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Assessing and Evaluating the Course Outcomes of Control Systems Course Mapping Complex Engineering Problem Solving Issues and Associated Knowledge Profiles with the Program Outcomes

Muhibul Haque Bhuyan

Abstract**—**In the current context, the engineering program educators need to think about how to develop the concepts and complex engineering problem-solving skills through various complex engineering activities by the undergraduate engineering students in various engineering courses. But most of them are facing challenges to assess and evaluate these skills of their students. In this study, detailed assessment and evaluation methods for the undergraduate Electrical and Electronic Engineering (EEE) program are stated using the Outcome-Based Education (OBE) approach. For this purpose, a final year course titled control systems has been selected. The assessment and evaluation approach, course contents, course objectives, course outcomes (COs), and their mapping to the program outcomes (POs) with complex engineering problems and activities via the knowledge profiles, performance indicators, rubrics of assessment, CO and PO attainment data, and other statistics, are reported for a student-cohort of control systems course registered by the students of BSc in EEE program in Spring 2021 Semester at the EEE Department of Southeast University (SEU). It is found that the target benchmark was achieved by the students of that course. Several recommendations for the continuous quality improvement (CQI) process are also provided.

Keywords**—**Complex engineering problem, knowledge profiles, OBE, control systems course, COs, PIs, POs, assessment rubrics.

I. Introduction

THE University Grants Commission (UGC), Bangladesh approved the Bachelor of Science in Electrical and Electronic Engineering (BSc in EEE) program of SEU on 15 November 2009 and after that, the BSc in EEE program was commenced from Spring 2010 Semester with only 36 students [1]. At the end of the Spring 2021 Semester, this department has produced around 600 graduates from 22 batches. However, the program was not accredited till July 2018 by the Board of Accreditation for Engineering and Technical Education (BAETE), which is the only accreditation body in Bangladesh [2]. It was a much-sought issue by the graduates of this department because without it they could not become a member of the Institution of Engineers, Bangladesh (IEB) one of the largest and prestigious national professional organizations for the BSc engineers of Bangladesh [3]. A BSc engineer needs an IEB membership to approve any engineering design. As such, the EEE graduates of SEU were facing serious problems in their jobs. Then in June 2017, the EEE Department applied for the IEB accreditation and obtained it in 2018 after a rigorous 3-day visit by a 4-member evaluation team in March 2018. However, that was given for a limited period of only one year [4] as by this time BAETE had switched to the Outcome-Based Accreditation (OBA) process because Bangladesh wants to graduate to full signatory status from its provisional membership of the Washington Accord. To obtain OBA, the program must have an Outcome-Based Curriculum (OBC) [5]. Therefore, the EEE Department designed an OBE curriculum and started to implement it from the Spring 2019 Semester. BAETE has two versions of its OBE Manual- the first manual was made effective on 1st July 2017 [5], and the second one was made effective from 1st January 2020 [6]. The department of EEE has applied based on the first version of the manual in March 2019 [5]. However, it failed to obtain accreditation due to some shortages. Now, it is looking for applying again addressing the previous shortcomings based on the new manual. But according to this manual, the outcome assessment should be made by also addressing the issues of complex engineering problems solving, complex engineering activities as well as aligning the PO with the appropriate knowledge profiles as given in the second BAETE manual [6].

This paper explains how the assessment and evaluation process of control systems course based on its defined COs by addressing complex engineering problem-solving issues and complex engineering activities by aligning it with the appropriate knowledge profiles are obtained through a definite assessment plan. Besides, CO-PO mapping, performance indicators, and rubrics of assessment are presented. Then the attainment levels for each student are calculated. It is to be pointed out that the BSc in EEE program has adopted twelve POs set by BAETE in its manual's second version [6].

The assessment and evaluations of this course and the other selected courses are used to determine the attainment level of the graduate attributes of the BSc in EEE program's students who will ultimately obtain the degree certificate. The data and evaluations are kept for the university management and the EEE Departments for the CQI process [7]. Not only that, this is needed for the program accreditation. If accreditation can be obtained then it would create a cumulative effect on the student admission in the subsequent semesters at this program. Because

M. H. Bhuyan is with the Department of Electrical and Electronic Engineering (EEE), Southeast University, 251/1 & 252 Tejgaon Industrial cum Commercial Area, Dhaka 1208, Bangladesh (phone: 88-01815-657346; e-mail: muhibulhb@gmail.com).

the number of public and private universities is increasing rapidly in Bangladesh and it has gone past 150 [8], there is an acute crisis and competition of collecting a reasonable quantity of quality students. This would help the program as well as the department to sustain itself in the long run. It would create more opportunities for the graduates of this program in the future and thus they would be able to contribute to society and the nation.

II. Literature Review

COs assessment is essential to measure POs in outcome-based engineering education [9], [10]. COs are assessed from each course in each semester. These are mapped to the POs to evaluate the students' PO attainment level [11], [12]. In literature, a method was found to calculate the COs from a set of predefined goals [13]. CO and hence PO assessments are being performed by identifying, collecting, analyzing, and interpreting the components of various examination data to ascertain the matches between the expectations and actual outcomes. The requirement for the development of a sustainable assessment methodology was stressed [14]. An effective assessment method uses quantitative, qualitative, direct, and/or indirect methods to measure the outcomes of the engineering education being provided at the tertiary level [15].

