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Curriculum Compliance Improvement Model for Addressing Program Outcomes in Engineering Education

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Abstract - The teaching-learning methodology in the engineering education system is moving from a teacher-centric model to a student-centric model. The student-centered learning model is a method of learning or teaching that keeps the learner at the center. Outcome-Based Education (OBE) is an education model that focuses on the student-centric model which equips the students with the desired knowledge, skill, attitude, and behavior at the time of graduation. The National Board of Accreditation (NBA) is an accrediting body in India and its norms ensure that professional programs adopt OBE, and as an initiative, it has defined twelve Program Outcomes (POs). These POs are to be demonstrated by the graduates upon completion of the program. Professional programs curriculum will play a vital role in the attainment of POs. Therefore, the curriculum has to be designed in such a way that all the POs need to be addressed. The majority of the courses in the curriculum address the first five POs and are called disciplinary outcomes. The rest seven POs i.e PO6 to PO12 are generally named as professional outcomes and to address these POs, the department has to put in additional effort. In this paper, a Curriculum Compliance Improvement Model (CCIM) is proposed that performs the gap analysis of the existing curriculum and aid to enhance the curriculum compliance for PO attainment by suggesting suitable actions. These actions can be implemented by fine-tuning the curriculum design and teaching-learning process which will provide an environment for the students to attain all the graduate attributes (POs), the proposed model is illustrated through a case study. Overall, the model proposed is useful for the Tier-1 institutions that are keen on their students attaining all the graduating attributes, and also, ensures to meet the objectives of the accreditation procedure.

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Keywords— Accreditation, Course Outcomes, Disciplinary Outcomes, Engineering education, Outcomes-Based Education, Program Outcomes, Gap Analysis, Curriculum Design.

1. Introduction

Recently industries are finding it difficult to recruit engineers who are capable of addressing state-of-art challenges. Also, industries need engineers who think holistically. Engineers, by the very nature of their work, not only apply the knowledge of science and fundamentals of engineering to solve engineering problems that are complex, but are also able to identify, articulate, analyze, and evaluate complex problems for reaching sustainable conclusions. Apart from having technical skills, they should possess extensive professional ethics, and strong written and oral communications skills. In addition, they function effectively as an individual, and as a member or a leader in diverse teams. In this context, engineering education plays a vital role in laying a foundation for technological innovation and development that drive the overall growth of the nation in long term and help solve societal problems. Therefore, there is a necessity to improve the engineering education system to ascertain the overall development of graduating engineers and in this regard, many initiatives have been recommended to be implemented by national and international accreditation bodies in higher educational institutes.

A. National Board of Accreditation

The National Board of Accreditation (NBA) is an accreditation agency in India and has become a permanent member of the Washington Accord (WA) . WA is an international agreement among bodies responsible for accrediting undergraduate engineering degree programs. The objective of the NBA is to assess and accredit professional programs offered by technical institutions and promote global quality standards for technical education in India. The NBA norms ensure that programs must work to prepare the graduates with good knowledge of fundamentals and to acquire a sufficient level of professional competency to meet the requirements of the engineering profession regionally and globally. NBA recommends institutions offering professional programs adopt the Outcome-Based Education (OBE) delivery model.

B. Outcome-Based Education

The OBE is a student-centric teaching and learning approach in which the course delivery and evaluation are planned to attain a set of stated objectives and outcomes . OBE aims at equippingstudents with the desired knowledge, skill, attitude,and behavior at the time of graduation. The OBE emphasizes on

- objectives and outcomes of each course/activity
- what the students are able to demonstrate at the end of the engineering degree program
- teaching-learning process and suitable assessment methods
- assessing the students to know whether the students have achieved defined outcomes

With this objective NBA has defined twelve graduating attributes as Program Outcomes (POs) common to all engineering programs.

C. Program Outcomes

The POs are statements that indicate what the graduates would demonstrate upon completion of the engineering program. PO statements relate to the knowledge, skill set, analytical ability, behavior, and attitude that graduates obtain through the program. As such, POs define the professional profile of a graduate. These POs are in line with the WA-defined graduate attributes. The first five POs are dominantly technical and disciplinary outcomes, and the remaining is professional outcomes also known as generic outcomes as shown in Fig. 1. Both the disciplinary and professional outcomes are assessed (PO Attainment) to award the engineering degree.

