Outcome Based Education (OBE): Defining the Process and Practice for Engineering Education

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ABSTRACT Outcome Based Education aka OBE is one of the de-facto standards for modern educational system. An outcome is a culminating demonstration of learning that the students should be able to do at the end of a course, and in process at end of the degree program. Therefore, OBE is an approach to education in which decisions about the curriculum are driven by the exit learning outcomes that the students should perform in their professional life. An engineer is a unique combination of different skill sets that must be mastered to resolve nontrivial real-life engineering problems. Consequently, the adoption of OBE in engineering education is the compelling necessity. This study offers a comprehensive, ready to adopt OBE framework for tertiary level engineering programs complying with the benchmark mandates of the OBE and the guidelines of Washington Accord. Additionally, the framework is successfully deployed in the department of CSE, IUB for the design and implementation of the undergraduate CSE program, a transcript of which is also documented. This will assist the concerned institutions to design their program in OBE model to gain international academic equivalency and accreditation.

INDEX TERMS Outcome based education (OBE), program educational objective (PEO), program learning outcome (PLO), course learning outcome (CLO), rubric, continuous quality improvement (CQI).

I. INTRODUCTION
A good archer is not known by his arrows but by his aim. ~ Thomas Fuller

Outcome-based education aka OBE is a performance-based educational method in developing cutting edge tertiary level curriculum and is becoming a de-facto standard for many established and emerging education systems, e.g., in Europe, USA, Australia, Malaysia, India, Pakistan, Indonesia and Bangladesh. The emphasis of this method is on the development of pragmatic skill sets rather than emphasising on the educational process eloquence. In OBE, perpetration defines the process, conversely, students’ pragmatic learning or skill set development (defined as Outcomes in OBE) should drive the curriculum definition and its’ organisation, course content selection, teaching methods, and the assessment process [1], [2]. Therefore, OBE is an approach to education in which decisions about the curriculum are driven by the exit learning outcomes that the students should display at the end of each course and in the process at the end of their graduation [2], [3]. This mechanism of OBE is crucial for developing engineering graduates who are knowledgeable, creative, highly skilled, flexible, innovative, a critical thinker, problem solver and possess the entrepreneurial spirit to tackle the challenges of the 4th industrial revolution [4], [5].

OBE creates an atmosphere where students are driven by what they can learn and use to solve real-life problems [3]. Therefore, OBE teaching is inductive, which many academic researchers argue a better way to motivate students in learning. Because, in inductive teaching, the teacher begins by presenting students with a specific challenge, such as a complex
real world problem to be solved, data on a specific research phenomena to interpret, or a case study to analyse [2], [3]. The learning process is thereafter supported by high-quality sharable resources, teaching and assessments with standard rubrics [4].

In a nutshell, OBE is a combination of three types of competencies: a) practical: knowing how to do things, ability to make decisions, b) fundamental: understanding what you are doing and why, c) reflective: learn and adapt through self-reflection; apply knowledge appropriately and responsibly. Learners take responsibility for their own learning and are motivated by feedback and affirmation of their worth [6], [7].

To this end, the UGC (University Grant Commission), Bangladesh as well as the IEB (Institution of Engineers, Bangladesh) have instructed all the Engineering Universities including 52 public universities [8] and 108 private universities [9] to revise their undergraduate program curricula in favor of the OBE process and provided resources to support the transition [10]. Majority of the Universities also took initiatives on this track [11].

However, the effort is falling short due to the lack of comprehensive understanding of the OBE process and practices, proper documentation, and a full-fledged OBE framework that concretely defines the core essence of the OBE mandate. Therefore, this research is targeted in filling up this vacuum through empirical investigation on the following research questions.

**RQ1** What OBE framework can be defined to assist the academic stake holders (e.g., Teachers, Students, and CQI cell) to learn, design and implement an engineering program in OBE model?

**RQ2** How to instantiate the framework to transform an Engineering Program to OBE model considering the design, implementation and quality mandates?

**RQ3** What academic quality assurance model can be a good fit for the Continuous Quality Improvement (CQI) in OBE process and practices?

In order to address these research questions, a constructive research approach is adopted to define a comprehensive academic framework that possesses the core essence of the OBE mandates, then provide an empirical validation of the framework by successfully deploying it to design the Computer Science and Engineering (CSE) Program offered by the Department of CSE, Independent University (IUB) [38], one of the top ranked private universities in Bangladesh. Alongside, a CQI model is defined and instantiated to address the quality assurance requirements of the OBE process.

Our literature survey along this track identified an ample amount of research contributions detailing different perspectives of the OBE process and practices. However, very little has been reported to offer a comprehensive framework that supports encyclopedic understanding and implementation of the process. This study is a humble effort to address this void in research by formally defining the OBE process and practices in terms of a readily adoptable academic framework for engineering studies at tertiary level.

This paper is organised as follows, in Section II the philosophy of OBE is defined and the arguments in favor of its’ adoption is rationalized along with the motivation for this work, Section III details the OBE mandate that an Engineering Program must comply for a clinical adoption of the same, Section IV highlights the research method adopted for the study, Section V details the OBE framework and the CQI model that strictly comply with the mandate, Section VI presents a successful instantiation of the framework in the CSE department, Independent University, weaknesses and challenges faced during the instantiation process is discussed in Section VII and finally, pave to the future work and the concluding remarks are drawn in Section VIII and IX, respectively.

### II. OUTCOME BASED EDUCATION: BACKGROUND AND RATIONALE

Outcome Based Education (OBE) is a way of designing, developing, delivering, and documenting instruction in terms of its intended goals and Outcomes [12]. Therefore, the curriculum is developed from the outcomes we want students to demonstrate, rather than writing objectives for the curriculum we already have [13].

Going by this perception, OBE is easy to conceptualise but difficult to define [13], [14]. The reasons are multi-fold. First, the educational outcomes need to be clearly specified and explicitly communicated with all concerned parties, including the students, the teachers, the industry, and academic stakeholders. Second, the curriculum and the course contents, their organisation, educational strategies, teaching methods, assessment procedures must be defined in terms of the learning outcomes. Finally, the educational environment should be adjusted in the context of the learning outcomes, and all amendments to be adequately documented. All in all, OBE defines a tractable method to teach, measure and track all the engineering skill sets that are indispensable for professional establishment of the students.

Therefore, OBE is a paradigm shift in the academic process and practices, moving away from the Traditional Education (TE). The TE is an input-based educational process where the learning is content based, assessment is solely based on the conventional examinations, and any possible result is happily accepted. The sole motive of learning thus boils down to getting good grades and attain a high CGPA at the end of the program [15], [16]. Therefore, TE is focused on CGPA which is a monotonous way to evaluate a student, leaving a little means to identify the strength or weaknesses of a student. With OBE, we can measure the strengths and weaknesses of the students with evidence and can prescribe an academic means to improve their learning. A comparative perspective between these two educational paradigms is shown in Figure 1.

The development of OBE was heavily contributed by the pioneer work of Spady during 1988 in schools of the United States of America. The initial motive was to carry out reforms through increasing accountability, while patronizing more
school autonomy or flexibility [2], [17], [18]. Later on it gradually spread within the realm of Medical Education as well [19], [20], [21]. However, this move towards OBE also attracted adverse criticism from many academic stakeholders. One argument is that education should be open-ended, not constrained by outcomes [2], whereas others flagged it inappropriate to include and emphasise on attitudes and values in the stated outcomes [2]. On this track [17] and [22] criticize OBE, highlighting that education should be valued for its own sake, not because it leads to some outcomes. According to them, defining education as a set of outcomes often restricts the wonderful, unpredictable voyages of teaching and learning through discovery and inquiry.