The primary requisite of an accreditation body is to evaluate that whether the graduates of the program under consideration have attained their stipulated set of knowledge, skills, and attitudes that they are required to accomplish at the time of their graduation but before getting the degree. After that, they look for the other vital adjuvant environment that is necessary for the learners to attain their goals [1], [15].

Various CO and PO measurement techniques are available in the literature to calculate the attainment of POs. However, direct and indirect measurement methods are the most common and widely used methods [16], [17]. The direct measurement method is used particularly for the calculation of CO measurement [18], [19]. Since the CO assessment method can demonstrate how a specific PO of a program has been addressed in the curriculum, this task consumes a lot of time, energy, and effort from the program.

Direct assessment is executed using direct evidence taken from the courses being taught by finding its association with the topics, skills, and some other features [20]. This method can also be used for program and institution-level outcomes. Though there are many tools available for direct assessment, the direct examination tool is the most common. Besides, writing samples, oral presentations, etc. can also be used as direct assessment tools [21]. Though these are essential components, they are not capable of providing the complete assessment. It only conveys the learning attainment but not the way or purpose of the learning process. On the other hand, the indirect assessment can deliver insight into the learning environment and thus helps to determine in which way or how the learning process may be enriched [17] because the indirect assessment emphasizes the factors associated with the learning but not with the learning itself. One of the most common tools used in the indirect assessment method is the survey through which several questionnaires are set to collect the data from the students, faculty members, alumni, employers of the graduates, industry advisory panel members, curriculum committee members, and other stakeholders. Thus, it can give us specific insight into the outcome and its effectiveness for a particular course or PO [17].

An approach for direct assessment was suggested to assess how well an individual student can achieve the COs and POs to define a set of measurable performance indicators in strong co-relationship with the courses under consideration [22]. The performance indicators (PIs) are the measurable attributes characterizing the students' skill-sets and the stages required to fulfill the POs [21].

The control systems course is an important core course in the curriculum of the undergraduate EEE program. It is usually offered in the third or final year of the program. This course is like a multi-disciplinary engineering course requiring the knowledge of electrical, electronics, and mechanical engineering as well as computer programming. Besides, as per the new manual, it is required to address the complex engineering problem solving and activities aligning with the knowledge profiles of the POs. It needs multiple domains of knowledge to attain multiple POs [23]. As a result, it has become more perplexing to the faculty members to ensure the attainment of the course and hence the POs [24]. A kind of motivation is also needed from them towards the students [25].

In 2018, the BAETE became the provisional signatory of the Washington Accord, which is an international accreditation or recognition agreement through the International Engineering Alliance (IEA) for tertiary-level engineering qualifications between the bodies responsible for accreditation in its signatory countries and regions [26]. Now BAETE wants to graduate to the full-signatory status. As such, they have brought changes in their accreditation manual including the knowledge profile mapping with the POs, the ranges of solving the complex engineering problems, and performing complex engineering activities [6]. Therefore, if an institution wishes to seek accreditation of their engineering program, they must design the respective program curriculum including such issues. All the engineering educators of that program must be able to design complex engineering problems and analyze the learning outcomes of their students through various complex engineering activities. In the past, a survey was conducted to explore whether the engineering faculty members have any idea or skills in this matter. However, it was observed that most of the faculty members have no idea regarding this issue. Therefore, the researchers suggested conducting extensive training to enhance the capacity of the faculty members by OBE-experts. After that, the faculty members would be capable to design complex engineering problems and activities to assess as well as evaluate the course outcomes and hence program outcomes of their students [27].

A new approach was proposed to develop undergraduate engineering student's proficiency to decipher complex engineering problems by a group of researchers based on their practices. They suggested improving the student's ability on complex engineering problem-solving skills through engineering practice and then combining it with theoretical knowledge obtained from their university courses [28].

Another research paper indicated that due to the failure of understanding the complex engineering problem issues from the multi-disciplinary perspective with conflicting objectives, often engineering design and the system fail. They have studied the failure using a computer simulator and used the structure-behavior-function (SBF) theory to validate the engineering students' need to understand the multi-disciplinary design factors as well as theoretical knowledge [29].

In another research paper, it was found that the complex engineering problem creation, integration, solution, and assessment issues were addressed with the established infrastructure models in the detailed course contents in line with the departmental vision, mission, and objectives of the course. To assess the outcomes, they used both direct and indirect methods. They also suggested revisiting the pedagogical approach on the teaching-learning process of the students so that they could become able to develop solutions to complex engineering problems and as such, they suggested utilizing the psychomotor domain along with the cognitive and affective domains of Bloom's Taxonomy [30]. Therefore, in this work, we have also suggested using all three domains of Bloom's Taxonomy for the control systems. Basic criteria intended to measure students' progress towards the outcomes of the control systems course for the EEE program have been developed with assessment tools and PIs. The depth and breadth of the course material must be described elaborately than its set of outcome indicative standards; because this set of standards provides a few rudimentary data about what the students could have grasped as well as achieved. However, this set of standards may be the same each semester when the control systems course would be offered to the students. Then the comprehensive set of standards, as well as the evaluations of the major qualifying requirements for the undergraduate students and also the other assessment data, provides us an actual portrait of what the BSc in EEE program is accomplishing. Faculty members of the control systems course of the program should try to establish a correlation among the assessment components and the evaluations needed to the students' performances to the set of standards and program objectives. While grading the students' answers and evaluating their achievement, a course-based assessment is to be used and their obtained scores are to be tabulated independently [25].