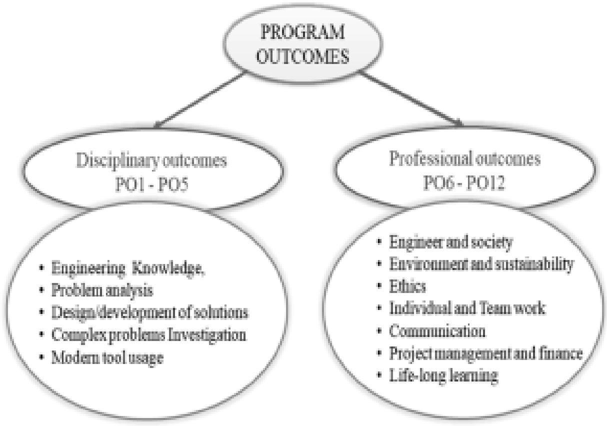

Fig. 1 : Graduate attributes

D. Program Outcome attainment methods

The POs are achieved through direct and indirect methods (Kavitha et al., 2017) and are depicted in Fig. **2.** POs are attained through the curriculum in the direct method, whereas various surveys and activities such as employer surveys, graduate exit surveys, extra and co-curricular activities are considered in the indirect method. NBA has prioritized the contributions for indirect and direct methods as 20% and 80% respectively, this distribution reveals that curriculum plays a major role in PO attainment. The curriculum designed for the program aims to achieve the attainment of POs. Generally, the curriculum maintains a balance in the structure of engineering sciences, basic sciences, professional core courses, professional core electives, open electives, humanity and social sciences, and others. Each course has a set of defined Course Outcomes (COs) that are quantitatively assessed and mapped to the POs.

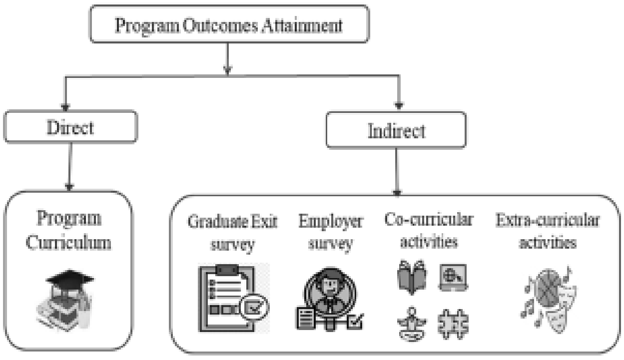

Fig. 2 : POs attainment methods

E. Motivation

The POs are by nature meant to be straightforward and assessable. The potential challenge is to orient the course design framework to attain the POs. At times, the curriculum designed may not satisfactorily address all the POs. Therefore, the department requires to make an additional effort so that the students acquire all the graduate attributes at the time of completion of the degree. In this direction, an attempt has been made in this article to propose a model to improve curriculum compliance for the attainment of POs in Tier-1 institutions.

The remaining sections of the article are organized as follows; the recent research carried out with respect to engineering education and OBE by various authors is summarized in the next section. The architecture of the proposed Curriculum Compliance Improvement Model (CCIM) along with the list of terms used and corresponding definitions are discussed in section 3. The working of the proposed model is illustrated with a case study in section 4. Finally, section 5 presents the concluding words on the proposed model.

2. Literature Review

Engineering education is a well-researched topic in the recent past. Researchers have come up with various innovative methods (Visscher-Voerman & Muller, 2017) to implement the engineering education tasks such as curriculum design (Parashar & Parashar, 2012) (Technology & Author, 2019) (DeGoede & Jain, 2012), Teaching Learning Process (TLP), assessment, etc. Most of the national and international accreditation bodies accept degrees obtained through OBE. Hence, all the engineering education tasks should be in line with OBE.

The curriculum design process in engineering education is considered an engineering design process (Rompelman & De Graaff, 2006) where every task of curriculum design is solved as an engineering problem by applying engineering tools along with the logical usage of the systems approach. In (S. Johnson & Ramadas, 2020) a curriculum development method is proposed in which the authors emphasize that new courses should be designed with a proper and measurable set of outcomes along with assessment metrics so that courses can contribute to the attainment of POs.

In (Priya Vaijayanthi & Raja Murugadoss, 2019) authors have proposed a framework for the curriculum design of the Computer Science and Engineering (CSE) program based on OBE, similarly in (Technology & Author, 2019) authors have also emphasized the mobility of the curriculum along with design. Few authors have researched designing a curriculum to adhere to the Please replace ABET with " Accreditation Board for Engineering and Technology (ABET)"accreditation system, in (Felder & Brent, 2003) authors have proposed a strategy to design a curriculum using program and course-level activities to meet the ABET requirement.

Authors (G. Johnson & Siller, 2020) demonstrate a view of the engineering curriculum at a higher level, they have used a knowledge taxonomy, and have come up with a new method to design a curriculum based on the taxonomy of knowledge. Researchers have also come up with new methods to attain the POs in OBE. Authors (Karimi et al., 2004) discuss the assessments of courses and POs and also describe a procedure to collect and analyze the data to improve the quality of assessment of the Under Graduation (UG) program.