However, this liberal notion of education might hold for arts, humanities, or related disciplines [23] but not for disciplines like medical science or engineering where we cannot afford the luxury of ignoring the graduates who acquire a specified set of skill through clearly specified learning outcomes in the curriculum [2], [24]. Realizing the benefits of OBE, in the Europe, the training over the OBE process and practices got significant acceptance in the universities in recent decade [24], [25].

However, this is worth noticing that OBE is not the only academic model that strive for outcome driven educational process. Rather, the CDIO framework is a highly appreciated academic model adopted by hundreds of universities across the globe for engineering education [26], [27]. At its’ core, the CDIO framework essentially emphasises on the commonly shared presumption that engineering graduates preferably become competent to Conceive(C) – Design(D) — Implement(I) — Operate(O) complex value-added engineering methods and tools to create real-world systems and products [28], [29], [30]. In order to train such engineering graduates, the CDIO conducts 12 standards for program evaluation [28], [31] namely, CDIO as the context, CDIO syllabus outcomes, integrated curriculum, introduction to engineering, design build experiences, CDIO workspaces, integrated learning experiences, active learning, enhancement of staff CDIO skills, enhancement of staff teaching skills, CDIO skills assessment and CDIO program evaluation.

In academic research and development CDIO is often applied with other educational criteria and approaches, such as ABET accreditation [28], [32], STEEP analysis and knowledge taxonomies [31], and OBE model [32] to develop engineering curriculum.

However, this research is strictly focused on the adoption of OBE model in engineering education due to the fact that in recent years, the academic regulatory bodies for tertiary education in Bangladesh, the University Grant Commission (UGC) and the Institution of Engineers(IEB) have made it compulsory for every university in the country to revise the curriculum of all degree programs into OBE model [2], [4], [10], [11]. The motive is to ensure the quality of engineering education through standardisation of academic process and practices, and to achieve international accreditation and equivalency [5].

Additionally, this deployment of OBE in all the universities and across all the programs in Bangladesh will dully contribute to the attainment of the following SDGs of the Peoples Republic of Bangladesh [33].

a. Quality Education (SDG 4)
   The adoption of the OBE framework will create an inclusive & equitable quality engineering learning and feedback mechanism. This in turn will ensure lifelong learning for the graduates where they can effectively apply the learned engineering knowledge.

b. Industry, Innovation, and Infrastructure (SDG 9)
   A learning system where students and teachers alike can explicitly build the relationship between the learned knowledge and its’ pragmatic utilization, there exists ample possibility of innovative entrepreneurship to accelerate 4th IR in Bangladesh.

III. OUTCOME BASED EDUCATION: MANDATE

The principal mandate of Outcome Based Education (OBE) specifies the outcomes, students should be able to demonstrate upon leaving the system [17]. To achieve this, OBE advice to implement or adjust all necessary academic processes to ensuring that students master those outcomes [34]. For an Engineering Program to exhaustively comply with OBE principles, following mandates (Table 1) need to be met [34], [35].
TABLE 1. The OBE mandates.

| (a) | A collectively endorsed vision statement that reflects commitment to success for all students and corresponding mission that provides the means for translating that commitment into action. |
| (b) | Clearly defined publicly derived exit outcomes commonly known as PEO (Program Educational Objectives) and PLO (Program Learning Outcomes) that students must demonstrate at the point of their graduation. |
| (c) | A tightly articulated curriculum framework of program, course and unit learning outcomes (CLO) that derive from the exit outcomes. |
| (d) | A system of instructional decision making and delivery that employs a variety of methods, assures successful demonstration of all outcomes (CLOs) and provides more than one chance for students to be successful. |
| (e) | A criterion-referenced system (commonly known as Rubrics) of assessment. This ensures benchmark assessment practice that is transparent, focused, unbiased and performance driven. |
| (f) | An ongoing system of program improvement, commonly known as CQI (Continuous Quality Improvement) process that includes academic process measurement and improvement, staff accountability, effective leadership and staff collaboration. |
| (g) | A database of significant, visionary outcomes for all students, plus key indicators of the program effectiveness, that is used and updated regularly to improve conditions and practices that affect student and staff success. |

IV. SCOPE OF THE STUDY AND METHODOLOGY

The core contribution of this study is three-fold.

To develop a comprehensive OBE framework for tertiary level engineering programs. Tertiary level program refers to the post-secondary education offered by the universities, and technical colleges [36]. These programs focus on learning endeavors in specialised fields, a successful culmination of which leads to the achievement of an academic degree certificate [37]. The proposed framework must comply with the benchmark mandates of the OBE process and practices as dictated in Section III. Moreover, the OBE guidelines offered by the Washington Accord [5] and the BAETE, IEB [10] are duly addressed within the framework to ensure national and international academic equivalency and accreditation. This framework is detailed in Section V-A.

Alongside, an academic quality assurance model is developed as part of the proposed OBE framework to track, monitor, measure and plan for the continuous quality improvement (CQI) within the OBE process and practices. Section V-E articulates this model.

Finally, deploy the proposed framework to design and implement the undergraduate CSE program offered by the Department of Computer Science and Engineering (CSE), Independent University (IUB), Bangladesh [38]. A transcript of this implementation is documented in Section VI to demonstrate the concrete conceptualisation and an empirical validation of the framework.

The overall contribution of this paper will effectively support all the concerned stakeholders by offering in-depth understanding of (a) the Outcome Based Education (OBE) process and practices, (b) a detail step-by-step process definition for developing a program curriculum and associated teaching, learning and assessment strategies in OBE, and (c) adopting a evidence based academic process monitoring, assessment and accreditation strategy for ensuring continuous quality improvement (CQI). The academic institutions, the departments, faculties, students, the CQI (Continuous Quality Improvement) monitoring cell, and the accreditation bodies (e.g., UGC and IEB) are among the beneficiary stakeholders.

In concrete terms, the institution has a ready to adopt reference framework with all necessary detail to learn, design, implement and practice OBE within an engineering program. Alongside, the CQI cell can track and evaluate the key parameters of the OBE process to plan for progressive quality improvement. Finally, the governing and accreditation bodies have a benchmark framework for coherent and homogeneous assessment of all the engineering programs across the universities to ensure alignment with the international educational standards.

To conduct this study, the Constructive Research Approach (CRA) is fostered as the core research method. By definition, CRA offers a methodology that creates innovative constructions to solve real world problems and thus contributes to the field of study where it is applied [39], [40], [41]. The concrete adoption of the CRA mandates in relation to this research is presented in Figure 2 and is elaborated below. [39], [41]:

(a) CRA method empirically investigates for a real-world issue/problem which requires solution and acquire in-depth understanding on the issue. Then, define the requirements based on the understanding to be implemented for resolving the issue. Accordingly, this study carried out a detail survey on the contemporary research on OBE process, practices, and mandates. Reported results and guidelines are accumulated to address the need for developing the framework.

(b) Design innovative artefact to solve the issue, and empirically validate the designed solution, and make a theoretical contribution through carefully linking the solution to existing body of knowledge. The designed OBE framework and the integrated CQI model accumulate the core mandates of the OBE and consists of the best practices from the related research. The framework is then applied for the design and implementation of an engineering program that signifies its’ empirical validation.