III. Objectives of the Work

The main objective of this work is to suggest a technique to design the complex engineering problems for the students of the control systems course and then find a definite method to assess and evaluate the course and POs of BSc in EEE program. However, the other objectives of this study are to-

i. Review several works on the OBE-based assessment and evaluation process and prepare an assessment plan for calculating the attainment of the COs of the control systems course to transfer knowledge of control systems design and complex engineering problem-solving that are very much relevant to the undergraduate EEE program.
ii. Evaluate the accomplishment level of each student.
iii. Evaluate the accomplishment level of PO mapped to the outcome of the control systems course.
iv. Determine the robust and fragile parts of the course and endorse suitable educative activities to be adopted by the EEE Department for further quality improvement.

IV. Methodology

At SEU, three undergraduate engineering programs, viz. BSc in Computer Science and Engineering (CSE), BSc in EEE, and BSc in Textile Engineering (TE) obtained accreditation from the BAETE to ensure its quality and acceptability to various stakeholders [1], [26]. However, the validity for this accreditation was given for a short period of 1-3 years. After that, all these three programs have to apply for renewal of their accreditation by adopting an OBE system. Therefore, the EEE Department switched to the OBE system from the Spring 2021 Semester. In this context, the EEE Department was to prepare a list of measurement methods and PIs to measure the COs and POs [1]. As a first step, the EEE Department developed an OBE-based curriculum, created open-ended obligatory laboratory set-up and experiments by purchasing important machines, equipment, and instrument, with the relevant laboratory manuals, trained the faculty members on OBE-based teaching-learning and assessment, formulated OBE-based teaching guidelines, familiarized the students on OBE-based practices, and so on [1].

In the literature, there are several PO assessment models available [31]. Of them, the most three prominent models are:

1. Accumulated model
2. Dominating model, and
3. Culmination model.

In the first case, all courses of the curriculum are used to measure the POs; whereas in the second method, some of the core courses are selected to measure the POs, and the third model is very selective in choosing courses to measure the POs, it uses only 3-5 core courses of during the final year to contribute to all the POs. The EEE Department has decided to go with the second model and as such it has selected 10 core theory, 5 core laboratory, 1 general education, and 3 capstone design project courses to assess the POs. Hence it has prepared a list of PIs and a set of rubrics. Besides, it will also use an assessment plan to determine the CO attainments and hence to evaluate the POs. Control Systems course is an important core course in the curriculum of BSc in EEE program.

Each CO of Control Systems course was mapped to at least one PO of the BSc in EEE program. The course teacher had to identify various components to assess the COs attainment by the students through an assessment plan. Based on the assessment plan, questions were formulated by maintaining the action verbs of the cognitive domain level of course learning outcomes of Bloom's taxonomy. After that, the assessment data were evaluated and used to calculate the partial PO attainment. The complex engineering problem solving and activities issues were addressed by giving course projects and reports, long assignments and were assessed by using a set of rubrics. Then data were analyzed separately and used to compute the PO attainment directly.

A. Course Outcomes

CO measures the knowledge level, skills, and attitudes of a successful student when a specific semester ends with the completion of several courses. Control Systems course is a higher-level core course of the BSc in EEE program. The knowledge and skills attained in this course are directly related to their jobs as well. Therefore, the COs of this course should be designed in such a way that the students can develop their complex engineering problem (CP) solving skills with knowledge profile (WK) level through various complex engineering activities (EA) and attitude towards designing various complex control systems. Accordingly, the contents of this course are designed and given as [32]: Introduction to control systems; linear system models: transfer function, block diagram, and signal flow graph (SFG). State variables: SFG to state variables, transfer function to the state variable, and vice-versa. Feedback control system: closed-loop systems, parameter sensitivity, transient characteristics of control systems, the effect of an additional pole and zero on the system response and system types, and steady-state error. Routh stability criterion; analysis of feedback control system: root locus method and frequency response method. Design of feedback control system: controllability and observability, root locus, frequency response, and state variable methods. Digital control systems: introduction, sampled-data systems, stability analysis in z-domain.

To prepare the COs, appropriate action verbs were used and three COs were prepared for this course with an initial phrase like the following-

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

[CO1] Model various types of control systems having appropriate transfer functions for each block to get correct analog and digital responses for any standard input signals

[CO2] Evaluate the system's performance quantitatively and qualitatively for steady-state and transient conditions

[CO3] Design and analyze various control systems meeting the stability/other criteria using MATLAB/Simulink

B. Program Outcomes

The BSc in EEE program requires a minimum of 153 credits to earn the degree maintaining the guiding principles of UGC, Bangladesh [33], and BAETE, Bangladesh. There are 12 POs stated in the BAETE Manual mapping with knowledge profiles, complex engineering problem-solving issues, and complex EAs [6], and all of these POs are adopted in the curriculum of the BSc in EEE program of SEU [32]. Graduates of this program are anticipated that they would achieve these 12 POs at the point of their graduation.