In (Rajak et al., 2019) authors concentrated on weak learners and emphasized on gap analysis procedure for individual courses not meeting the target, and discussed the corrective actions for the non-attainment. In (Balasubramani, 2016) and (Jayarekha & Dakshayini, 2015) the authors have demonstrated the attainment of POs through COs as a case study adhering to NBA. A simple method to estimate the level of attainment of POs and Program Specific Outcomes is proposed by (Soragaon & Mahesh, 2016) for preparing the Self-Assessment Report of NBA.

Overall, it is concluded from the existing literature that, though there is an ample number of publications in curriculum design, TLP, assessments, etc., still institutions face challenges in implementing OBE and the accreditation process. Very few researchers have addressed the compliance of the designed curriculum with the POs. Hence, an attempt has been made in this article to identify the gaps in the curriculum and suggest necessary actions to overcome the gaps.

3. Proposed Work

The proposed CCIM is presented in this section. The model performs the gap analysis of the given program curriculum and provides an action plan to enhance the curriculum compliance for each PO that is not addressed adequately through the existing curriculum. The architecture of CCIM, definitions of the terms related to CCIM, the process of Gap analysis, and actions to be taken for each PO to enhance curriculum compliance are presented in the following subsections.

Respective departments have to take the initiative to implement the proposed model for each program/s that comes under its umbrella. Department has to constitute an Academic Affairs Committee (AAC) for each program to monitor the academic affairs of the program. AAC is responsible for achieving academic excellence in the department by improving academic activities such as updating syllabi for various courses, verifying curriculum compliance for PO attainment, and improving teaching and evaluation techniques. The constitution, roles, and responsibilities of AAC are as follows.

Constituents:

- Head of the department
- Professors and Associate Professors

Roles and responsibilities:

- Scrutiny of the scheme and syllabus designed by the course coordinators.
- Identification and introduction of new courses as per the industry requirement.
- Preparation of a draft copy of the program curriculum to meet the POs and Program Educational Objectives (PEO)s of the program considering market trends, industry feedback, University Grants Commission (UGC)/All India Council for Technical Education (AICTE) norms, university norms, scheme, syllabus of reputed institutions, and existing syllabus.
- Approval of new teaching-learning methods based on course contents designed by the course coordinator/s.
- Verification of curriculum compliance for the attainment of POs.
- Setting up the minimum number of courses contributing to each POs from the curriculum.
- Checking for the attainment of all POs at the end of each academic year.

A. Curriculum Compliance Improvement Model

As discussed earlier, only the first five POs are addressed through the curriculum. To address the professional POs, the course coordinator/s has to plan suitable actions and get them approved by the AAC before implementation. The proper curriculum design and planning, and incorporation of actions in the course ensure that all the twelve skills are acquired by engineering students at the time of graduation. The architecture for implementing the CCIM is presented in Fig. 3, where the existing program curriculum and the minimum courses defined by the AAC are the inputs and the program curriculum addressing all the graduate attributes is the output. The gap analysis and the action plan are the major subcomponents of the architecture.

B. Definitions

The terms used in the proposed model are listed below along with definitions.

a. Course Outcomes

The COs are the assertions that describe what the students will demonstrate with respect to knowledge, skill, attitude, and behavior upon the completion of the course.

b. CO-PO matrix

This matrix defines the relationship between COs and POs. For example, the CO-PO matrix for the

