the required characteristics accurately of the given system/signal.	Identify most of the required characteristics accurately of the given system/signal.	Identify some of the required characteristics accurately of the given system/signal.	Unable to identify most of the required characteristics accurately of the given system/signal.
60%	Based on the characteristics, classify the system/signal as continuous- or discrete-time, linear or nonlinear, time-invariant or time-varying, digital or analog, periodic or aperiodic, deterministic or probabilistic, causal or non-causal and	Based on the characteristics, classify the system/signal as continuous- or discrete-time, linear or nonlinear, time-invariant or time-varying, digital or analog, periodic or aperiodic, deterministic or probabilistic, causal or non-causal and	Based on the characteristics, classify the system/signal as continuous- or discrete-time, linear or nonlinear, time-invariant or time-varying, digital or analog, periodic or aperiodic, deterministic or probabilistic, causal or non-causal and energy or power using explanation for logical	Based on the characteristics, unable to properly classify the system/signal as continuous- or discrete-time, linear or nonlinear, time-invariant or time-varying, digital or analog, periodic or aperiodic, deterministic or probabilistic, causal or non-causal and energy

	energy or power using thoroughly explained logical reasoning and mathematical expressions.	energy or power using adequately explained logical reasoning and mathematical expressions.	reasoning and mathematical expressions that contains some errors.	or power using explanation for logical reasoning and mathematical expressions.

2.2.4. Rubrics for [CO-4_SO-11_PI-40]

Course Outcome	CO-4: Determine LTI system response by applying the convolution sum and convolution integral techniques.
ABET Student Outcome	SO-11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
Performance Indicator	P1-40: Determine LTI system response by performing convolution sum and convolution integral techniques based upon the type of input signal.
Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. Draw and properly label the input and impulse response signals presented by the equation in the question. 2. Write all the steps correctly using convolution technique (able to draw correctly all the corresponding input and impulse response signals with proper labelling) to find the corresponding output on all the instants of time where output exists 3. The output signal is drawn correctly and properly labelled with respect to amplitude and time-axis.

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
10%	Draw and properly label the input and impulse response signals presented by the equation in the question.	Draw and properly label the input and impulse response signals presented by the equation in the question.	Draw and properly label the input and impulse response signals presented by the equation in the question.	Unable to draw and properly label the input and impulse response signals presented by the equation in the question.
70%	Write all the steps correctly using convolution technique (able to draw correctly all the corresponding input and impulse response signals with proper labeling) to find the corresponding output on all the instants of time where output exists.	Write majority of the steps correctly using convolution technique (able to draw to draw correctly majority of the corresponding input and impulse response signals in case of convolution Sum) to find the corresponding output at majority of the time instants where output exists.	Write some of the steps correctly using convolution technique (able to draw to correctly only some of the corresponding input and impulse response signals in case of convolution Sum) to find the corresponding output at some instants of the time where output exists.	Unable to write correctly majority of the steps using convolution technique (Unable to draw correctly majority of the corresponding input and impulse response signals in case of convolution Sum) to find the corresponding output at each instant of time where output exists.
20%	The output signal is drawn correctly and properly labelled with respect to amplitude and time-axis.	Majority of the output signal is drawn correctly and properly labelled with respect to amplitude and time-axis.	Some of the output signal is drawn correctly and properly labelled with respect to amplitude and time-axis.	Majority of the output signal is drawn incorrectly and not properly labelled with respect to amplitude and time-axis

2.2.5. Rubrics for [CO-5_SO-11_PI-38]

Course Outcome	CO-5: Analyze LTI systems based on their impulse response; find the various characteristics of LTI systems such as causal/non-causal, memory less/with memory, stability etc.
ABET Student Outcome	SO-11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
Performance Indicator	P1-38: Analyze LTI systems based on their impulse response; find the various characteristics of LTI systems such as causal/non-causal, memory less/with memory, stability etc.
Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. Identify the characteristics of the given impulse response of the system. 2. Based on the characteristics of the impulse response, analyze the LTI system accurately in terms of system with or without memory, Invertible or noninvertible, causal or non-causal, stable or unstable etc using thoroughly explained logical reasoning and mathematical expressions.