There are various methods of class conduction processes at the EEE Department, such as face-to-face student meetings, on-site lecture classes, lecture and discussion sessions through Google Meet or Zoom online platforms, etc. Google Classrooms are used for the class management and assessment processes. They also give each course syllabus of their courses to the students on the class start date of the concerned semester. The course syllabus provides all the necessary information of the course at the beginning of the semester, like course contents, course objectives, course learning outcomes, course requirements, classroom policies, a chronological list of lecturer outlines, number of quizzes, class tests, midterm, and final examinations and their timetables, text and reference books, teaching domains and levels, teaching-learning-assessment strategies for each lecture class, assessment and grading policies, CO-PO-WK-CP-EA mappings, etc. [34].

C. CO-PO Mapping and Performance Assessment

PI validates the attainment level of various learners of a program [1]. In the control systems course, direct measurement techniques are used to obtain students' knowledge or skills against quantifiable against each CO to be mapped ultimately to a particular PO. However, when issues of complex engineering problems and activities are to be addressed, these are done through the rubric-based assessment and using various PIs. However, each student must obtain a "threshold score" of 50% on a percentage scale (100% being the highest) to achieve his or her engineering degree [1], [34]. These percentage levels indicate the students' ability to perform at the time of their graduation from the BSc in EEE program.

A graduate needs to fulfill the requirements of knowledge, skills, and attitude through their knowledge profiles mapped from various COs to POs, ability to solve complex engineering problem-solving skills, and perform various complexing EA to demonstrate his/her accomplishment overall 12 POs stated in the BAETE manual [6], and adopted by the BSc in EEE curriculum [32]. Various PIs and direct assessment tools used in the control systems course are furnished in Table I with the CO-PO-WK-CP-EA mapping. To transfer necessary knowledge of control systems course at various cognitive domain levels of Bloom's taxonomy, various teaching-learning techniques are applied since it was found effective in several studies [23], [35]-[38]. In Table I, CO mapped to corresponding teaching-learning domains of Bloom's taxonomy, teaching-learning strategies for the CO, mapped PO with required WK, CPs, and EAs as per BAETE manual [6], and assessment tools are depicted.

In Table II, each component of direct assessment tools is shown with appropriate cognitive domain level and allotted marks through an appropriately designed assessment plan assuming a linear relationship between all of the above three COs and its components of direct assessment tools of control systems course.

TABLE I
CO-PO MAPPING, TEACHING DOMAIN, TEACHING-LEARNING STRATEGY, AND ASSESSMENT TOOLS OF CONTROL SYSTEMS COURSE

CO	Teaching Domain/	Teaching-Learning Strategy	PO with associated Knowledge Profile (WK) and Complex Engineering Problem (CP)	Direct Assessment

	Level			Tools
[CO1] Model various types of control systems having appropriate transfer functions for each block to get correct analog and digital responses for any standard input signals	Cognitive Domain/ Apply	Lecture Discussion Demonstration Problem Solving Flip classroom Question and Answer	PO1 (Engineering Knowledge) WK1(Natural Science Knowledge); WK2: (Mathematics Knowledge); WK3 (Engineering Fundamentals Knowledge); WK4 (Engineering Specialist Knowledge) CP1 (Depth of Knowledge); CP2 (Range of Conflicting; Requirements); CP7 (Interdependence)	Direct Assessment Tools like Midterm Exam Final Exam Project Work
[CO2] Evaluate the system's performance quantitatively and qualitatively for steady-state and transient conditions	Cognitive Domain/ Evaluate	Lecture Discussion Problem Solving Flip classroom Question and Answer	PO2 (Problem Analysis) WK1 (Natural Science Knowledge); WK2: (Mathematics Knowledge); WK3 (Engineering Fundamentals Knowledge); WK4 (Engineering Specialist Knowledge) CP1 (Depth of Knowledge) CP3 (Depth of Analysis)	Project Report Project Presentation
[CO3] Design and analyze various control systems meeting the stability/other criteria using MATLAB/Simulink	Cognitive Domain/ Create	Lecture Discussion Problem Solving Flip classroom Question and Answer	PO3 (Design/Development of Solutions) WK5 (Engineering Design) CP1 (Depth of Knowledge) CP3 (Depth of Analysis) CP4 (Familiarity of Issues)	

TABLE II
ASSESSMENT PLAN OF CONTROL SYSTEMS COURSE

Item	Q#	CL	Marks	CO1	CO2	CO3
Midterm Exam	Q1(a)	C3	4.0	√		
	Q1(b)	C5	4.0		√	
	Q2(b)	C3	4.0	√		
	Q3(a)	C6	6.0			√
Final Exam	Q1(a)	C3	3.0	√		
	Q2(a)	C5	5.0		√	
	Q3(a)	C5	5.0		√	
	Q3(b)	C6	5.0			√
	Q4(a)	C3	4.0	√		
	Q4(b)	C6	6.0			√
Total	10	-	46.0			

The question distribution in terms of the number of questions and amount of allotted marks is shown in Table III, which shows that not a single question is set from the 'Remember' or 'Understand' level of the cognitive domain. Questions have mainly been set from three higher levels, viz. 'Apply', 'Evaluate', and 'Create'. Control systems course is a higher-level course in the curriculum of BSc in EEE program. Therefore, it is predictable that the students should be able to solve some of the application-level problems and mostly solve problems related to 'Evaluate', and 'Create' levels as we need to address some complex engineering problem-solving issues. If we look at Table III, we observe that though an almost equal number of questions has been set from three levels 3, 5, and 6 with a proportion of 40%, 30%, and 30% of the total number of questions to assess or measure the COs but the marks allotted for the levels 3, 5, and 6 are 32.6%, 30.4, and 37% of the total allotted marks respectively, because design problems are emphasized.