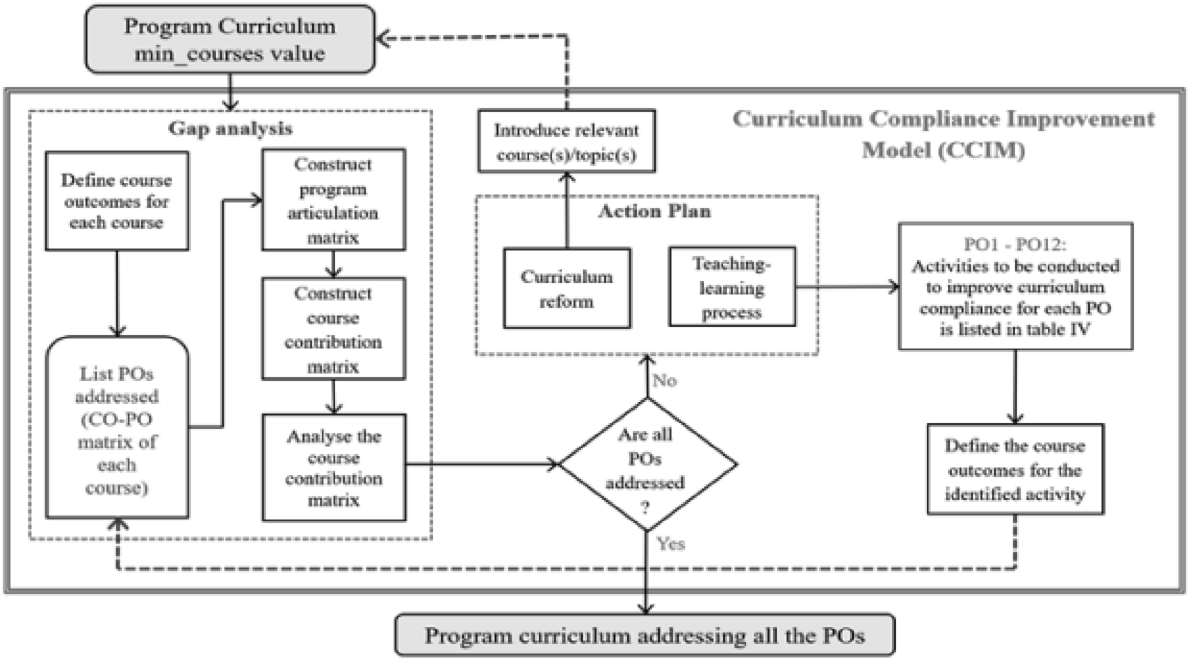

Fig. 3 : Curriculum Compliance Improvement Model

course CS404 is given in Table 1. It depicts that, four COs are defined for the course and are mapped to PO1, PO3, PO4, and PO5.

c. Program articulation matrix

The program articulation matrix is constructed by mapping POs addressed by each course and is shown in Table 2. Mapped POs are represented by '√', otherwise, it is '-'. As per the CO-PO matrix, course CS404 is addressing PO1, PO3, PO4, and PO5 and hence mapped to respective POs.

d. Course contribution matrix

It gives the number of courses contributing to each PO from the curriculum. This is obtained by summing all '√' in the respective PO column of Table 2 and the summed value is shown in Table 3.

e. min_courses

It represents the minimum number of courses to be contributed to each PO from the curriculum. This is defined by the AAC. For example, if min_courses is set to '5' by AAC, it indicates that at least 5 courses must address each PO from the curriculum.

f. num(PO)

This depicts the number of courses contributing to PO. This is obtained from the course contribution matrix. Table 3 depicts that num (PO1) = 7, num(PO2) = 3, and so on.

Table 1 : CO-PO matrix of the course CS404

COs \ POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓		✓									
CO2	✓			✓								
CO3	✓				✓							
CO4	✓											
	PO1		**PO3**	**PO4**	**PO5**							

Table 2 : Program Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CS101	✓	-	-	-	-	-	-	-	-	-	-	-
CS102	✓	-	-	-	-	-	-	-	-	-	-	-
CS403	✓	-	✓	-	✓	-	-	-	-	-	-	-
CS404	✓	-	✓	✓	✓	-	-	-	-	-	-	-
..	..	..	..	..	..	..	..	..	..	..	..	..
CS6MP	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	✓
CS803	✓	✓	-	✓	✓	✓	-	-	-	-	✓	-
CS8MP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 3 : Course Contribution Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
Number of courses contributing to POs	7	3	4	4	5	2	2	2	2	2	3	2

C. Gap Analysis and Action plan

CCIM accepts the program curriculum and min_courses defined by the AAC as its input. Two major phases of CCIM are : (a) Gap analysis, and (b) Action plan, and each component is discussed below. Steps involved in gap analysis and action plan are given by Algorithm -A:

a. Gap Analysis

To identify the gaps in the curriculum initially a CO-PO matrix is constructed followed by the construction of a program articulation and course contribution matrix. Based on the min_courses value defined by AAC the gap analysis phase verifies whether the existing curriculum is addressing all the POs. If all the POs are addressed as per the standards set by the AAC, the existing syllabus is retained else, the action plan is invoked.

b. Action Plan

If all the graduate attributes are not addressed by the existing curriculum, the necessary action plans have to be implemented. The procedure to select the appropriate action plan is through Improve_compliance () and the flow chart for Improve_compliance () is given in Fig. 4. The gaps in the curriculum can be addressed in either of the following two ways

- Through curriculum reforms
- Through teaching-learning process

Improving compliance through curriculum reforms:

To achieve the prescribed threshold credits for each POs, the existing curriculum may need reforms. The AAC has to identify the POs that need to be addressed through curriculum reforms and take any of the following actions.