V. OUTCOME BASED EDUCATION (OBE): PROCESS AND PRACTICE

Engineering accreditation standards are derived from the philosophy, paradigm and principles of the Outcome Based Education (OBE) model [12], [13], [14], [15], [19], [42], [43]. These standards are defined by the International Engineering Alliance’s (IEA), and Washington Accord [5] for worldwide equivalency and quality assurance of engineering education at tertiary level.

This research is committed to examine the essential theories and practices of authentic OBE model for the
implementation of a holistic and comprehensive educational framework for tertiary level Engineering Program. In the following sections the OBE framework is detailed, and a case study is presented thereafter to rationalise the applicability of the same.

A. THE OBE FRAMEWORK

The proposed framework as defined in Figure 3 is the comprehensive realization of the OBE mandates (detailed in Section III) and the guidelines suggested by the Washington Accord [5] and BAETE accreditation manual [10] for Engineering Education. This model is precise and compact, yet comprehensive enough to address each key stake and activity that needs to be accomplished for a successful adoption of OBE within an Engineering program.

According to this framework, there should have four distinct but interconnected processes which need to be executed in sequence. At first, the process inception (segment (a) in Figure 3) has to be conducted. This includes defining the vision and corresponding mission statements for the program. Relating to the mission, Program Educational Objectives (PEO) should be developed. The PEOs, in a nutshell, are the desired professional attributes/engineering abilities achievable by the graduates within 3 to 5 years of their graduation. Finally, a set of PLOs (Program Learning Outcome) are defined and mapped with the PEOs. These PLOs dictate the engineering qualities that students must progressively learn during their graduation. A relationship among these components is presented in Figure 4 and is detailed across the Sections V-B1 to V-B3. Furthermore, the structure of the curriculum must provide both breadth and depth within the range of engineering and science topics consistent with the PEOs, PLOs and students’ learning outcomes.

1) DEFINE VISION AND MISSION

Vision and mission statements are strategic public declarations of a Program, Department, Faculty or the University to indicate the purpose and priorities of that entity. For an Engineering Program, vision and mission statements define the purpose of the program and how students should learn, respectively. Therefore, the Vision statement must outline
definition should be consistent with the vision and mission statements of the Program.

(b) Each PEO must be supported by well-defined program curriculum and teaching-learning process.

(c) A clear justification on how the curriculum and the academic process contribute to the attainment of the PEOs.

Additionally, vision and mission statements can keep the program on track by creating a bridge between the department and various stakeholders, guiding the decision-making process for resource allocation, policy formation and progressive improvement.

2) DEFINE PROGRAM EDUCATIONAL OBJECTIVE (PEO)

Program Educational Objectives (PEOs) are the broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve. PEOs can be assessed based on the attributes and accomplishments of the graduates who have worked for 3 to 5 years after graduation [10]. Also, PEO definitions should comply with the mission statements of the program [19]. An Engineering program should define PEOs that are clear, concise, assessable, and realistic within the context of available resources. The PEO definition should adhere to the requirements listed in Table 2 [10], [19].

Additionally, the PEO attainment should be measured periodically to evaluate the effectiveness of the program. For this, a well-defined evaluation process need to be prepared and executed. This process should comply with the guidelines detailed in Table 3.

3) DEFINE PROGRAM LEARNING OUTCOME (PLO) AND PROGRAM SPECIFIC OUTCOME (PSO)

Program Learning Outcomes (PLOs) or graduate attributes are the narrower statements that describe what students are expected to know and be able to do by the time of graduation [2], [5], [10]. PLO statements relate to the knowledge, skills, and attitudes that the students acquire progressively throughout the program. The program curriculum and courses must be designed and executed accordingly so that by the time of graduation, students have achieved an acceptable minimum level of knowledge, skills and behavioural traits addressed by the PLOs.
To comply with the requirements of Washington Accord [5] and BAEETE [10], [11] guidelines, an Engineering programs must achieve the 12 (twelve) PLOs as defined in Table 4. In addition to these PLOs, the engineering program may define and include additional ones [10]. These additional set of PLOs that are defined beyond the 12 mandatory ones (in Table 4) are popularly termed as the Program Specific Outcomes (PSOs). There are usually two to four PSOs defined for the program. This task of PSO definition is performed by the head of the department with full cooperation of the expert faculties, and get the consent from the head of the institution. According to the standards, the PSOs must be defined in relation to the Program Educational Objectives (PEOs). This implies that a PSO should precisely state what specific knowledge, skills and attitude the graduates should achieve at the point of their graduation that will assist them to attain the corresponding PEO in their professional life.

To accomplish these PLOs (Table 4) and the PSOs, the program curriculum should encompasses all the attributes from the Knowledge Profile (K1 – K8), the ranges of Complex Problem Solving (P1 – P7) and Complex Engineering Activities (A1 – A5) as presented in the supplementary material.

4) RELATIONSHIP AMONG THE THREE

Figure 4 draws the relationship and dependency among the three components, i.e., the Vision and Mission, the Program Educational Objective (PEO) and the Program Learning Outcome (PEO). This relationship dictates that the program vision is achievable through the execution of the mission statements, which in turn must be reflected in the PEOs. PEOs are attained by the graduates within 3 to 5 years of their graduation. Finally, the PEOs are mapped to the PLOs which provide a tractable set of engineering attributes that the students must progressively learn during the period of their graduation.

C. PROCESS EXECUTION: COURSE LEVEL

At the course level, the OBE process defines several key activities that involves the restructuring of each course outline/curriculum, sketch the Course Learning Outcomes (CLOs) and their mapping with the PLOs, defining teaching and learning methods, associating appropriate evaluation and assessment tools, and a detailed reporting practices in education [44]. This paradigm shift in academic practice will reflect in the achievement of high order learning and mastery of the students rather than the accumulation of course credits only [45], [46].

1) DEFINE COURSE LEARNING OUTCOME (CLO)

In the OBE model, each course in the curriculum should have a set of CLOs depicting what level of engineering knowledge and skills the students are able to acquire with successful completion of the the course [20], [47]. Therefore, CLOs are specific to a course characteristics, the position / level of the course in the curriculum and the graduation requirement of the specific major [47]. A CLO within a course should define,

| TABLE 4. Definition of PLOs that must be achieved by the engineering program. |
|-----------------------------|-----------------------------|
| **[PLO-a]** Engineering knowledge: Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in K1 to K4 (see appendix) respectively to the solution of complex engineering problems. |
| **[PLO-b]** Problem analysis: Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (K1 to K4) |
| **[PLO-c]** Design/development of solutions: Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (K5) |
| **[PLO-d]** Investigation: Conduct investigations of complex problems using research-based knowledge (K8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions. |
| **[PLO-e]** Modern tool usage: Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering problems, with an understanding of the limitations. (K6) |
| **[PLO-f]** The engineer and society: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems. (K7) |
| **[PLO-g]** Environment and sustainability: Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts. (K7) |
| **[PLO-h]** Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. (K7) |
| **[PLO-i]** Individual work and teamwork: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings. |
| **[PLO-j]** Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentiations, and give and receive clear instructions. |
| **[PLO-k]** Project management and finance: Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments. |
| **[PLO-l]** Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change. |

What students would know and be able to do after completion of a course [20]. Therefore, each course in the program must have multiple CLOs.

Each of the CLOs should be appropriately defined using action verbs chosen from the Blooms’ Taxonomy [21], [48]. This is worth mentioning here that the classical Blooms Taxonomy proposed during 1950’s [48] is not adopted for this study due its’ inherited limitations to cover all perspectives of human learning [49]. Rather, the revised Blooms taxonomy proposed by Anderson and Krathwohl [50], [51] is used.
owing to its comprehensiveness and greater acceptance in the academic world. This taxonomy of educational objectives is a framework of action verbs for classifying statements of what the students are expected to learn [50], [51]. Therefore, the choice of action verbs defines the exact learning outcome that the students must learn and perform within the scope of a CLO. Furthermore, Blooms’ action verbs help to align a CLO definition to that of the PLO with which it has been mapped (as described below) [51].