A performance scale developed in earlier work as shown in Table IV is used from different direct assessment tools [38]. The CO achievement target for the control systems course was set to 50 also, that is, at least 50% of the registered students must attain a minimum of 50% marks at the satisfactory level.

TABLE III
NUMBER AND PERCENTAGE DISTRIBUTIONS OF THE QUESTIONS OF CONTROL SYSTEMS COURSE ACCORDING TO THE 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 %
C3	Apply	4	40%	15	32.6%
C5	Evaluate	3	30%	14	30.4%
C6	Create	3	30%	17	37.0%
Total		10	100.00%	46.0	100.00%

TABLE IV
PERFORMANCE SCALE BASED ON THE PERCENTAGE OF OBTAINED MARKS

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%

D. PO Assessment

The POs can be measured from COs of various courses and directly using PIs based on rubrics from various course projects for any course. In this course, there are three COs and mapped to three different POs of the program. The attainment of PO from COs is calculated as per the following steps [39]:

i. Each CO is mapped to one PO only.
ii. According to Table I, CO1 contributes to attaining PO1, CO2 supports achieving PO2, and CO3 donates to accomplish PO3.
iii. A PO is accomplished when a cohort of aggregated students total in the 'Excellent', 'Very Good', 'Good', and 'Satisfactory' stages is equal to at least 50% and above in combination.
iv. The PO accomplishment is computed according to the following rule-

PO1_RUB: Rubric for Assessment of Program Outcome 1 (PO1)
Target Course Outcome: CO1; Program Outcome: PO1

Southeast University

Course Code	EEE335	Course Title	Control Systems	Section	1	Semester	Fall 2019
Course Teacher Name		Designation					

Student ID #	
Student Name	

Indicator	Poor (1)	Average (2)	Good (3)	Very Good (4)	Excellent (5)	Marks
PO1.1) Apply knowledge of mathematics to model control systems	Fails to understand and apply linear algebra and differential equation to model electrical or electronic circuits or mechanical systems	Understands linear algebra and differential equation to model electrical or electronic circuits or mechanical systems but can't apply knowledge of it	Can apply knowledge of linear algebra and differential equation to model simple electrical or electronic circuits or mechanical systems satisfactorily	Can apply knowledge of linear algebra and differential equation to model simple electrical or electronic circuits or mechanical systems satisfactorily but can't solve it accurately and can't extend its application	Demonstrates satisfactory application of linear algebra and differential equation to model electrical or electronic circuits or mechanical systems and also can combine such systems to extend its application	
PO1.2) Apply concepts and theories of engineering to model control systems	Fails to apply fundamental concepts and theories of engineering (like KVL, KCL, etc.) to model electrical or electronic circuits or mechanical systems	Understands a little to apply fundamental concepts and theories of engineering to model electrical or electronic circuits or mechanical systems	Demonstrates satisfactory application of fundamental concepts and theories of engineering to model electrical or electronic circuits or mechanical systems	Demonstrates accurate application of fundamental concepts and theories of engineering to model electrical or electronic circuits or mechanical systems but can't extend	Demonstrates accurate application of fundamental concepts and theories of engineering to model electrical or electronic circuits or mechanical systems and can extend	
PO1.3) Convert science and engineering problems to solvable control system models	Fails to transform science and engineering problems into solvable mathematical models	Shows limited and less than adequate transformation of science and engineering problems into solvable mathematical models	Demonstrates satisfactory transformation of science and engineering problems into solvable mathematical models	Understands and applies proper transformation of science and engineering problems into solvable mathematical models but not an accurate solution	Understands and applies proper transformation of science and engineering problems into solvable mathematical models into an accurate solution	
PO1.4) Response to Questions	Fails to answer a single question related to modeling of control systems	Can answer a few questions related to modeling of control systems at Remember/ Understand level	Can answer a few questions related to modeling of control systems up to Synthesis level	Can answer most of the questions related to modeling of control systems up to Evaluate level	Can answer all of the questions related to modeling of control systems up to Create level	

Comments of Course Teacher	Assessed by (Signature & Date)	Total (Out of 20)

Fig. 1 Rubric for assessment of Program Outcome, PO1 with target Course Outcome, CO1

PO2_RUB: Rubric for Assessment of Program Outcome 2 (PO2)
Target Course Outcome: CO2; Program Outcome: PO2

Southeast University

Course Code	EEE335	Course Title	Control Systems	Section	1	Semester	Fall 2019
Course Teacher Name		Designation					