- Introduce a new theory course
- Introduce new topics to the existing theory course
- Introduce a new laboratory course
- Introduce new experiments, and tools to the existing laboratory course

Improving compliance through Teaching-learning Process:

If the gaps identified can be supplemented through the teaching-learning process, the appropriate actions for each PO are carried out through conducting suitable activities as summarized in Table 4. The

Algorithm – A: Gap analysis and action plan process

Step 1: **Gap analysis**
- a: Construct a CO-PO matrix for each course
- b: Construct program articulation matrix
- b: Construct course contribution matrix
- b: Analyze the course contribution matrix to check whether all POs are addressed

Step 2: If all POs satisfy the minimum criteria value as per *min_courses*, *go to* step 5

Step 3: //**Action Plan**: Invoke procedure which gives action plan for POs not having *min_courses* value *Improve_ compliance ()*

Step 4: Write COs for identified TLP activity, map CO to respective PO, and *go to step* 1

Step 5: Freeze the curriculum of the current academic year

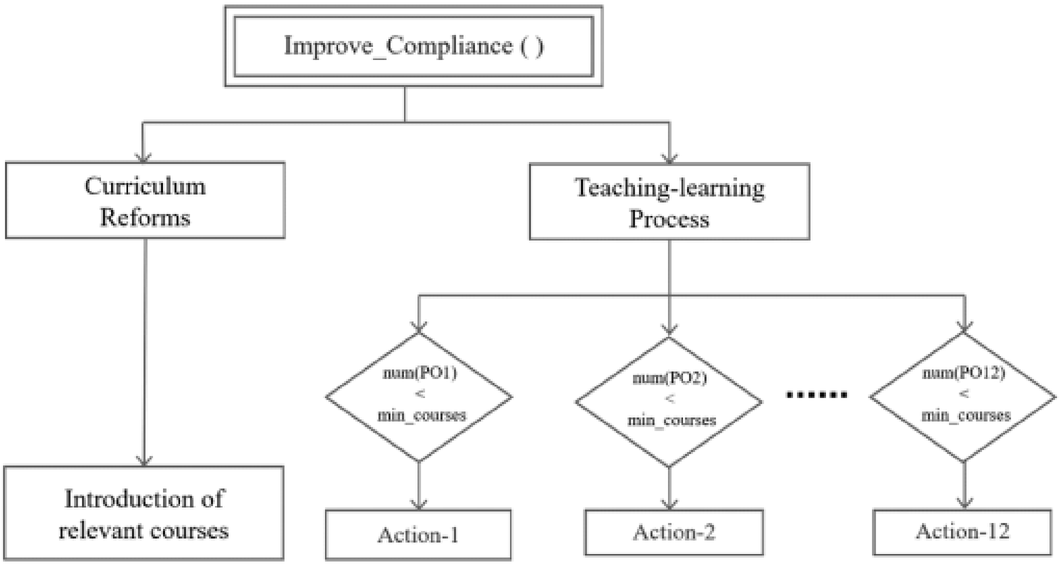

Fig. 4 : Number of credits contributing to each PO [num(PO)] verified against min_courses

Table 4 : Actions to improve curriculum compliance for each PO

Actions	Graduate attributes/POs	Teaching Learning Process (TLP)	Competency attained through TLP
Disciplinary Outcomes (PO1 – PO5)			
Action-1	**PO1:** Engineering knowledge:	• Students have to solve chapter - end problems in the majority of the courses.	Demonstrate competency in solving engineering problems
Action-2	**PO2:** Problem analysis	• A teacher has to conduct activities involving tasks such as problem formulation, data collection, validation, modeling, experimentation, and interpretation of results. • Identify courses and meticulously plan for group assignments and mini-projects involving at least two-three problem-analysis activities.	Demonstrate an ability to recognize, and formulate engineering problems that are complex and provide a solution, and analyze results.
Action-3	**PO3:** Design / Development of Solutions	• Identify courses and plan for mini projects/ Practical group assignments on health, environmental, cultural, safety, and societal issues. Insist students to provide design solutions by consulting stakeholders and domain experts.	Demonstrate an ability to provide various /alternate design solutions.

