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Outcome Based Education from Capability Maturity Model Perspective

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Abstract: ***Engineering colleges require their faculty to continue learning new things and enhance our quality of education. Engineering education should bring about new aspects, knowledge, and practices whereby transform the orientation of existing teaching and learning process and every engineering discipline should embrace other disciplines and perspectives in handling new challenges in a transdisciplinary approach[1][2]. As it is obvious to all of us to understand what processes we have, and why we have them, the current Outcome Based Education (OBE) [1] demands the engineering faculty to conduct more rigorous research to identify the good practices with strong theoretical orientations of OBE. So, through this research paper, we recommend that the engineering process of designing, analysis, implementation and verification & validation should be introduced from the earliest stages of the teaching and learning process, right from the first year to achieve excellence in Teaching and learning process.***

Keywords: Outcome Based Education, Capability Maturity Model, Engineering Education, and Process Framework

1. Introduction

Over the past decade, most research in teaching and learning process has emphasized the application of OBE by just introducing hard practices which are more concerned with the methodological and technical side. But still lot of study should happen on improving bottom-line results and achieving high quality outcomes by applying process oriented techniques to convert current **curriculum-goals-completion evaluation method** (traditional test score based curriculum assessment) to **Outcome-Goals-completion evaluation method** (Learning Strategies and Learning outcome i.e. expected capabilities of students). This is done by quantifying and reducing non-value added activities, and adapt to systematic approach to compute the outcome-goals-completion percentage. The technical education should be delivered using a blended learning mode and it is very important that the students should be engaged in experiential learning, working together in teams in order to bring out an expected outcome. The research paper will provide the decomposition of curriculum goals based on the graduation requirements and methods to continuous improvement of engineering education by applying CMMI process model [3].

2. Application of Quality Assurance and Quality Control on Engineering Education

As the engineering graduates join the workforce in various industries and work on complex systems in a highly competitive environment, OBE suggests cognitive model learning process to the education system to assess students' experience regarding a particular course, perceived competence and the outcome. The following table shows the commitment from both faculty and students to achieve learning outcomes as expected by OBE.

Table 1: The activities to be performed by both faculty and students to achieve learning outcomes

Faculty	Students
Creation of a curriculum framework that outlines specific, measurable outcomes	Demonstrate that they know and are able to do
Emphasize setting clear standards for observable, measurable outcomes	Will be measured whether they have achieved the stated standard
Assess and measure whether the student can perform the required task	Will be assessed against learning outcomes for a subject area which includes everything from mere recitation of fact to complex analysis and interpretation
Track and report not just a single overall grade for a subject, but also give information about several specific outcomes within that subject	Students' strengths and weaknesses will be identified
Focus on the individual needs of the students	Compared with his/her own prior performance and recognised for their individual improvements.

The proposed method has been applied in two classes of 60 and 72 undergraduate students, which identifies controls and proposes changes in the learning model of a teaching system with the goal of controlling the fulfillment of a study program of a course. The research faced few challenges like more collaboration and team playing skills of engineering graduates, and the present conventional engineering curriculum leaves very little space and time for learning skills and understand group dynamics. Furthermore, this results in even academically high achieving graduates lack necessary technical (hands-on) skills.

3. Major Pitfalls

In OBE the practices are expected to be cultivated as a skilful work force to enter into job market, or research organisations or even become entrepreneurs [4]. Curriculum, assessments, and professional development are aligned to the standards and students are assessed against the standards unlike the traditional education which is concerned only about delivering content. In a traditional education system as we follow right now, the curriculum is designed by the by those who created the textbooks rather than the assembled groups of stakeholders (Board of Studies) to create standards based on consensus of what students should know and be able to do (applying reasoning, creation, and problem solving). The disruptive nature of OBE offers several challenges while incorporation in the area of teaching and learning as provided below[4][5].

a) Getting the cart before the horse – current education system in especially the Tier-II institutions (Institutions that are affiliated to a particular university) do not address OBE needs as the most of the universities still demand curriculum-goals-completion evaluation method.
b) The Universities still are not evaluating as per OBE needs
c) Insufficient stakeholder buy-in exists
d) Cost of collecting the metrics as per National Board for Accreditation (NBA) is greater than the benefits to be derived because of the gap between the OBE evaluation methodologies and curriculam-goals-completion evaluation method.