Student ID #	
Student Name	

Indicator	Poor (1)	Average (2)	Good (3)	Very Good (4)	Excellent (5)	Marks
PO2.1) Apply knowledge of mathematics and natural sciences to identify parameters of control systems	Fails to understand and apply linear algebra and differential equation to identify parameters of electrical or electronic circuits or mechanical or electro-mechanical systems	Understands linear algebra and differential equation to model electrical or electronic circuits or mechanical or electro-mechanical systems but can't apply knowledge of it	Can apply knowledge of linear algebra and differential equation to identify parameters of simple electrical or electronic circuits or mechanical or electro-mechanical systems satisfactorily	Can apply knowledge of linear algebra and differential equation to identify parameters of simple electrical or electronic circuits or mechanical or electro-mechanical systems satisfactorily but can't solve it accurately and can't extend its application	Demonstrates satisfactory application of linear algebra and differential equation to identify parameters of electrical or electronic circuits or mechanical or electro-mechanical systems and also can combine such systems to extend its application	
PO2.2) Apply concepts and theories of engineering to formulate equations of control systems	Fails to apply fundamental concepts and theories of engineering (like KVL, KCL, etc.) to formulate electrical or electronic circuits or mechanical or electro-mechanical systems	Understands a little to apply fundamental concepts and theories of engineering to formulate electrical or electronic circuits or mechanical or electro-mechanical systems	Demonstrates satisfactory application of fundamental concepts and theories of engineering to formulate electrical or electronic circuits or mechanical or electro-mechanical systems	Demonstrates accurate application of fundamental concepts and theories of engineering to formulate electrical or electronic circuits or mechanical or electro-mechanical systems but can't extend	Demonstrates accurate application of fundamental concepts and theories of engineering to formulate electrical or electronic circuits or mechanical or electro-mechanical systems and can extend	
PO2.3) Compute and evaluate control system's parameters from formulae and graphs	Fails to compute and evaluate control system's parameters accurately at transient and steady-state conditions; can't extract any graphical parameters	Can compute control system's parameters accurately at certain but not all conditions and can't evaluate at all; can't extract any graphical parameters	Can compute control system's parameters at most of the conditions but can't evaluate at all; can extract some graphical parameters but can't evaluate	Can compute control system's parameters at most of the conditions but can't evaluate properly; can extract all graphical parameters but can't evaluate	Can compute accurately and evaluate properly control system's parameters at all conditions; can extract all graphical parameters and can evaluate properly	
PO2.4) Response to Questions	Fails to answer a single question related to quantitative and qualitative system's performance at various conditions	Can answer a few questions related to quantitative and qualitative system's performance at some of the conditions only	Can answer a few questions related to quantitative and qualitative system's performance at various conditions and synthesize	Can answer most of the questions related to quantitative and qualitative system's performance at various conditions and evaluate	Can answer all of the quantitative and qualitative system's performance at all conditions and evaluate	

Comments of Course Teacher	Assessed by (Signature & Date)	Total (Out of 20)

Fig. 2 Rubric for assessment of Program Outcome, PO2 with target Course Outcome, CO2

PO3_RUB: Rubric for Assessment of Program Outcome 3 (PO3)
Target Course Outcome: CO3; Program Outcome: PO3

Southeast University

Course Code	EEE335	Course Title	Control Systems	Section	1	Semester	Fall 2019
Course Teacher Name		Designation					

Student ID #	
Student Name	

Indicator	Poor (1)	Average (2)	Good (3)	Very Good (4)	Excellent (5)	Marks
PO3.1) Define design specifications and constraints of control systems	Fails to understand and write proper design specifications and constraints of electrical or electronic circuits or mechanical or electro-mechanical systems	Understands proper design specifications and constraints of electrical or electronic circuits or mechanical or electro-mechanical systems but can't write it	Understands proper design specifications and constraints of electrical or electronic circuits or mechanical or electro-mechanical systems but can't write with constraints	Understands and can write proper design specifications of electrical or electronic circuits or mechanical or electro-mechanical systems but can't apply constraints	Understands and can write proper design specifications of electrical or electronic circuits or mechanical or electro-mechanical systems and can also apply constraints	
PO3.2) Produce design alternatives of control systems	Fails to understand and produce design alternatives of electrical or electronic circuits or mechanical or electro-mechanical systems	Understands design alternatives of electrical or electronic circuits or mechanical or electro-mechanical systems but can't produce it	Understands design alternatives of electrical or electronic circuits or mechanical or electro-mechanical systems but can't produce it properly	Understands design alternatives of electrical or electronic circuits or mechanical or electro-mechanical systems and can produce it with limited analysis of new model	Understands and can produce design alternatives of electrical or electronic circuits or mechanical or electro-mechanical systems with proper analysis of it	
PO3.3) Utilize proven design methods, practices and available resources to achieve design intent	Fails to understand and utilize proven design methodologies and practices and available resources to achieve design intent	Understands proven design methodologies and practices and available resources but can't utilize to achieve design intent	Understands proven design methodologies and practices but not all available resources to achieve design intent and can utilize it though not so efficiently and accurately	Understands and utilizes design methodologies and practices and all available resources to achieve design intent but not so efficiently and accurately	Understands and utilizes proper, proven, and alternative design methodologies and practices and available resources to achieve design intent efficiently and accurately	
PO3.4) Test and validate the system responses meeting several specifications and constraints	Fails to verify the designed control systems meeting the design specifications and constraints	Understands the designed control system's verification methods meeting the design specifications and constraints but fails to test	Understands the designed control system's verification methods meeting the design specifications and constraints and can test but can't validate	Understands the designed control system's verification methods meeting the design specifications and constraints; can test and validate but not properly	Understands the designed control system's verification methods meeting the design specifications and constraints and can test and validate it properly	
PO3.5) Response to Questions	Fails to answer a single question related to design, test and validation	Can answer a few questions related to design, but not test and validation	Can answer a few questions related to design and test, but not validation	Can answer most of the questions related to design, test, and validation	Can answer all questions related to design, test, and validation properly	

Comments of Course Teacher	Assessed by (Signature & Date)	Total (Out of 25)

Fig. 3 Rubric for assessment of Program Outcome, PO3 with target Course Outcome, CO3

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 but in the developing stage and require extensive care for the attainment of COs and POs.

b. Score ≥ 50% → achieved

b.i. Score ≥ 50% but < 60% → marginally achieved with a satisfactory rank

b.ii. Score ≥ 60% but < 70% → achieved with a good rank, however, need improvements in knowledge and skills.