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
30%	Accurately Identify all required characteristics of the given impulse response of the system.	Accurately Identify most of the required characteristics of the given impulse response of the system.	Accurately Identify some of the required characteristics of the given impulse response of the system.	Major errors to identify most of the required characteristics of the given impulse response of the system.
70%	Based on the characteristics of the impulse response, classify the LTI system accurately with respect to the system being with or without memory, Invertible or noninvertible, causal or non-causal, stable or unstable etc. using thoroughly explained logical reasoning and mathematical expressions.	Based on the characteristics of the impulse response, classify the LTI system accurately with respect to the system being with or without memory, Invertible or noninvertible, causal or non-causal, stable or unstable etc. using adequately explained logical reasoning and mathematical expressions.	Based on the characteristics of the impulse response, classify the LTI system accurately with respect to the system being with or without memory, Invertible or noninvertible, causal or non-causal, stable or unstable etc. using explanation for logical reasoning and mathematical expressions that contains some errors.	Based on the characteristics of the impulse response, unable to properly classify the LTI system accurately with respect to the system being with or without memory, Invertible or noninvertible, causal or non-causal, stable or unstable etc. using explanation for logical reasoning and mathematical expressions.

2.2.6. Rubrics for [CO-6_SO-11_PI-37]

Course Outcome	CO-6: Characterize LTI systems by representing their differential and difference equations using block diagrams.
ABET Student Outcome	SO-11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
Performance Indicator	P1-37: Use given differential (continuous time) and difference (discrete time) equations to obtain the block diagram representation of an LTI system; solve these equations using given parameters to find the explicit relationship between input and output.

Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. For an LTI system whose Implicit relationship between the inputs and outputs are given by the linear constant-coefficient differential/difference equation, solve it to find the explicit relationship between output and input using recursive/nonrecursive solution. 2. Use given auxiliary conditions to have exact relationship between input and output. 3. And/or draw block diagram of the given LTI systems represented by differential/difference equation.

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
50%	For an LTI system whose Implicit relationship between the inputs and outputs are given by the linear constant-coefficient differential/difference equation, solve it to find accurately the explicit relationship between output and input using recursive / nonrecursive solution.	For an LTI system whose Implicit relationship between the inputs and outputs are given by the linear constant-coefficient differential/difference equation, solve with minor errors the explicit relationship between output and input using recursive / nonrecursive solution.	For an LTI system whose Implicit relationship between the inputs and outputs are given by the linear constant-coefficient differential/difference equation, solve with minor errors the explicit relationship between output and input using recursive/nonrecursive solution.	For an LTI system whose Implicit relationship between the inputs and outputs are given by the linear constant-coefficient differential/difference equation, solve with major errors the explicit relationship between output and input using recursive / nonrecursive solution.
20%	Use given auxiliary conditions accurately to have exact relationship between input and output.	Use given auxiliary conditions accurately to have exact relationship between input and output.	Use given auxiliary conditions to have exact relationship between input and output with minor errors.	Use given auxiliary conditions to have exact relationship between input and output with major errors.
30%	And/or accurately draw block diagram of the given LTI systems represented by differential/difference equation.	And/or draw block diagram with minor errors of the given LTI systems represented by differential/difference equation.	And/or draw block diagram with minor errors of the given LTI systems represented by differential/difference equation.	And/or draw block diagram with major errors of the given LTI systems represented by differential/difference equation.