Action-4	**PO4:** Conduct investigations of complex problems	• Identify open-ended problems/experiments in any of the courses and insist students to identify an experimental approach to solve complex engineering problems. In addition, students have to integrate information from raw data and reach valid conclusions for the problem identified using appropriate procedures.	Demonstrate an ability to conduct experiments and able to provide reasonable conclusions by analy zing the result of an experiment.
Action-5	**PO5:** Modern tool usage	• Encourage the students to identify modern tools relevant to: ○ the course for solving a given problem ○ conduct laboratory experiments. Insist students to verify results obtained from tools. Obtained results shall be verified against the accuracy and limitations of the tool.	Demonstrate an ability to assess the suitability and tools constraints that are used for solving complex engineering problems.
Professional Outcomes (PO6 – PO12)			
Action-6	PO6: The engineer and society	• Identify courses and *plan for case studies* relevant to health, legal, societal, safety, and cultural issues and insist students to understand legislation, regulations, codes, and standards and describe engineering solutions relevant to issues.	Establish an understanding of engineering roles, legislation, regulations, codes, and principles in providing solutions pertaining to legal health, enviro nment public welfare , and safety.
Action-7	**PO7:** Environment and sustainability	• Identify courses and incorporate case studies that bring the attention of students concerning sustainability issues.	Demonstrate an ability to apply sustainable principles while providing design solutions.
Action-8	**PO8:** Ethics	• Include a rubric with a focus on ethical issues during the evaluation of mini projects, assignments, seminars, major projects, case studies, group assignments, open - ended problems, etc.	Demonstrate an ability to commit to professional responsibilities and ethics.
Action-9	**PO9:** Individual and teamwork	• Include a rubric with a focus ○ to evaluate contributions from individual/ team ○ to work as a team leader/member during the evaluation of mini projects, group assignments, major projects, group assignments, and wherever group activities are conducted.	Demonstrate effectively to work as an individual, and as a member or leader in diverse teams/multidisciplinary settings.
Action-10	**PO10:** Communication	• Encourage students to present and submit the report on assignments, mini projects, seminars, major projects, group activities, etc. • Provide web resources on prescribed self-study topics and insist students present and submit the report.	Demonstrate competency in listening, speaking, presenting, and comprehension.
Action-11	**PO11:** Project management and finance	• Insist students to apply project management tools to timetable the tasks of the major project, so it is accomplished on time and within the budget.	Demonstrate an ability to schedule/execute engineering activity for the given constraints such as time and budget.
Action-12	**PO12:** Life-long learning	• Identify course(s)/topics that require additional learning individually and independentl y by students and insist students to understand the concepts, present and submit the report. • Include a rubric with a focus on life-long learning during the evaluation of mini projects, assignments, seminars, major projects, case studies, group assignments, Internships, open-ended problems, etc. • Insist students to i dentify deficiencies or gaps in knowledge for the planned teaching learning activity and to provide a strategy to address the gaps.	Demonstrate the competencies • to identify gaps in existing solution and provide a strategy which closes the gap. • in understanding new courses/topics • to identify changing trends in engineering and providing engineering solution.

activities suggested are to be meticulously planned by course coordinator/s to improve compliance for POs attainment. The planned activities are to be designed, implemented, and assessed by the course coordinator/s. Relevant evaluation rubrics for assessment are to be developed as per the activity. As per the evaluation results, the extent of attainment of POs is estimated. The procedures for the assessment and attainment of POs are not in the scope of the article and it has to be addressed individually.

4. Case Study

Siddaganga Institute of Technology (SIT) is one of the self-financing leading institutes and is located in Tumakuru, a southern district of Karnataka, India. It is an autonomous institute under Visvesvaraya Technological University. SIT offers a Bachelor of Engineering (BE) program in CSE, and it is accredited by NBA. The curriculum of the CSE program is taken as a case study. IV, VI, and VIII semester courses of the academic year 2019-2020 are considered to illustrate.

Illustration of gap analysis and action plan process

For the illustration of the proposed model, courses of even semester in BE, and CSE program is considered and the list of IV, VI, and VIII semester courses along with credits are given in Table 5. Initially, AAC defines the minimum number of courses to be contributed to each PO for attainment. Let min_courses = 10 (only even semester courses are considered).

Step 1: Gap Analysis

a. The CO-PO matrix is constructed for each course in the curriculum

b. The program articulation matrix is constructed using the CO-PO matrix and is shown in Table 6. POs addressed by each course of IV, VI, and VIII

Table 5 : Courses and credits (total number of courses = 26)