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

b.iv. Score ≥ 80% → achieved with an excellent rank and may not need further improvement measures

E. Developing PIs

Since this control systems course has three COs that are mapped to three different POs, it is required to design three rubrics to assess these 3 POs from this course if students undertake this course in a semester. In this work, three rubrics are developed for the assessment of three POs and are shown in Figs. 1-3. A rubric has four to five key performance indicators (KPIs) and each KPI has five levels from 1 to 5, where 1 means poor, 2 means average, 3 means good, 4 means very good, and 5 means excellent. So, the maximum achievable points for one CO mapped to one PO and from one course are 4×5 = 20 or 5×5 = 25.

F. Data Collection

A sample of 30 students' data is used in this study from the control systems course offered in the Fall 2020 Semester at the Day shift program of the EEE Department. Data were taken from midterm and final examinations of the Control Systems course for one cohort of students. Though the OBE curriculum was made effective from the Spring 2019 Semester with the freshmen, to test the OBE procedures addressing complex engineering problem solving with appropriate knowledge profile mapping to COs and POs, assessment and evaluations were performed for several higher-level courses, such as electromagnetics, semiconductor devices, control systems, etc. of the old non-OBE curriculum. Besides, a course project was assigned to be performed using MATLAB. The project report and viva-voce marks were also used in this analysis.

V. Results and Discussions

A. CO-PO Evaluation

Table V provides the attainment data of three COs and POs in terms of the number of students. Since one CO is mapped to one PO, so data will be the same for partial PO attainment as well. As such, it is not shown separately. That means this table shows how many students could achieve the engineering knowledge level through CO1 at what capacity through their learning of various laws, rules, and theorems related to analog and digital control system modeling and derivation of their transfer functions. It shows that 26 students out of 30 could achieve satisfactory or its above level, that is, more than 86% of the students in the class could achieve PO1 partially through

CO1. This table also shows how the capability of the participating students has been developed on the computation of the system's performance parameters both quantitatively and qualitatively at steady-state and transient conditions through CO2 and thus contributes to partial attainment of PO2 by the students of this cohort. It shows that 25 students out of 30 could achieve satisfactory or its above level, that is, more than 83% of the students in the class. Besides, it is observed that the skills required to design and analyze various control systems meeting some design specifications and constraints using MATLAB/Simulink software package have been met by 19 out of 30 students, that is more than 63% of students under this cohort and hence PO3. It is interesting to observe that a significant number of students (11 out of 30 students, or more than 36% students of the total participants) could not achieve this particular CO3. It may be due to the design constraints, complex engineering problem-related issues, test and validation works of the designed system, report writing, viva-voce examination on the assigned projects, etc.

TABLE V
NUMBER OF STUDENTS ACHIEVING THE PERFORMANCE LEVELS FOR ALL COS OR POS OF THE CONTROL SYSTEMS COURSE OF EEE DEPARTMENT

	Excellent	Very Good	Good	Satisfactory	Developing	Un-satisfactory
CO1	5	2	9	10	3	1
CO2	3	4	7	11	4	1
CO3	1	2	3	13	9	2