Additionally, each CLO should be categorised into appropriate Booms Learning domain (e.g., cognitive, affective or psychomotor) based on the intended student learnings from that CLO [50], [51]. For reference, the cognitive domain measures the acquisition of the delivered knowledge, the affective domain measures the tacit knowledge acquired through a learning process (e.g., feelings, emotions, and attitudes), and the psychomotor domain tunes the human capabilities in solving real-life problems through the application of the earned knowledge and expertise. Figure 5 accumulates all these tasks that must be performed in sequence to define the CLOs for a course. A concrete conceptualisation of this CLO definition process is presented in Section VI-E.

Furthermore, a CLO must have either a strong or partial correlation with one or more PLOs. Ideally, this alignment should be either one-to-one or many-to-one from CLO to PLO. Accordingly, each course must have a clear correlation defined between the CLOs and the PLOs. This correlation dictates what learning outcomes (CLOs) from a given course will assist the students in achieving the engineering attributes/qualities defined by the mapped PLO. A snapshot of this correlation from course CLOs to the PLOs is presented in Figure 6.

The CLO definition activities should be carried out by the respective course faculties as they are the experts in the subject matter. All the faculty members should be adequately trained on how to establish the course learning outcomes by exploiting the Blooms Taxonomy of action verbs and learning levels, and associating them to an appropriate PLO [2], [3], [10], [11].
FIGURE 6. All the CLOs in each course in the curriculum must correspond to one of the 12 PLOs for engineering program.

TABLE 5. Guidelines for developing a course outline.

| (a) | Define the knowledge basis / course content that are core to the comprehensive teaching and learning of the CLOs. |
| (b) | Course content should be adequately detailed to understand what exactly are being taught and learned. |
| (c) | Course content should be organized across the weekly teaching hours and in categories (e.g., part of it covered in theory and in the lab sessions). The association between the weekly content and a CLO must be explicitly drawn. |
| (d) | Appropriate teaching (e.g., lecture, discussion, tutorial session) and evaluation methods (e.g., quiz, term examination, viva, report) for each CLO and the weekly course content should be documented. |

2) DEVELOP COURSE CONTENT
For each course, the knowledge basis (i.e., the syllabus/ course content) [20] need to be designed such that it covers comprehensively all the CLOs specified for that course [52]. The content must be registered in a document that is conventionally termed as the Course Outline. In relation to the knowledge base, the course outline must address the guidelines detailed in Table 5.

A significant issue in today’s engineering education is that the tech intensive engineering world is ever evolving, that constantly pouring cutting edge, contemporary knowledge expansion and associated techniques within the syllabus. This leads to the problem of information overload and curriculum congestion in designing the course content [53]. In this regard, consideration of the learning outcomes (CLOs) can lead to a meaningful assessment of what can be included in a course syllabus, what existing content can be complimented to better comply with the CLOs, and what can be omitted that was previously included [54], [55]. The CLOs may also provide guidance on the level of depth for a course content required to effectively teach a student at their stage of educational development. For instance, should the students be generally familiar with the concepts / topic and get a clear understanding on how to explore further on the subject matter, or, do they need a complete mastery of the topic to apply it solving real-life problems? [53], [54]

3) DEFINE ASSESSMENT APPROACH
Teaching in OBE is dedicated to assist the students to comprehensively learn the subject matter in achieving the CLOs. In doing so, both the course stakeholders (e.g., the teacher and the students) should know how well the student is performing in reaching the educational outcomes. Assessment is the process by which the teacher and the student, a like, gain knowledge of the student’s progress [35], [56].

The measurement of the CLOs and the attainment of the associated PLO for a student must be authentic and direct [16]. Direct methods of assessment are accomplished through the explicit evaluation of students’ knowledge or skills against measurable performance indicators or rubrics [57]. The assessment should be formulated in such a way that it should reflect as closely as possible to the actual tasks that students will face as an Engineer/ professional [20]. Direct assessment can be carried out using various assessment tools, such as examinations, class tests, assignments, project work, presentation, project reporting, viva, laboratory test, among others [3], [57]. A CLO can be assessed using one or more of the assessment tools as appropriately selected. Assessment reports should be evaluated based on well-defined rubrics (i.e., the explicit criteria to measure the extent to which a student learn and perform in each assessment).

The scores of all the assessments associated with a CLO, collectively contributes toward the attainment of that CLO, which in turn feeds into the assessment and the attainment of the mapped PLO. Therefore, the assessment of a PLO directly relies on the assessment of the relative CLOs [56]. This model of assessment is depicted in Figure 7. Once the assessment is done, the results of the attainment and associated evidence (e.g., the answer scripts, or project report) should be preserved and be produced as per requirement, e.g., for evaluation by the accreditation committee.

This model of performance measurement is called performance-based assessment [20]. This form of assessment requires that the student to use knowledge in a particular way to satisfactorily complete the task assigned. Therefore, students will not be able to perform satisfactorily if they lack either the knowledge or the ability to apply it. A knowledgeable student who is unable to comprehend the knowledge in assessing the given problem will not be able to solve it with the acquired knowledge. Therefore, this assessment approach in OBE evaluates the competency of the students.
which requires simultaneous application of knowledge and the ability to apply [20], [57].

4) LEARNING MEASUREMENT
Measuring the extent to which the students learned a subject matter in achieving a CLO should be done using the associated rubric. Each rubric consists of a set of measurable qualities which can evaluate the fundamental building blocks of that specific subject matter. Each measurable quality should have a assigned mark to be achieved. Accumulation of such marks in each quality would lead to the attainment of the CLO under consideration if the total mark exceeds a preset threshold. This measurement of learning is carried out for all participating students. The transcript of rubric evaluation is recorded along with the associated assessment evidence (e.g., exam scripts, class test scripts, Lab reports).

Finally, during the end of the course, a well-structured student feedback and teachers’ evaluation on the course are taken as part of the CQI process (discussed in Section V-E).

D. COMPREHENSIVE OBE PROCESS EXECUTION AND MONITORING
For program wide implementation of the OBE process and practices, each course in the curriculum must be adopted to OBE, as prescribed in Section V-C. Thereafter, for each course, semester wise course file must be maintained. This file should include the course curriculum, examination questions and answer scripts, a summary of the student performance and attainment of the outcomes with feedback for future development [52], [57], [58].

Furthermore, course wise attainment of the CLOs by the students should be used to measure the attainment of the corresponding PLOs, and in turn, the achievement of the PEOs. This record must be maintained for each student to track their learning progress, and to produce OBE certification and transcripts at the time of graduation.

Finally, archival of all the above-mentioned documentation in a structured template is required for the overall process monitoring and management. For instance, observing the learning progress of the students, measuring the ratio of CLO / PLO attainment in relation to individual course or the program, measuring which CLOs are better performing for effective learning of the students, and figuring out what need to be improved / adjusted further.

OBE model also requires validation, verification, and accreditation of the program from concerned authorities, e.g., from UGC and IEB for Universities in Bangladesh. This process requires evidence-based archiving of the course file and associated reporting. Therefore, having a well-defined process for monitoring and supervision of the OBE process at program level is an indispensable need.