4. Principles of Process Framework

The activities have to be aligned to monitor and achieve the student's performance as the outcome during their period of study. Through OBE, the students are expected to gain experiences developing their skill in terms of problem solving, analysis, synthesis, communication, team work, and professionalism by focusing on improving their performance and by understanding their objectives of the course that they are pursuing. But unfortunately, the implementation of the OBE of tier-II institutions has suffered due the prevailing ambiguity in defining learning outcomes of the curriculum and syllabus provided by the affiliated university and the institutions have varied learning outcomes for the same courses provided by the affiliated University. There is also confusion in relating the assessment methods for student achievements (exam based assessment driven by the affiliated University) to the assessment methods for the learning outcomes supposed to be measured by the institution. Due to this, the implementation of the OBE for Tier-II institutions face challenges by spending incredible amount of time on the current hybrid educational system i.e. relating traditional examination based assessment to deriving learning outcomes as expected by OBE. So, there is a need to maintain accreditation as way of promoting quality rigour in relevance to engineering education.

Watts S. Humphrey (CMM key author) describes the problem this way, "Engineers are understandably skeptical about changes to their work habits: although they may be willing to make a few minor changes, they will generally stick fairly closely to what has worked for them in the past until they are convinced a new method will be more effective. This however, is a chicken and egg problem: engineers only believe new methods work after they use them and see the results, but they will not use the methods until they believe they work". A process is a set of activities, methods, or practices and transformations used to assess and monitor institution's performance in terms of faculty contributions and students' performance to assure various stakeholders of a quality education and for improving academic excellence. The expected results that can be achieved by following a particular process by predicting the outcomes that can be expected and applying the same processes across all the departments in the institution is called process capability. The Programme Outcomes defined by OBE represent the knowledge, skills and values the engineering graduates should possess as a result of undertaking the programme, i.e., what the student is expected to be able to do after the completion of the programme[1][2][4]. So, the actual results achieved by following a process which is called as the process performance has to be compared with the expected results i.e. predicting the outcomes achieved through process capability. This shows that there is a need to extend capability maturity model for assessing the effectiveness of quality assurance in engineering education by determining existing standards as a basis for improvement. So, the OBE framework provides us the vision to practice and produce outcome, while it balances capability improvement with supporting strategic implementation plans time-to-time, so that the improvement in the processes will be brought incrementally across the institution.

The following diagram shows how we implement the process management in educational institutions to improve the teaching quality and produce the outcome.

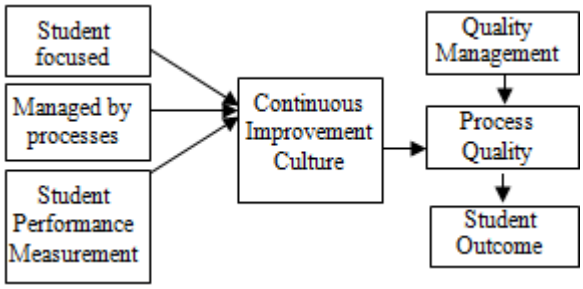

Figure 1: Outcome Based Education Continuous Improvement Culture

5. Success Factors of Outcome Based Education

Any engineering institution should have a framework based on empirical validation of various methodologies followed across the institutions focusing on ways of doing activities towards achieving the learning outcomes and not just what to do.

The success of OBE is based on several factors:

a) The need of OBE has to be recognised by senior management, who endorsed change.
b) The value of the OBE has to be proved with high-visibility.
c) Add the process which derive value

d) Involve the faculty who add value
e) Flow value from industry and society demand
f) Department level planning helps formulate the big picture and provides incremental direction for improvement.
g) Optimize across departments
h) A viable communication plan among the stakeholders keeps the program alive.
i) Measure and respond

The Curricula and assessment should be developed to demonstrate the students' knowledge and ability toward the mastery of the subject area. We propose to undertake a review of process areas, goals and practices used in CMM by considering the basic elements such as the faculty, the student, the learning environment as well as the content taught and, finally, the assessment.

6. Applying Capability Maturity Model to Outcome Based Education

Pursuit of process frameworks and quality standard CMMI® has brought more discipline and maturity to manufacturing and services industries. Outcome-based education is a method of teaching that focuses on to determine what things are essential for the students to be able to do to ensure and examine if the students have achieved the programme outcomes at the end of their study. The current situation in technical education in India is the lack of clarity on the term learning outcome itself. In order to be able to assess the institution's performance and take corrective actions to further improve the teaching and learning methods, by implementing Capability Maturity Model (CMM) to assess and evaluate the capability and maturity of processes could be used to define programme goals, planning of assessment activities, identify the improvement of the outcomes, and implement the improved activities to achieve the expected outcome. This CMM model is considered as the appropriate model because it provides an evolutionary path that focuses on five levels of process maturity: Level 1—Initial, Level 2—Repeatable, Level 3—Defined, Level 4—Managed, and Level 5—Optimizing. Each level of CMM consists of Key Process Areas (KPAs) and also steps to achieve those KPAs and also provides a path for incremental and continued process improvement.