SEMESTER - IV		SEMESTER - VI		SEMESTER - VIII	
Course title	Credits	Course title	Credits	Course title	Credits
Probability and Applications for IT	4	Mobile Application Development Laboratory	1.5	Foundations of Block Chain (PE)	3
ARM Microcontroller and Embedded Systems	3.5	Software Project Management	3		
		System Software and Compiler Design	4.5	High Performance Computing (PE)	3
Theory of Computation	3.5	Computer Networks	4		
Analysis and Design of Algorithms	3	Computer Networks Laboratory	1.5	Internet of Things (PE)	3
Object-Oriented Programming with C++	4	Mini Project	2	Foundation of Data Science (PE)	3
Unix and Shell Programming	3	Aptitude Related Analytical Skills	1		
Analysis and Design of Algorithms Laboratory	1.5	Web Technologies and its Applications	3	Technical Seminar	1
		Artificial Intelligence (PE)	3	Major Project	13
Microcontroller and Embedded Systems Laboratory	1.5	Cloud Computing (PE)	3	Cyber Security	3
		Programming with Python	3		
***Note:** PE – Professional Elective					

Table 6 :Program Articulation Matrix

Sl. No.	Course title	*min_courses* = 10											
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
IV SEMESTER COURSES													
1	Probability and Applications for IT	✓	-	-	-	✓	-	-	-	-	-	-	-
2	ARM Microcontroller and Embedded Systems	✓	-	✓	-	-	-	-	-	-	-	-	-
3	Object-Oriented Programming with C++	✓	✓	✓		-	-	-	-	-	-	-	-
4	Analysis and Design of Algorithms	✓	✓	✓	✓	-	-	-	-	-	-	-	-

5	Theory of Computation	✓	✓	✓	-	-	-	-	-	-	-	-	-
6	Unix and Shell Programming	✓	-	✓	-	✓	-	-	-	-	-	-	-
7	Analysis and Design of Algorithms Laboratory	✓	✓	✓	-	-	-	-	-	-	-	-	-
8	Microcontroller and Embedded Systems Laboratory	✓	-	✓	✓	✓	-	-	-	-	-	-	-
VI SEMESTER COURSES													
9	Software Project Management	✓	-	-	-	-	-	-	-	-	-	✓	-
10	Computer Networks	✓	✓		✓	-	-	-	-	-	-	-	-
11	System Software & Compiler Design	✓	✓	✓	-	-	-	-	-	-	-	-	-
12	Computer Networks Laboratory	✓	-	✓	-	✓	-	-	-	-	-	-	-
13	Mobile Application Development Laboratory	✓	-	-	-	✓	-	-	-	-	-	-	-
14	Mini Project	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
15	Aptitude Related Analytical Skills	✓	✓	-	-	-	-	-	-	-	-	-	-
16	Cloud Computing (PE)	✓	✓	-	-	✓	✓	-	-	-	-	-	-
17	Artificial Intelligence (PE)	✓	✓	✓	-	✓	-	-	-	-	-	-	-
18	Web Technologies and its Applications	✓	-	✓	-	✓	-	-	-	-	-	-	-
19	Programming with Python	✓	-	✓	-	✓	-	-	-	-	-	-	-
VIII SEMESTER COURSES													
20	Technical Seminar	✓	✓	-	✓	-	-	-	-	-	✓	-	-
21	Major Project	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Cyber Security	✓	✓	-	-	✓	✓	-	-	-	-	-	-
23	Foundations of Block Chain (PE)	✓	-	-	✓	✓	✓	-	-	-	-	-	-
24	High Performance Computing (PE)	✓	✓	✓	✓	-	-	-	-	-	-	-	-
25	Internet of Things (PE)	✓	-	-	✓	✓	✓	-	-	-	-	-	-
26	Foundation of Data Science (PE)	✓	✓	✓	✓	✓	-	-	-	-	-	-	-

Table 7 : Course Contribution Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
Number of courses contributing to PO	26	15	17	10	15	6	2	2	2	3	3	2

semesters are mapped to respective POs.

c. The course contribution matrix is derived from Table 6 and is shown in Table 7 and it gives the number of courses addressing each PO.

d. Analysis: From Table 7 it is observed that the number of courses contributing to PO1 - PO5 are 26, 15, 17, 10, and 15 respectively.

Step 2: The first five POs satisfy the min_courses value. However, PO6 - PO12 are not satisfying the minimum criteria as defined by the AAC. Hence, go to Step 3. Check whether all POs satisfy the min_courses value. If satisfied go to step 5.

Step 3: From gap analysis in step 1, it is identified that the PO6-PO12 are not adequately addressed, hence suitable Teaching –Learning activities need to be planned. Therefore, invoke Improve_ compliance() procedure which gives an action plan for POs not having min_courses value

As a sample, the actions listed in Table 4 for PO6 are demonstrated under the section 'Plan to improve the compliance of PO6'. This procedure is repeated until all POs reach the min_course criteria.

Step 4: The actions planned in step 3 are implemented under the section 'Implementation of planned action'. And the syllabi, CO-PO matrix, program articulation matrix, and course contribution matrix are updated accordingly, then go to step 1.