E. CQI PROCESS MANAGEMENT: PROGRAM LEVEL
Continuous Quality Improvement (CQI) is a formal process initiated and overseen by a schools/department/program to audit and improve the quality of the education [59], [60].
This is a never-ending organisational process improvement cycle that uses quality indicators [61]. The origin and application of the CQI process can be traced back in the industries as an approach to quality control for services or products [62], [63].

According to OBE mandate, the engineering program must have a continuous quality improvement (CQI) mechanism [60]. It should demonstrate an established system for periodically compiling [60] the followings (Table 6).

**TABLE 6. Basics of the CQI process.**

| (a) | Track and Compile the OBE process intensive parameters to assess the compliance of the academic practice with the OBE mandate. |
| (b) | Include a mechanism for tracking and obtaining feedback from students, faculties, the graduates and their employers. |
| (c) | Getting feedback from the external stakeholders (e.g., academic and industry experts) on the academic KPIs. |
| (d) | Preparing a Self-Assessment Report (SAR) to be evaluated by the accreditation bodies. |

The outcomes of these assessments are evaluated, the shortcomings are identified, and are used for the improvement planning of the program during the next iteration. For instance, integrating the improvements within the course outlines for the upcoming semester [56], [58], [64].

A comprehensive CQI mechanism should mobilise two independent processes for measuring the quality; the outcome of which is collectively contributed towards the planning for academic quality improvement. These processes are shown in segment (d) in Figure 3 and are defined in Table 7.

**TABLE 7. CQI process definition.**

**OBE Process CQI**

This approach is an internal measurement [64] of the quality parameters concerning every aspect of the OBE process and practices followed in the engineering program. The process is elaborated in Section V-E1.

**CQI through External Evaluation**

This approach is an external measurement [64] of the quality parameters with the involvement of the neutral stakeholders participating from different domain of interests. For instance, academic and industry experts, members from the accreditation board, and the alumni. This process is elaborated in Section V-E2.

1) **OBE PROCESS CQI**

This approach of measuring quality is internal to the department offering the program [64]. Through this process, the department implements a CQI mechanism for measuring the parameters that contributes to both the academic and administrative eloquence. Figure 8 presents this approach with a detail taxonomy of (a) all the measurable parameters in distinct CQI categories, (b) associated methods for measuring those parameters, and (c) the segments of the OBE process to which the assessment can contribute for quality improvement.

According to this figure, internal quality can be assessed in five distinct CQI categories, e.g., *Student Feedback on the course, Faculty Feedback on the course, OBE Process statistics, and OBE Process Data Analytic.*

Student feedback should be taken at the end of each course while all the learning and assessment process is completed. This feedback should ask the students to assess their expectations, learning experience and overall satisfaction with the course. Therefore, observations on the appropriateness of the CLOs, depth of the course content, teaching and assessment methods should be the focus of this feedback.

The concerned course faculty should offer a transcript of OBE process implementation in the course. The faculty should assess the appropriateness of the CLOs in relation to their impact on student teaching and learning, evaluate depth of the course content against required domain specific knowledge, fitness of the assessment rubrics in evaluating student learning, and finally, on the plan for improvement. The program should evaluate the teaching quality on a regular basis considering the feedback from the faculty members and the students.

Apart from the current students, the graduating students can shed overarching light on the OBE process and practices. Student Exit Survey is designed to elicit this reflection from the passing students every year. Measurable key parameters in this survey should include, (a) the clarity and ease of the academic process and practices experienced by the student, (b) adequacy of assistance in academic, procedural, and extracurricular activities, (c) appropriateness of the resources in relation to teaching, learning, and research.

Finally, gleaning OBE process statistics and associated data analytic can produce both quantitative and qualitative insights that can be used for the CQI process in autonomous and semi-autonomous way. For instance, based on the evaluation record in each course, the attainment statistics of the CLOs and corresponding PLOs can be derived. This derivation can be done for the students, for individual courses and for the program. The scope of these statistics in executing the CQI process is multi-modal. For example, a students’ academic progress report in relation to the learning outcomes can be traced quantitatively as achievement of CLOs is directly proportional to how a student is absorbing the essence of the engineering curriculum. The absorbed learning curve of a student can be used to predict their future performance, and the ultimate achievements. If required, a constructive performance improvement plan can be prescribed indicating the key academic activities that the student must execute.

Outcome of the above mentioned categorical quality assessment can be linked to different key OBE process activities for quality improvement, as shown in Figure 8. For example, the outcome of the student feedback and the faculty feedback on a course can directly contribute to the improvement of the same (e.g., adjustment of the CLOs, revising the course contents and the teaching methods, among others).
2) EXTERNAL EVALUATION FOR CQI

This approach of CQI measurement is external [64] to the OBE process, and is carried out with the involvement of the neutral stakeholders participating from different domain of interest and expertise. Integral part of this external CQI measurement process are the academic experts on the concerned
engineering domain, technology intensive industry experts, affiliated accreditation board(s), and the alumni association.

Running this CQI process requires a regulated communication channel established between the educational institution and the external stakeholders, as listed above. A comprehensive framework for this is presented in Figure 9. This framework explicitly highlights the list of external participants, their scope of contribution in the CQI process, associated approaches / communication channel through which assessment and improvement plan can be developed, and finally, the OBE process areas where this CQI plan can be applied.

The industry experts often participate in the university academic activities in multiple capacities. This includes, supervising senior students in conducting their industry intensive internships, taking tech-intensive courses, or conducting focused workshops or seminars. The industry experts, therefore, should be encouraged to provide feedback concerning the quality of the teaching-learning process. This is effective for the overall quality improvement, as the industry has a fair share of contribution in developing an engineering curriculum and associated teaching environment that should facilitate contemporary knowledge integration and pragmatic teaching and learning.

Only the industry participation can ensure that the curriculum is relevant, updated, and meets the needs of the industry, particularly in the areas that experiencing rapid changes. Therefore, an engineering program should have an Industry Advisory Panel (IAP) and an Alumni Association (AA) for this purpose (as shown in Figure 9). The IAP or AA may meet at certain intervals with the department on defined agendas to develop plan for improvement (refer to column 2 in Figure 9).

Alumni Association (AA) can also contribute in the improvement of other key aspects of the OBE process, as they are the people who establish the bridge between the institution and the outside world. Therefore, alumni opinion should be collected on the curriculum, its’ relevance to the career development and job satisfaction, contribution of the program in developing the research and academic career, and the overall quality of services in relation to the resource allocation, access and utilisation, ease of administrative process and practices, and the student support.

The Academic Advisory Panel (AAP) on the other hand, is a university-level external committee that should be responsible for the academic quality assurance and enhancement processes. The AAP should be composed of distinguished academicians on the concerned domain, preferably external to the program and the university. This panel will assess all the key aspects of the OBE, assess then against the external best practice guidelines, relevant benchmark statements to derive quality improvement plan.

In general, the Accreditation Board monitors and enforces standards to enhance the quality of practice and reduce incompetence in the academic program [5], [11]. In doing so, the board forms an assessment committee with experts who periodically invigilates the program under scrutiny, assess several key aspects, and suggests accordingly. The committee reviews the Self-Assessment Reports (SAR) prepared by the program and evaluate it against the academic benchmarks and KPIs. In the process, they identify areas that need improvement and propose appropriate solutions. The program is accredited based on the merit of its’ OBE process eloquence.

Overall, the accreditation board evaluates and ensures the followings [10], [11], (a) ensure that graduates acquire all the required engineering attributes mandated by the national and international standards at the time of their graduation, (b) standardise and equivalent the engineering education program nationally and internationally, and (c) provide a mechanism for the continual improvement of existing engineering programs through evaluation and feedback [11].