2.2.7. Rubrics for [CO-7_SO-11_PI-53]

Course Outcome	CO-7: Apply the Fourier series for analyzing the frequency spectrum of periodic signals.
ABET Student Outcome	SO-11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
Performance Indicator	P1-53: Analyze the frequency spectrum of periodic CT/DT signals by applying Fourier series and obtain the coefficients of constituent signals; or use given coefficients of harmonically related constituent basic signals to reconstruct the periodic signal.
Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. Examine the given periodic CT/DT signal to determine the fundamental frequency OR Substitute the coefficients of the given Fourier series to obtain the detailed exponential form of the given periodic CT/DT signal 2. Simplify the detailed exponential form to obtain the coefficients OR the time domain representation of the CT/DT periodic signal

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)

40%	Examine the given periodic CT/DT signal to determine the fundamental frequency OR Substitute the coefficients of the given Fourier series to accurately obtain the detailed exponential form of the given periodic CT/DT signal.	Examine the given periodic CT/DT signal to determine the fundamental frequency OR Substitute the coefficients of the given Fourier series to accurately obtain the detailed exponential form of the given periodic CT/DT signal.	Examine the given periodic CT/DT signal to determine the fundamental frequency OR Substitute the coefficients of the given Fourier series to obtain with minor errors the detailed exponential form of the given periodic CT/DT signal.	Examine the given periodic CT/DT signal to determine the fundamental frequency OR Substitute the coefficients of the given Fourier series to obtain with major errors the detailed exponential form of the given periodic CT/DT signal.
60%	Simplify the detailed exponential form to accurately obtain the coefficients OR the time domain representation of the CT/DT periodic signal.	Simplify the detailed exponential form to obtain with minor error the coefficients OR the time domain representation of the CT/DT periodic signal.	Simplify the detailed exponential form to obtain with minor errors the coefficients OR the time domain representation of the CT/DT periodic signal.	Simplify the detailed exponential form to obtain with major errors the coefficients OR the time domain representation of the CT/DT periodic signal.

2.2.8. Rubrics for [CO-8_SO-11_PI-54]

Course Outcome	CO-8: Apply continuous-time and discrete-time Fourier transform for analyzing the frequency spectrum of periodic and aperiodic signals.
ABET Student Outcome	SO-11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
Performance Indicator	P1-54: Analyze the frequency spectrum of periodic and aperiodic CT/DT signals by applying Fourier transform; convert given signal in frequency domain to time domain using inverse Fourier transform.
Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. Examine the given form to identify in terms of time-domain/frequency-domain signal, periodic/aperiodic signal and CT/DT signal for correctly applying the corresponding technique /equation. 2. Find the corresponding values OR insert the values in the corresponding equation to accurately obtain the required form.

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
20%	Examine the given form of the signal to identify in terms of time-domain/frequency-domain, periodic/aperiodic and CT/DT signal for accurately applying the corresponding technique /equation.	Examine the given form of the signal to identify in terms of time-domain/frequency-domain, periodic/aperiodic signal and CT/DT signal for accurately applying the corresponding technique /equation.	Examine the given form of the signal to identify in terms of time-domain/frequency-domain signal, periodic/aperiodic signal and CT/DT signal for applying with minor error the corresponding technique /equation.	Examine the given form of the signal to identify in terms of time-domain/frequency-domain, periodic/aperiodic and CT/DT for applying with major error the corresponding technique /equation.

80%	Find the corresponding values OR insert the values in the corresponding equation to correctly obtain the required form / result.	Find the corresponding values OR insert the values in the corresponding equation to obtain with minor errors the required form / result.	Find the corresponding values OR insert the values in the corresponding equation to obtain with minor errors the required form / result.	Find the corresponding values OR insert the values in the corresponding equation to obtain with major errors the required form / result.