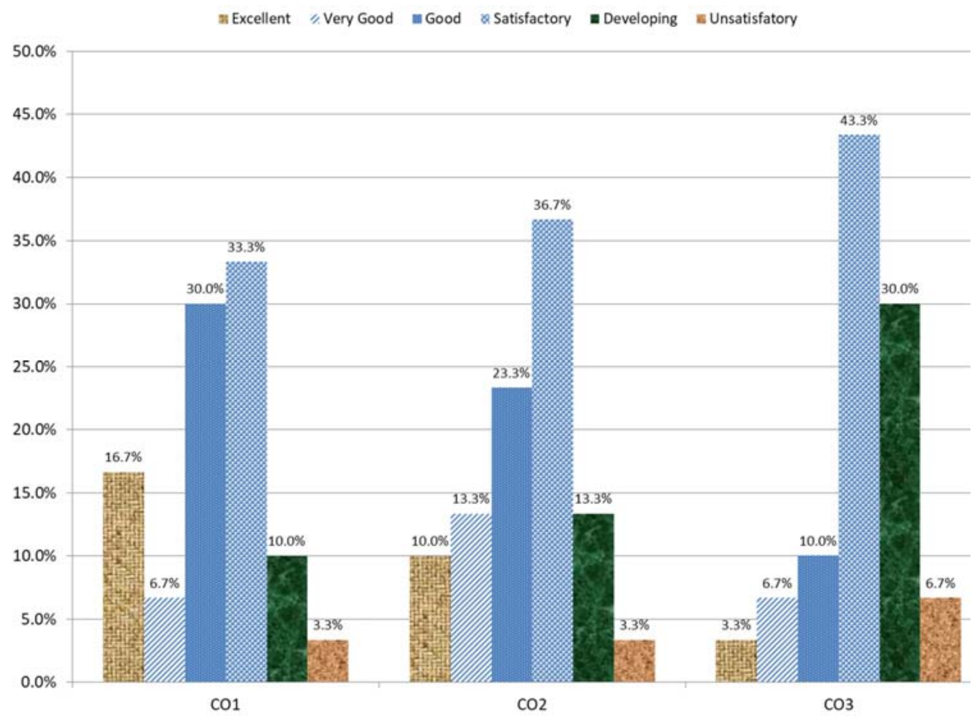

Fig. 4 CO or PO evaluation attainment report summary

The obtained results have been represented graphically in Fig. 4 that shows the attainment levels of each CO and hence the corresponding PO. Since the attainment benchmark has been set at 50% for control systems course, it may be inferred that this cohort of students could achieve all COs and hence could contribute to respective POs from this course; because the sum of percentage data from satisfactory to excellent level is well above 50% for three COs, i.e., 86.67%, 83.33%, and 63.33% for CO1, CO2, and CO3 respectively. However, it is required to take care of the other students who could not go above their target CO levels of control systems course.

B. Suggestions for Improvement

Since a significant number of students could not achieve the target level of COs and hence could not contribute to their POs mapped to COs of control systems course, hence to develop those students' attainment levels of these COs, a suggestion list has been prepared to recover it. It is expected that the suggestions would help the concerned students and the future course teachers of control systems course. Besides, the suggestions may help for further improvement of the course contents as well. However, there are still many scopes and provisions for the new course teacher to improvise further for remedial actions or undertake any corrective measures so that the concerned students may achieve their target level. The recommended corrective measures are as follows:

a. Giving students more homeworks for practice and assignments on problems of control systems;
b. Sparing some time with the students on tutorial classes to make them understand the theories and problems on control systems;
c. Referring to several standard text or reference books on control systems course;
d. Improvising teaching-learning strategies to address non-

attained course materials;

e. Giving detailed and well-prepared lecture slides to the students to make sure that they understand it;
f. Using real-life examples of control systems course;
g. Taking extra classes and tutorials on control systems' design and simulation in MATLAB/Simulink;
h. Helping students on test and validation methodologies;
i. Guiding students to prepare their reports, presentations, and viva-voce examinations.

The EEE Department has recruited qualified faculty members who are experts in conducting control systems based on the OBE curriculum and teaching-learning methodologies. Besides, the department should continue its faculty training processes for further improvement and improvisation.

VI. Conclusion

This article explained in detail how the control systems course is being taught and assessed by the faculty members based on the outcome-based model in the BSc in EEE program. This model follows the BAETE manual for outcome assessment by addressing the complex engineering problem-solving issues with the associated knowledge profiles. For this purpose, COs of the control systems course are developed and then mapped to the POs, and associated CPs, WKs as suggested in the BAETE manual. Then three rubrics were also developed with 4-5 KPIs and 5 performance levels. The initial target level for each CO was set at 50% and the students of a particular cohort could achieve this target. Finally, a list of corrective measures was suggested for further improvement so that the CO attainment levels improve in the future. In this work, data collection and analysis procedures were manual. In the future, software may be developed to automate the assessment and evaluation of this huge amount of data.

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Muhibul Haque Bhuyan (MIEEE’07–) became a Member (M) of the World Academy of Science, Engineering and Technology in 2005, born in Dhaka, Bangladesh on 25 July 1972. He did his BSc, MSc, and PhD degrees in Electrical and Electronic Engineering (EEE) from Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh in 1998, 2002, and 2011 respectively.

Currently, he is working as a Professor of the Department of Electrical and Electronic Engineering of Southeast University, Dhaka, Bangladesh. He led this department as the Departmental Chairman from 1st March 2016 to 10th March 2021. Previously, he worked at the Green University of Bangladesh, Dhaka as a Professor and Chairman of the EEE Department; Daffodil International University, Dhaka, Bangladesh as an Assistant Professor and Head of ETE Department; Presidency University, Dhaka, Bangladesh as an Assistant Professor and American International University Bangladesh (AIUB), Dhaka as a Faculty Member since June 1999. He also worked as a Researcher in the Center of Excellence Program of Hiroshima University, Japan from July 2003 to March 2004. He has served as an Adjunct Faculty at several universities like AUST, IIUC, EWU, DIU, PU, etc. So far, he has published over 60 research papers in national and international journals and presented over 50 research works at national and international conferences.

His research interests include MOS device modeling, biomedical engineering, control system design, online practices of teaching and learning, outcome-based engineering education, assessment, and evaluation. He is a program evaluator of the Board of Accreditation of Engineering and Technical Education (BAETE), Dhaka, Bangladesh under IEB.

Prof. Bhuyan is a Member of IEEE, USA, Executive Member of Bangladesh Electronics and Informatics Society (BEIS), and Fellow of the Institution of Engineers Bangladesh (IEB). He is a regular reviewer and technical/editorial/organizing committee member of several national and international journals and conferences. He was the Organizing Chair of the IEEE 22nd International Conference on Computer and Information Technology (ICCIT) held at Southeast University, Dhaka, Bangladesh during 18-20 December 2019. He is the recipient of the Bangladesh Education Leadership Awards (Best Professor in Electrical Engineering) in 2017 from the South Asian Partnership Awards, Mumbai, India.