Finally, assessment of the market demand should complement the overall external CQI process with concerns that might assist fine tuning the student guidance and grooming process. For instance, feedback from the employers can provide a fair and honest view about the efforts of an institution which creates the basic structure of a student’s knowledge, attitude, and personality [5], [35]. To maintain the continuous quality improvement, it is necessary to create a platform where employers can express their viewpoints about the graduates of an institution.

VI. CASE STUDY: IMPLEMENTATION OF OBE FOR CSE PROGRAM IN IUB

The prescribed OBE framework is realised in the Department of CSE, IUB [38] for the the program Bachelor in Computer Science and Engineering (CSE). This adoption is due to the following core concerns, (a) to extract the essence and benefits of the authentic OBE process and practices for the implementation of a holistic educational process that maximizes student learning, and (b) comply with the national (e.g., IEB, UGC) and international (e.g., Washington Accord) academic standardisation bodies for the equivalency and quality assurance of the degree offered.

A. PROCESS INCEPTION FOR THE CSE PROGRAM

The Department of CSE is offering the program for the last twenty-three years of her academic activities. Currently, CSE is the largest department in the university hosting more than two thousand three hundred students, and sixty distinguished faculty members [38]. The OBE is integrated within this program through a step-by-step execution of the activities prescribed in the proposed framework (Section V), the detail of which is presented in Table 8.

To carry out these activities, a consortium of highly skilled and qualified faculties from the School of Engineering, IUB is formed and facilitated. All the authors of this article are part of this consortium. Apart from their long traits of academic qualifications and track records, each of the authors often took part in the workshops, seminars and certification programs to enhance their knowledge and expertise on the OBE process. Four of the authors are the active members of the OBE curriculum evaluation board, IEB, and take part in periodic assessment of programs seeking for the accreditation.
TABLE 8. Step-by-Step process followed in adopting the OBE framework.

(a) **In-depth** understanding of the OBE framework as detailed in Section V.

(b) **Detail anatomy** of the exiting academic process.

(c) **Finding out** the mismatches between the two.

(d) **Listing down** the course of actions and deliverables in adopting the OBE framework.

(e) **Commence the execution** to realise the OBE process and practices in the program.

(f) **Additionally**, periodic seminars, workshops, invited talks, expert visit and assessment have been carried out for the assurance of authentic implementation and integration of the process.

B. VISION, MISSION AND PEO DEFINITION

The Vision and corresponding Mission statements of the program is articulated by following the guideline advocated in Section V-B1. Figure 10 details the two.

In a gradual decomposition of the mission statements, the next task is to delicately craft the Program Educational Objectives (PEOs) that will clearly state how the CSE graduates will accomplish their professional goals in perceiving the mission statements. This definition of the PEOs and their contribution towards the attainment of the Mission statements is materialized in Figures 11 and 12, respectively.

C. ADOPTION AND REFINEMENT OF THE PLOs

Program Learning Outcomes (PLOs) or graduate attributes [2], [5], [10] are the set of quantifiable engineering intensive knowledge, skill sets, and attitudes that the graduates must learn and apply with confidence by the time they are graduated. As persuaded in Section V-B3, for each Engineering program, the Washington Accord [5] and the local governing body in Bangladesh, BAETE [10], [11] have defined twelve mandatory PLOs. The engineering program must teach and measure these PLOs with adequate evidence for getting accreditation from the above-mentioned authorities.

Therefore, the CSE program has seamlessly adopted the listed PLOs (Table 4) to define its’ curriculum, and integrated them with the PEOs for tractable achievement by the graduates. The alignment between the twelve PLOs towards the attainment of the PEOs are detailed in Figure 13.
D. DEFINING THE CURRICULUM

The next step in the process is to overhaul the program curriculum with all possible adjustments in the existing courses, and integrate new courses with contemporary content to address the comprehensive attainment of the PLOs. There must be both breadth and depth in the curriculum across the range of engineering, science and ethical contents consistent with the PLOs [10]. Considering this mandate, the curriculum designed for the CSE program has a comprehensive coverage of all required academic dimensions for adequate teaching and learning of the designated PLOs. Figure 16 sketch the categorical view of the curriculum with a mapping towards the attainment of the PLOs. The detail curriculum can be found in the department website [65].

Finally, the design of each course outline should be such that through its’ execution the students will achieve an acceptable minimum level of engineering skill traits addressed by the mapped PLOs [10], [11]. This process is detailed in the following section.

E. COURSE LEVEL OBE PROCESS IMPLEMENTATION

Once the program level arrangements are set, the course level process execution begins. This is the most important process in the OBE framework that shapes the actual learning of the students. Therefore, the guidelines of the OBE framework (Figure 3) is adopted verbatim for defining the outline for each course, detailing the learning outcomes (CLOs), their association with the contents and evaluation strategies towards the attainment of the mapped PLOs. All these necessary definitions for each course are documented in individual course files, titled Course Outline.

For the demonstration of a course outline, the course titled Introduction to Computer Studies with course code CSC101 is selected. This is one of the mandatory foundation courses for the CSE students. The content is to teach Python as an introduction to the era of computer programming. Every semester around 20 (twenty) sections are offered with 30 students enrolled per section for this course. This is the most demanding and exhaustive course in the CSE program, as successful accomplishment of the course is the prerequisite to enrol for next level major courses.

The identification and documentation of the Course Learning Outcomes (CLOs) is the starting point of developing the course outline. The CLO matrix for the course CSC101 is described in Figure 15.

As can be observed from this figure, 4 (four) CLOs are defined for the course, two of them belongs to the Cognitive and the other two belongs to the Psychomotor learning level in the Blooms taxonomy. CLO1 and CLO2 focus on the development of demonstration, determination, and applied programming skills for the students. Whereas, CLO3 and CLO4 target to enhance the use of programming logic, and model/develop solutions for the given engineering challenges. This arrangements are shown in the columns 1, 2 and 3 of the Figure 15.

PLOs are often compound in nature having multiple engineering qualities to be achieved in order to attain them. Realising this fact, two CLOs are mapped to one PLO. As can be seen in column 4 and 5 in Figure 15, CLO1 and CLO2 are contributing towards the attainment of PLO-a, and CLO3 and CLO4 are supporting to achieve the PLO-e. This mapping means that a student must have to successfully learn and pass both CLO1 and CLO2 to achieve / pass PLO-a.
The next step in defining the course outline is to define the course content/curriculum that is tightly mapped towards the comprehensive learning of the listed CLOs. Additionally, appropriate teaching-learning strategies and CLO assessment method(s) must be bound with the content. Figure 16 shows (a) a snapshot of weekly course content/topic distribution for CSC101, (b) associated teaching-learning and assessment strategies, and (c) maps what weekly contents are relevant to which CLOs. This systematic detailing serves both the teachers and the students, a like to get a clear picture on what engineering qualities to be developed within the course, and how to deliver/acquire those qualities.

Following the content definition, the assessment and evaluation strategy should be detailed for the course. In accordance with the OBE guideline, assessment should be carried out in two strategic categories for a course, e.g., Continuous Assessment and Summative Assessment. There are several Assessment Tools within each of the categories that can be deployed/selected for evaluation.

A detail taxonomy of assessment for the course, CSC101 is developed in Figure 17. For each type of assessment, a equal share of marks (50%) are allocated. Under the Continuous Assessment type, five distinct assessment tools are used, namely class tests (15%), lab assessment (10%), lab test (10%), and Progressive Project Assessment (10%). For Summative Assessment type two assessment tools are selected, e.g., Mid Term Exam (20%) and Final Term Exam (30%).