2.2.9 Rubrics for [CO-9_SO-9_PI-12]

Course Outcome	CO-9: Conduct research to study and examine the real-life applications of convolution techniques, Fourier series and Fourier transform.
ABET Student Outcome	SO-9: a recognition of the need for, and an ability to engage in life-long learning
Performance Indicator	P1-12: Perform literature survey on given engineering problem/application; Locate requested technical information using the internet, company provided or external resources; provide professional research citations for technical information relevant to the topic of research; assimilate technical information in an organized format for presenting the practicality of application of engineering solutions to existing problems.
Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. Locate and gather relevant information by utilizing multiple sources such as library, web, manufacturer catalogue or engineering data sheets, news article, technical magazines etc. 2. Assimilate relevant information in all topics such as: (i) Background of engineering problems, (ii) contemporary solutions, (iii) limitations/issues of contemporary solutions 3. Accurately provide appropriate and complete list of references

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
40%	Locate and gather relevant information by utilizing multiple sources such as library, web, manufacturer catalogue or engineering data sheets, news article, technical magazines etc.;	Locate and gather relevant information by utilizing at least two sources such as library, web, manufacturer catalogue or engineering data sheets, news article, technical magazines etc.; AND/OR	Locate and gather relevant information by utilizing at least one source such as library, web, manufacturer catalogue or engineering data sheets, news article, technical magazines etc.; AND/OR	Unable to locate and gather relevant information by utilizing at least one source such as library, web, manufacturer catalogue or engineering data sheets, news article, technical magazines etc.; AND/OR
50%	Assimilate relevant information in all topics such as: (i) Background of engineering problems, (ii) contemporary solutions, (iii) limitations/issues of contemporary solutions	Assimilate relevant information in three topics such as: (i) Background of engineering problems, (ii) contemporary solutions, (iii) limitations/issues of contemporary solutions AND/OR	Assimilate relevant information in two topics such as: (i) Background of engineering problems, (ii) contemporary solutions, (iii) limitations/issues of contemporary solutions AND/OR	Unable to assimilate relevant information in two topics such as: (i) Background of engineering problems, (ii) contemporary solutions, (iii) limitations/issues of contemporary solutions AND/OR

10%	Accurately provide appropriate and complete list of references	Minor deficiency in providing appropriate and complete list of references	Minor deficiency in providing appropriate and complete list of references	Major deficiency in providing appropriate and complete list of references

2.2.10 Rubrics for [CO-10_SO-11_PI-61]

Course Outcome	CO-10: Apply Z-transform, inverse Z-Transform and its properties for the analysis of LTI systems.
ABET Student Outcome	SO-11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
Performance Indicator	P1-61: Analyze LTI systems by applying Z-transform, inverse Z-transform and its properties; obtain Z-transform of the given signal; draw the region of convergence; find its poles and zeros; or use inverse Z-transform to obtain the time domain signal.
Highest Expectation Student Activity (Sequential with All Gradable Major Steps)	1. Determine accurately the z-transform or inverse z-transform of the given sequence and/or accurately find the region of convergence (ROC). 2. Find system poles and system zeros of the given sequence accurately and accurately sketch pole-zero plot and indicate the region of convergence in the plot. 3. Indicate accurately whether Fourier Transform of the sequence exists using logical reasoning.

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
50%	Determine accurately the z-transform or inverse z-transform of the given sequence and/or accurately find the region of convergence (ROC). AND / OR	Determine accurately the z-transform or inverse z-transform of the given sequence and/or accurately find the region of convergence (ROC). AND / OR	Determine the z-transform or inverse z-transform of the given sequence with minor errors and/or find the region of convergence (ROC) with minor errors. AND / OR	Determine the z-transform or inverse z-transform of the given sequence with major errors and/or find the region of convergence (ROC) with major errors. AND / OR
40%	Find system poles and system zeros of the given sequence accurately and accurately sketch pole-zero plot and indicate the region of convergence in the plot. AND / OR	Find system poles and system zeros of the given sequence accurately and sketch pole-zero plot and indicate the region of convergence in the plot with minor errors. AND / OR	Find system poles and system zeros of the given sequence with minor errors and sketch pole-zero plot and indicate the region of convergence in the plot with minor errors. AND / OR	Find system poles and system zeros of the given sequence with major errors and sketch pole-zero plot and indicate the region of convergence in the plot with major errors. AND / OR
10%	Indicate accurately whether Fourier Transform of the sequence exists using logical reasoning.	Indicate accurately and/or inaccurately whether Fourier Transform of the sequence exists using logical reasoning.	Indicate accurately and/or inaccurately whether Fourier Transform of the sequence exists using logical reasoning.	Indicate accurately and/or inaccurately whether Fourier Transform of the sequence exists using logical reasoning.