The following are five levels in the basic Capability Maturity Model (CMM):

- ***Initial***: "ad-hoc" or "chaotic". At this level the institution follows the processes that are not under systematic management control.
- ***Repeatable***: The basic processes have been established, defined, and documented, which can be applied across all the departments, but still are often reactive.
- ***Defined***: The institution now uses internal control processes on every activity they perform on both academic and administration areas and can be standardized, documented, and integrated into a set of standard processes for the institution.
- ***Managed***: The institution analyzes, measures and controls processes across departmental units. Success is planned and predicted, rather than merely serendipitous.
- ***Optimising***: The institution focuses on continuous improvement of its processes and focuses on responsive innovations to better serve institutional needs.

CMM is a 5-level model that helps to understand and assess the maturity of the teaching-learning process used in the institution and to identify the critical steps and other validated practices implemented for the effectiveness and capability of the process. Adopting CMM in educational institutions in a phased manner (Educational Capability Maturity Model) will provide a road map for enhancing the teaching-learning process of the institute level. Process improvement is a systemic approach that helps institutions optimize the sequence of activities so that they may improve their outcomes[5]. The best practices and benchmarks for the processes of educational maturity model are to be examined and employed to compile a certain set of the targeted practices that might be for educational institutions.

Key Challenges addressed at institute level by implementing CMM

The institution focused on continuous improvement and built an ecosystem to monitor performance of the students and faculty. The quantitative performance improvement objectives that are predictable are aligned to the needs of internal and external stakeholders and will be revised time to time [6].

a) Increased innovation in Teaching-Learning methodology and usage of Learning Management System (LMS) which has to be customized as per the learning curve of the students.
b) Evaluated different strategies in Teaching-Learning methodology and select the most suitable approach.
c) Focused to deliver best practical-oriented based learning to the meritorious students
d) Analysed students' feedback and take proactive actions to eliminate issues related to slow learners before they occur.
e) Evaluated the learnability of online courses to help students meet their needs.

The following table shows that in-line with the OBE, we customized our approach in consonance with CMM that enabled the institution to leverage and use the model to instill the systematic approach for process improvement.

Table 2: Implementing CMM model for process improvement in our institution

CMM Steps	Actions Performed
Initial (Unpredictable and reactive)	Work got completed, but often delayed and the analysis of the data from the reports generated was lacking.
Managed (Managed at the department level, but proactive measures were not taken and but still reactive)	The academic tasks were planned, performed, and measured. But there were no proactive decisions made to avoid bottlenecks like improving the results of slow learners, improvement in the R&D, etc.
Defined (Proactive rather reactive)	The departments/programmes started forming Special Interest Groups (SIGs) and Advanced Training Groups (ATGs) in specific domains and technologies to implement practical-oriented training to the academic performers. The processes were framed to monitor the performance of both faculty and students.

	Performance Based Appraisal System (PBAS) for faculty was implemented. Bridge Classes are implemented for lateral entry students. Remedial classes are conducted for slow learners.
Quantitatively Managed	The institution started data-driven quantitative performance improvement objectives that are predictable and aligned to the needs of internal and external stakeholders.
Optimsing (Stability)	The institution focused on continuous improvement and provides a platform for adaptability and innovation in teaching and learning process. Established Incubation Centers and Skill Development Centers, Increased Industry-Institute Interaction (I-I-I), and Corporate Social Responsibility activities. These activities have improved the learning curve of both students and faculty. Students have started participating national level competitions, hackathons, learathons, etc.

7. Conclusion

Outcome Based Education is a competency-based approach to education transforms the process of teaching and learning process from traditional teaching methodology, which is based on inputs to the one that focuses upon the outcomes. Through this paper we attempt to apply the CMM model [3]to engineering education, and develop an Educational Capability Maturity Model (E-CMM) to teaching-learning process to improve teaching quality, continous quality improvement, and the sustainability of quality achievement. As the education system is a complex network of systems, structures, processes, and people, we need to combine our skills and resources as described by the E-CMM process model which cascades down to our individual work activities in order to implement OBE successfully.

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