Selection of assessment tools are underpinned by the definition of the CLOs to be assessed and the Blooms learning level associated with them (refer to Figure 15). Additionally, an explicit mapping between the four CLOs to that of the Assessment tools are drawn in Column 5 in Figure 17.

The final key element in developing the course outline is the definition of the Rubrics for each CLO that will be used to assess and mark the assessment taken for a CLO. To illustrate this arrangement, let’s consider that the CLO1 for course CSC101 (Figure 15) is going to be evaluated using Class Test-2 (refer to Figure 17). The course teacher prepares the assessment question by taking into account the topics associated with the CLO1 (Figure 16) and the Blooms Learning level (Figure 15) that defines the core learning objectives. Therefore, the questions for assessing the CLO1
in Class Test-2 must evaluate whether the students are able to demonstrate the ability to solve simple problems by applying their acquired domain specific knowledge.

Then to assess and measuring the extent to which the students learned the subject matter in achieving CLO-1, the Rubric associated with the CLO is used. Figure 18 presents the standard definition of the Rubric to evaluate Class Test-2 for CLO-1 in Course CSC101. Consistent with the definition of Rubrics from Section V-C4, the rubric for CLO-1 has five evaluation categories that is targeted to measure and grade five distinct qualities associated with the Demonstration skills. Each category is graded within the range of 0-5 marks which leads to a maximum attainable mark of 25. If a student can achieve at least 60% marks out of 25 then he/she will achieve the CLO-1. This threshold is often set by the course faculties who are the domain experts. Using rubrics of this sort, offers an academic standard, transparency and traceability in evaluation that helps the teachers in defending how and why a student is evaluated in relation to their performance.

Finally, the transcript of rubric evaluation, i.e., the student answer scripts for Class Test-2 is categorically stored in the official google drive folder for any further reference and correspondence.

**F. A COMPREHENSIVE COURSE OUTLINE**

A comprehensive course outline for OBE should be complemented with other necessary information apart from the mandatory ones sketched in Section VI-E. These additional amendments in the course outline often increases the comprehensiveness of the content, and its’ clarity among the concerned stakeholders, e.g., students, guardians, teachers, and evaluators. For reference, the detailed course outline for CSC101 is presented in the supplementary material.

**G. OBE CERTIFICATION PROCESS: PROGRAM LEVEL**

For the program wide implementation of the OBE process and practices, the approach depicted in Section VI-E is reproduced for each foundation, major and minor courses offered under the CSE program.

To measure the attainment of the CLOs and the corresponding PLOs in each course, an automated OBE evaluation sheet in XLSX has been developed. This evaluation sheet is designed for each course, and hold every detail required to automatically calculate the attainment of the CLOs and PLOs for each student upon entry of the marks associated with the CLOs.

A snapshot of the XLSX evaluation sheet for the course CSC101 is explained in Figure 19. The first tab in this sheet is for course evaluation settings. The subsequent tabs are to evaluate each CLO in the course in accordance with the associated Rubrics and calculates whether the students attained the CLOs. Therefore, the number of tabs for CLO evaluation is equal to the total number of CLOs defined for that course. In case of CSC101, there are four CLO evaluation tabs. The final tab is to automatically measure the attainment of the PLOs depending on the result of the mapped CLOs.

In the course evaluation settings tab, the faculty member has to enter the followings, (a) the course, section and faculty information, (b) student id and names for the section, and (c) the course CLOs and PLOs mapping with total evaluation marks for each CLO and corresponding passing marks (60% in general). Upon successful entry of these information, the CLO and PLO evacuation tabs are automatically populated with the required information, e.g., detail of CLO and PLO, evacuation marks, student list, and other associated statistics. This arrangement is shown in part (a) of Figure 19.

In each CLO tab, the corresponding Rubric table is implemented for marking the assessment. As shown in part (b) of Figure 19, the marking table is developed based on the Rubric (in Figure 18) defined for assessing the Class Test-2 for CLO-1 (in Figure 17). While the mark for each student is entered in the Rubric table, the calculation for CLO pass/fail is auto calculated by the sheet. Finally, the PLO achievement is automatically derived based on the mapping between the course CLOs and the PLOs. For the course CSC101, CLO1 and CLO2 are mapped with PLO-a (as detailed in Figure 15), therefore, if a student passes both the CLOs only then he/she attains PLO-a. This attainment of PLOs is recorded in the PLO attainment tab (part (c) of Figure 19).

This process of CLO and PLO assessment is recorded for each student across all the courses and are accumulated to generate OBE certification and transcripts at the time of their graduation. Additionally, for each course, a course file is maintained in official google drive folder. The course file for each course includes the course outline, the teaching and learning materials, examination questions and answer scripts, the xlsx grade sheet for each section and the scanned copy of the evaluated answer scripts. The feedback from the course teacher and the students are also collected at the end of the semester for improvement planning. Figure 20 illustrates the info graphics created with the course level CLO and PLO attainment together with the Program level PLO attainment. In all three cases, the average score (in %) and percentage of attained students are observed to assess the overall performances of the courses and the program in consideration in terms of overall CLO and PLO attainment.
FIGURE 19. The automated evaluation of CLOs for CSC101 Course. Upon entering rubric marks for each CLO, this grade sheet will automatically evaluate the attainment for the CLOs and corresponding PLOs for each student in the course.
The information recorded under each course file is periodically summarised for generating reports that are due for accreditation verification of the program.

**H. CQI PROCESS MANAGEMENT: PROGRAM LEVEL**

Adhering to the OBE framework (ref to Figure 3), the CQI (Continuous Quality Improvement) process defined for the CSE Program has two independent processes, namely, *OBE Process CQI and CQI through External Evaluation*. The outcome of these processes is evaluated both quantitatively and qualitatively to set the quality improvement action plan.

To maintain this process, a department level CQI cell composed of senior faculty members, and a university level CQI monitoring cell (known as IQAC - Institutional Quality Assurance Cell) is functional in IUB.

For the internal *OBE Process CQI*, data is collected under three categories, namely, Student Feedback on course, Faculty Feedback on course, and Student Exit Pole. These data are collected using data collection form developed by the departmental CQI team adhering to the quality assessment parameters defined in the OBE framework (ref to Figure 8). A representative data collection form for student course feedback is presented in the supplementary material. All the concerned stakeholders must take part in this process which includes the students participating and the faculties who are conducting the courses. Data are collected using google forms during the last week of the semester. Responses are recorded in the google sheets and are further processed by the department CQI team for detail assessment on the academic quality estimation parameters. For example, student feedback on a course is used as an indicator for determining the relevance and depth of the course content, and effectiveness of the teaching and assessment method in relation to students learning outcomes. Observed result of this process is then summarised for further improvement of the course concerning the contents, teaching, and learning methods, and assisting individual faculties to better equip with academic norm and practices.

Furthermore, the department of CSE is investing heavily in automating the OBE academic and evaluation process that will assist in result processing and certification, generating OBE statistics, and data analytic for monitoring academic practices, assessment, and quality control. Once operational, current XLSX based evacuation data will be ported to the automated system.

For conducting the CQI through External Evaluation, following consortium of external collaborators and evaluators are formed, (a) an Industry advisory panel (IAP), (b) an Academic Advisory Panel (AAP), (c) Alumni Association (AA) of the CSE program, and (d) coordination and compliance with the accreditation boards. This approach of quality assurance is consistent with the CQI framework proposed in Figure 9.