3. Continuous Quality Improvement (CQI)

3.1. EAMU Performance Vector Calculation

We have used customized web-based software 'EvalTools' from MAKTEAM Inc. [12, 14]. It has a module for identifying an assignment with specific questions with relative high coverage of a certain PI mapping to CO, and SO for EAMU calculation where EAMU is an abbreviation of 'Excellent', 'Adequate', 'Minimal', and 'Unsatisfactory'. It uses summative assessment by removing all the students

receiving 'DN', 'F', 'W' or 'I' grades in a course from EAMU calculations, thus including only the scores in a selected assignment of the remaining students. It computes the weighted average percentage of the assessments for every student. Weights are put as per the product of the student's percentage in the course grading scale and multiplication factor depending on course format. It then utilizes average percentage for determining the no of students falling into the EAMU categories using the preselected assessment criteria. It then computes the EAMU average rating by scaling it to 5 for a weighted average based on a 3-point scale as shown in Eq. (1) [15].

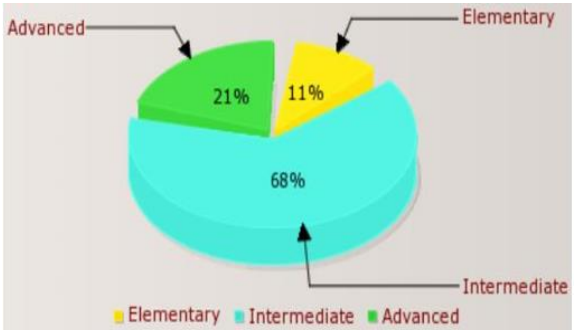

Figure 3. Percentage distribution coverage of three-levels skills of revised Bloom's taxonomy

$$EAMU\ Average = \frac{3 \times E + 2 \times A + 1 \times M + 0 \times U}{E + A + M + U} \times \left(\frac{5}{3}\right) \quad (1)$$

The EAMU vector for each CO is attained by counting each student's EAMU classifications in which 'Excellent' category is the scores >= 90%, similarly 'Adequate' has the scores range of >= 75% and < 90%, 'Minimal': scores >= 60% and < 75% and Unsatisfactory: scores < 60%. Finally, the average of the EAMU vector for each CO is attained after rescaling it to 5.

3.2. Course Outcomes Analysis for Fall-Semester

Based on EAMU vector, the students' performance as per the course outcome of the course 'Signals and Systems' for Fall-semester of 2017-18 is shown in the histogram plot of Figure 4. The color-coded visual results show that students have failed to perform well in the COs 2, 5, 6, 7, 8 and 10 whereas the student's performance also needs improvement in CO 9. Figure 5 shows the ABET Student Outcomes coverage by different COs and their EAMU average for the course 'Signals and Systems' for the Fall-semester of 2017-18. Similarly, Figure 6 shows the histogram plot of student outcome's EAMU average based on 5-point scale for the Fall-semester of 2017-18. It is evident that the student's performance in SO_1 and SO_11 is poor, whereas the performance of students in the SO 9 also needs improvement.