Step 5: When PO6-PO12 satisfies the min_courses value, the curriculum for the current academic year shall be freezed.

Plan to improve the compliance of PO6:

The activities listed in Table 4 against Action-6 are demonstrated in this section to show the improvement in curriculum compliance for the attainment of PO6. As per Action 6 in Table 4, AAC identifies the course

Table 8 : Case Study

Activity title: A case study on "*Disease Diagnosis*"
Students are instructed to follow the steps below: *Step 1* : Form a group comprising 2-4 students. *Step 2* : Each group visits local hospitals of their choice and understand the need for AI solution for diseasediagnosis. *Step 3* : Formulate a problem statement and conduct a literature survey on the existing solutions. Propose an AI-based solution. *Step 4* : Prepare a report on the proposed solution and present it.

Table 9 : Program outcomes addressed through a case study

Activity	Maps to	Justification for mapping	Acquired skill
Each group visits local hospitals of their choice and understand the need for AI solution for disease diagnosis.	PO6	This makes the students understand engineering's role in providing a solution to people and society.	Understanding the impact of Engineering on societal issues.
Formulate a problem statement and do a literature survey on the existing solution. Propose an AI-based solution.	PO2	This activity helps the students to acquire problem analyzing skills.	Problem analysis
Students work in a group; hence it creates an opportunity for students to • define rules, roles, charters, and agendas. • discuss, listen to, and respect each other.	PO9	This will help a student to work individually and as a team member effectively.	Individual and teamwork
Prepare a report on the proposed solution and present the same.	PO10	This will help the students to demonstrate effective communication at various levels.	Communication skills
Identify the gaps in existing solution, and proposes AI-based solutions.	PO12	This will help the students to recognize varying trends in engineering knowledge and practice.	Life-long learning

Table 10 : Updated course contribution matrix

`	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
Number of courses contributing to PO (before inclusion of case study)	26	15	17	10	15	6	2	2	2	3	3	2
Case study (addressed POs)		+1				+1			+1	+1		+1
Number of courses contributing to PO (After inclusion of case study)	26	16	17	10	15	7	2	2	3	4	3	3

Artificial Intelligence from the VI semester. The AAC suggests the course coordinator of the Artificial Intelligence plan for a case study. Course coordinators meticulously plan for a case study on Disease Diagnosis and an action plan to execute the case study is given in Table 8.

Implementation of planned action:

The POs addressed due to planning of case study assignment on 'disease diagnosis' are shown in Table 9 along with justification for mapping and the skills acquired by students. Accordingly, the incorporation of case study in respective courses address POs such as PO2, PO6, PO9, and PO10, thereby the number of courses contributing to concerned POs is incremented by one as shown in Table 10.

From the Table 10 , it is observed that , planned activity enhances curriculum compliance for the attainment of PO2, PO6, PO9, PO10, and PO12 Similarly, the improve_compliance() procedure is repeated for PO6-PO12, until all POs satisfy the minimum criteria value i.e. min_courses as defined by the AAC of the department. The case study presented in the current article serves as a proof of concept. Overall, the model proposed is useful for Tier-1 institutions that are keen on their students attaining all the graduating attributes. Also, they can apply this model to identify and rectify the gaps in the curriculum and document the same for the accreditation procedure.

5. Conclusion

Engineering education has gone through a paradigm shift from a teacher-centric model to a student-centric model in recent times. The OBE system emphasizes a student-centric learning model which stresses quantifying the outcomes of learning and the holistic growth of the students. In this direction NBA in India has set quality norms such that each program of the engineering institutions has to adhere to the standards, which are based on OBE. Each undergraduate student has to attain the graduate attributes defined by NBA. The curriculum is one of the main pillars of engineering education through which graduate attributes are attained. The design of the curriculum and its implementation through the teaching-learning process play a vital role in the attainment of graduate attributes. When the designed curriculum is inadequate to attain all the POs, additional measures have to be taken by the Academic Affairs Committee of the program.

In this direction, a Curriculum Compliance Improvement Model (CCIM) is proposed to ensure curriculum compliance for PO attainment. The curriculum is analyzed to identify the gaps and suitable actions to address the gap suggested. The proposed model is illustrated through a case study. It is concluded that the proposed model can be useful for Tier-1 institutions, keen about their students being equipped with the desired knowledge, skill, attitude, and behavior at the time of graduation. The accreditation procedure mainly focuses on evaluating the education process through documentation. In recent days every institution thrust on getting its programs accredited to justify its quality of education. In this view, the proposed model can aid them to identify and rectify the gaps in the curriculum and documenting the same for the accreditation procedure.

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