Concerned software development and Tech industry is deeply collaborating with the Department of CSE under several arrangements, which includes, conducting workshops and seminars, supervising internship program for senior students, assisting in design and development of courses. Therefore, the consortium of IAP is formed with the representatives from the collaborating industries. Periodic meetings with this consortium are arranged by the department on defined agendas that contributes to academic improvements.

Like IAP, the consortium of AAP is composed of the distinguished external academicians who are the domain expert and has in-depth knowledge of OBE process and practices. The core concern of this consortium is to periodically evaluate the alignment of different academic activities against the OBE standards, and in process suggest for further quality improvements.

Realising the fact that the Alumni plays a pivotal role in establishing the bridge between the institution and the outside world, the Department maintains a strong link with her Alumni through the Alumni Association (AA). This link is exploited periodically for getting feedback on their career development and job satisfaction, the impact of the degree towards achieving their career goals (considering, the curriculum, teaching and learning process, and associated facilities). The form designed for Alumni survey explicitly collects data on the raised concerns which is presented in the supplementary material for reference.

Finally, the CQI committee is responsible for preparing the Self-Assessment Report (SAR) to be submitted for
 accreditation to UGC and IEB. Additionally, this committee holds the assessment meetings with them as per schedule. The committee considers the suggestions and guidelines prescribed by the accreditation board to enhance the quality of academic practice in the program.

VII. WEAKNESSES AND CHALLENGES

For effective functioning of the process for implementing an OBE system, proper planning and its execution is required. Even with the clearly defined process and practices in-place (as devised in this paper), it is evident that the investment of time, effort and logistics is needed to ensure the smooth-running of OBE establishment and maintenance [66], [67].

The major challenge that was observed during the inception phase of the OBE implementation is the perception of the senior Professors towards this academic practice. The cumulative consensus was that this process adoption will be a wastage of time and effort, and comprises of too many procedural tasks that would overshadow the philosophy of the academic learning. They also put forward the criticisms against the OBE practices, citing that exaggeration on the standards and approaches would restrict the creative teaching and learning environment [68], and would over burden the academics, especially if there are limited support systems, mechanisms and resources, and a lack of planning during the implementation process [69]. This will push the academics to compromise the quality of content delivery, and student assessment.

Alongside, the junior faculties and teaching staffs (i.e., Teaching Assistants and Lab Instructors) raised the concern that framing everything within the course in terms of earning Outcomes in advance, would definitely restrict the unpredictable voyages of exploration that characterize learning through discovery and inquiry [2], [22].

Altogether, following approach was adopted to encounter the challenges and resistance discussed above to proceed with the OBE process implementation for the CSE program in IUB.

- The conflicts between the OBE mandates and the classical academic approach were discussed to identify the gaps, and to find the way to retain the best from both the paradigms. In doing so, a consortium of the senior faculties and the OBE experts (both external and internal) were formed to come up with a course of action, which was then converted by the OBE core committed to define the OBE framework.
- The Unclear and ambiguous setting of certain outcomes and inappropriate assessment tool selection by the faculties while defining the course outlines are resolved. This occurred due to the misunderstanding of the OBE mandates by the faculties. To clarify these misconceptions along with other associated issues, the OBE core committee designed a series of seminars and workshops involving the experts in the concerned domain. Each of these events highlighted one key aspect of the OBE process and had associated hands on exercises to clearly demonstrate the OBE adoption process to the concerned faculties.

VIII. OBSERVATIONS AND FUTURE RESEARCH

Future research on this track can fork in several directions that are tightly aligned to OBE process and practices. The proposed framework (Section V) has explicitly identified the core components and their inner working mechanism for effective adoption, and management of the OBE process. Many of these working processes require full-fledged digitization and automation for proper management. For instance, the mapping of all the core components, e.g., Missions, PEOs, PLOs, CLOs, the assessment methods, and evaluation rubrics in the program must be done in a software system. All the assessment marking against the rubrics also needs to be integrated within this system. This will facilitate automated evaluation and attainment of the CLOs, PLOs and PEOs. Consequently, the transcript of OBE certification can be generated automatically from this system. Additionally, many of the quality measurement parameters can be derived automatically from the system, the management can assess the program wise mapping among the core components to find out mismatches or discrepancies for further improvement, can identify the progress and learning curves of the students and suggest for improvement plans, among others. Therefore, the design and development of an education management system for OBE process can be a promising research direction. This system should support both OBE based evaluation as well as, the traditional evaluation based on the defined assessment criteria.

A potential research direction would be to define a mechanism for generating students’ portfolio of engineering expertise in relation to their performance towards the attainment of the CLOs and the PLOs. To put this into perspective, consider a student has performed exceptionally well in achieving PLO-e and PLO-h (ref to Table 4 for PLO detail), which were measured through several CLOs offered in multiple courses during his/her graduation. With this explicit tracking of learning, one can quantitatively define the students’ expertise in using diverse engineering tools (from PLO-e) for solving real life problems and can determine his ethical and moral standpoint (PLO-h) while serving the society. This mechanism of performance evaluation would assist the graduates to determine their career path and support the external stakeholders (e.g., the companies, academic institutions, and tech industries) to select candidates of their need effortlessly and confidently.

Another core research area in this track would be to define and implement a robust CQI management process adhering to the proposals detailed in this study. Automation and integration of AI driven Decision Support System for data analytic, prediction, and suggestion would be a key contribution. This system can offer support for observing the learning progress of the students, measuring the ratio of CLO/PLO attainment
in relation to individual course or the program, measuring which CLOs are better performing in supporting effective learning of the students and in turn figuring out what need to improve/adjust further, measuring teaching and assessment quality of the faculties and offer guidelines for enhancements, among others.

**IX. CONCLUSION**

This study defines a comprehensive and concrete academic framework that comply with the benchmark mandates and guidelines of the Outcome Based Education (OBE), documented in the authentic literature and manuals. Moreover, this framework adheres to the OBE specifications dictated by the national and international accreditation bodies (e.g., the Washington Accord, and the BAETE, IEB) for ensuring both national and international academic equivalency and accreditation. Therefore, the institutions offering tertiary level engineering programs have a ready to adopt reference framework with all the necessary detail to learn, design, implement and practice the OBE model.

The proposed academic quality assurance model can be used to track, monitor, measure and plan for the continuous quality improvement (CQI) within the OBE process and practices. This model will assist the institutional CQI monitoring cell to track and evaluate the key parameters of the OBE process to plan for progressive quality improvement. Additionally, the equivalency and accreditation bodies can use this framework as a benchmark for coherent and homogeneous assessment and certification of all the engineering programs across the universities.

Finally, this paper details a hands-on implementation of the framework for designing the undergraduate CSE program offered by the Department of CSE, IUB, Bangladesh. This step-by-step adoption process, in one-hand ensures the empirical validation of the framework, and on the other-hand, provides a clear perception on how to implement the OBE model for equivalent programs.

Therefore, the overarching contribution of this paper will adequately support all the concerned academic stakeholders by offering an in-depth understanding of (a) the Outcome Based Education (OBE) process and practices, (b) a detailed step-by-step process definition for developing a program curriculum and associated teaching, learning and assessment strategies in the OBE model, and (c) adopting a evidence based academic process monitoring, assessment and accreditation strategy for ensuring continuous quality improvement (CQI). The beneficiary stakeholders include but not limited to the academic institutions, the departments, faculties, students, the CQI (Continuous Quality Improvement) monitoring cell, and the accreditation bodies (e.g., UGC and IEB).

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