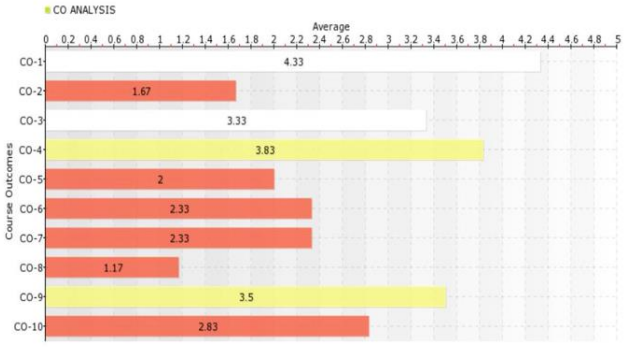

Figure 4. Course outcomes EAMU average based on 5-point scale for the Fall-semester of 2017-18

Item	Student Outcomes	Correlated Course Outcomes	E	A	M	U	Average
SO_1	an ability to apply knowledge of mathematics, science, and engineering	CO 1, CO 2, CO 3,	0	2	0	1	3.11
SO_9	a recognition of the need for, and an ability to engage in life-long learning	CO 9,	0	0	1	0	3.50
SO_11	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	CO 8, CO 4, CO 7, CO 6, CO 10, CO 5,	0	0	1	5	2.42

Figure 5. Student outcomes coverage by different COs and their EAMU average

Figure 6. Student outcomes EAMU average based on 5-point scale for the Fall-Semester of 2017-18

3.3. Modification in teaching and learning strategies

The following teaching and learning strategies were adopted to make the students perform better in the failing course outcomes.

1. It is very important to see the background of students and their habits of learning and their interests and concerns. As students from different countries have different backgrounds and have different mind sets. And their approach towards learning is different. As per OBE, every student can learn, but the way and the time taken by him is different. In other words, all students can learn, but not at the same pace. Different interactive activities are performed in order to know about students. It has helped us to learn more about our students, their specific needs and finding out the ways the students feel more comfortable.

2. Based on the response and feedback from the students, the lecture plans are changed accordingly. This has helped to create a nurturing and inclusive learning atmosphere where every student feels that he is there to learn.
3. Since English is not the mother language of Saudi students and almost all other students studying this course, they have a problem of understanding the lecture delivered in English. Also, most of the students don't start learning English from their 1st grade in school rather start it in their 4th grade or even later than that. That's why their learning process through lecture delivery in English is slow. This fact is taken into account and suggestions were made to the English Department for improving the English comprehension, writing and reading skills of the students. This fact is also considered in the lecture delivery and the lecture's pace is adjusted and feedback is constantly taken from the students in order to know that whether the students have grasped the given concepts.
4. It is also important to see the burden on the students as sometimes they are unable to perform well due to other parallel assignments or assessments related to other subjects going on, which affects their performance in a specific subject as they are unable to have sufficient time to prepare a specific assignment. This fact is taken into account at the department level and subsequent modifications are done on the assessment criteria related to subjects of electrical engineering to balance the load/burden on students.
5. To enable the students to represent diagrammatically the complex exponential and sinusoidal waveforms, the CO2 is added for enabling the students to have strong basics in signals of knowing the fundamental concepts about periodic signals such fundamental frequencies, the effects of change in frequency and change in phase shift so that they can use their solid base for the later course such communication systems, digital communication, and Mobile & wireless communication etc. More related problems are solved in the class and then the students were given problems in the class to solve in the groups and ask questions accordingly to clear their concepts in this regard.
6. For enabling the students to perform better in CO4, the problem-based learning approach is used. It was observed during lecture delivery, that although the technique of convolution sum and convolution integral was properly elaborated, but even then, the student don't understand and grasp the concept until they solve it by themselves. Therefore, two strategies were adopted, i.e. To elaborate the technique during the lecture, the students are asked to solve the full problem or part of it, so that they grasp the concept and clear their concepts if they have problems in solving it. Secondly the students are given homework to practice the problems at home. However, it was not helping it as the students were copying the homework from one another. Therefore, the tutorial sessions were conducted, and students were asked to solve the homework problems in that tutorial session. This has helped a lot and improved students' performance significantly.
7. With regards to the poor performance of the students in CO5, it is observed that students got confused and mixed it with the CO3. The CO3 relates to classification of systems into different categories based on the relationship between input and output of the system, whereas the CO5 is evaluation/classifications of systems based on their impulse responses. This fact is taken into account and is added in lecture delivery to clarify the differences between CO3 and CO5 so that they can perform well in both COs
8. With reference to CO6, the student performance is analyzed to find out the reasons of low performance in this CO, this was observed that students could not understand/extract auxiliary conditions given due to which they could not solve it properly by not applying the correct auxiliary conditions. This fact is taken into account and the students are clarified about how the extract the auxiliary conditions from the given question and to identify that whether the recursive solution needs to be used or not for the given question.
9. Regarding the students' performance in CO7 and CO8, it was observed that the students could not understand the difference between Continuous-Time and Discrete-Time signals and periodic and aperiodic signals due to which they could not apply the proper technique to solve the given question. The is considered and added in the lecture delivery to make the students to identify the difference between Continuous-Time and Discrete-Time signals and periodic and aperiodic signals so that they can understand the given question and solve it with the correct technique.
10. The reasons of student low performance in CO10 were that the students could not get enough time to comprehend the concepts properly as it was covered near to the end of the semester, therefore, it was planned to cover it in time and give homework and take quizzes from this CO so that the student can give proper time to this course outcome and could perform better.

3.4. Course Outcomes Analysis for Spring-Semester

The students' performance in the course outcome of the course 'Signals and Systems' for Spring-semester of 2017-18 is shown in the histogram plot of Figure 7. It is evident that due to the modifications in teaching and learning strategies, the student's performance has significantly improved in COs 2, 3, 4, 5, 6 and 7. However, the student's performance

has not improved in the CO8 and CO10 whereas the student performance has gone down in the CO1. Therefore, related to CO 8 and CO10, there needs to be seen further about how to improve student's performance in these COs as previous modifications in the teaching and learning strategies have not worked well which needs further attention. Figure 8 shows the histogram plot of student outcome's EAMU average based on 5-point scale for the Spring-semester of 2017-18. It is evident that the student's performance in SO_11 has significantly improved whereas with regards to SO_1 and SO_9, the student's performance has improved, but SO_1 needs further attention to improve student's performance in this SO.

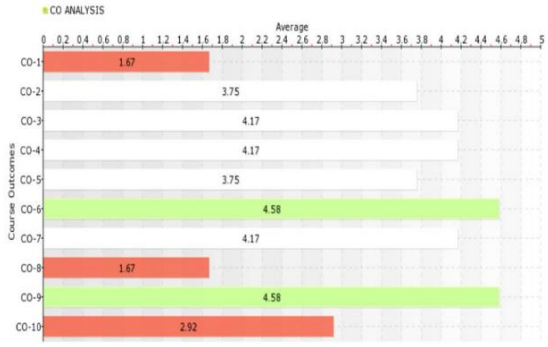

Figure 7. Course outcomes EAMU average based on 5-point scale for the Spring-semester of 2017-18

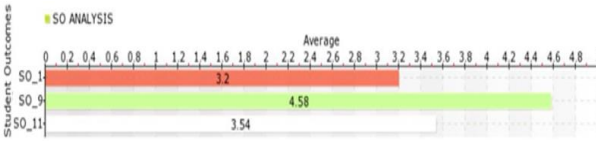

Figure 8. Student outcomes EAMU average based on 5-point scale for the Spring-Semester of 2017-18

4. Conclusions

The course outcomes, and specific performance indicators related to the 'Signals and Systems' course taught to the bachelor's students of Electrical Engineering and ABET student outcome coverage by the course outcomes of this course are discussed in this paper. The student's performance as per the course outcomes of the course 'Signals and Systems' for Fall-semester of 2017-18 are shown to highlight the failing COs in this course. The modifications done in teaching and learning strategies and different methodologies adopted to improve student's performance in the failing COs is discussed and the results achieved by these modified strategies are shown to highlight the significant student's improvement in different COs whereas the student' performance in two COs are not improved which need further attention and change of teaching strategies and methodologies is required to improve student performance related to those COs.

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