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Competency Based Education and Continuous Assessment in Laboratory to acquire higher order learning levels: Challenges, Process and Outcomes

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Abstract: Competency based education and its continuous assessment creates a strong interest amongst all stakeholders involved in laboratories. Hands on experience and project-based learning provide an opportunity for a personalized path to acquire higher order learning levels. A continuous assessment procedure has been implemented to impart knowledge-based on skill centric environment for lifelong learning. Five assessment components have been designed for the continuous improvement of skills all of which are required for higher order competencies. Laboratory assessments components have been designed by considering the teaching learning process, methodologies, complex engineering analysis, sustainable development, professional engineering practices and Continuous Improvement. These assessment components have brought about a radical transformation in Academic Performance Index (API), Success Index (SI), Placement, Higher Studies, Entrepreneurship (PHE) , attainment of Program Outcomes (PO's) and Program Specific Outcomes (PSO's). These outcomes indicate that students/graduates have acquired a higher order competency along with professional learning and hands on experience.

The proposed methodology for laboratory performance assessment components addresses the problems existing in conventional laboratory assessment methodology. In conventional methodologies, performance assessment is done based on laboratory report submitted by each group. The biggest drawback is that there are no specific guidelines for grading reports, large variance in assessment of senior and junior staff and no continuous evaluation system.

Aptitude brilliance can be improved through knowledge component assessment. In addition, written work component is vital in improving lifelong learning and soft skills or professional skills.

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The analysis of Questions Answered indicates the continuous reading practice which prepares them to grasp technical topics leading to benefits in employment as well as an improvement in individual Academic Performance. Interactive component gives them experience and opportunity for group discussion. Also, it helps in striking impactful conversations to address the needs, build network, perspective and intrinsic drivers which influence continuous improvement. Punctuality component is most critical and also key component to transform individual component to become a competent professional. It also helps to balance their professional and personal life.

Here outcomes are observed considering three engineering streams and over 8000 data points for three consecutive Academic Years. This paper result provides implications for academicians, Employers and Human Resource professionals of Industry. Also, this paper helps identify the Industry Academia gap existing between the skills needed in the industry and the university education the students receive.

Keywords: OBE, POs, PSO's, SI, API, Industry Institute Interaction, Assessment Components (AC's)

1. Introduction

The Outcome Based Education (OBE) is implemented for the quality assurance and improvement with emphasis on outcomes measurement rather than inputs of curriculum covered. In order to obtain the desired outcomes, teaching components and activities should be well organized, planned and continuously improved. Performance assessment and outcome measurement is an intricate process as it requires complex data analysis. These complex data sets are generated through direct and indirect tools which are used to assess the outcomes at course level, program and program specific level. These tools are based on both qualitative and quantitative methods. Also the assessment of these outcomes with reference to set targets are an indication for the next level of improvement. These assessment methods are implemented to measure learning outcomes in each session; this type of procedure and intervention consumes lot of time. Moreover, early identification of the students learning competencies and ability gives them more time and opportunity to improve before the actual completion of the unit or course. For this type of problem, we have proposed a methodology to improve the student learning competencies related to cognitive domain and affective domain through continuous assessment components methodology as.

1. The improvement of student's soft skills related to effective domain.
2. The improvement of Critical thinking skills related to cognitive domain.
3. The industrial skills like problem solving, design and development of solutions, development of intellectual skills, tools usage and project management.

The meta-analysis of the proposed methodology to address challenges existing in laboratory performance and outcomes assessment has been implemented. Challenges like assessment based on lab report submitted by each group, no specific guidelines for grading the report, and large variance between seniors and juniors' judgements in giving marks have been addressed.

2. Literature Survey

One of the improvements in higher education is the development of industry, research organization and institute interaction for the best development of students with employability skills and to orient them for lifelong learning as indicated in study of Authors (O.A. Shestopalova, 2019). Improving opportunities of higher education are related to the expansion of student's cognitive skills with respective to individual inclinations and potential.

The problem-based learning pedagogy initiative reported by authors (Hera Heru Sri Suryanti & Siti Supeni, 2019) showed improvement in students soft skills in order to prepare for superior HR. This pedagogy provides students many opportunities in the period of education for the development of aspects like critical thinking, adaptability, project management, team work and communication.

The purpose of the work presented by Authors (Dora H. Ivanova, etc., 2020) is to form tasks and analyse the practice of the quality assurance system to achieve excellence in higher education. The practical aspects of quality assurance of higher education in European Union's countries have been analysed which is reflected in the dynamics of Teaching, Learning & Resources, the structure of higher education degree seeking applicants, Graduation Outcomes, the World University Rankings, Peer perception of the higher education system. Gap identified in this paper is the pedagogical initiatives and their importance in the development of the quality assurance in Higher Education Institutes which has not been addressed. These pedagogical initiatives are essential to improve knowledge, skill, attitude and competencies along with the continuous assessment of these parameters.

The authors (Ha Duc Ngoc, etc., 2020) findings indicated the tenure tracking system for the teacher's development to adapt themselves to transforming education with emerging technologies, which is very essential. Pedagogical innovation, team work and open communication are essential requirements to improve effectiveness of Higher Education System. Based on this paper, it can be said that fostering a learning environment with a student centric approach empowers all the stakeholders. This also creates opportunities for the transformation of education leading to better performance. So, developing a well-equipped laboratory with state of art technologies are the key to adopting contemporary education and technologies. Assessment methods and its components will synchronize learning environment by creating opportunities to encourage collaboration and interaction between teachers and students.

Misstating the level of confidence in an answer can have ruinous outcomes as analysed by Authors (Gigi Yuen-Reed and Kyle B. Reed, Summer 2015). The assessment of the confidence and methods to improve or correct confidence is analysed and seldom featured as an important component. Confidence based scoring method is used to analyse and identify students' competencies. The gap identified here is, the scoring method which can be used to map individual learning blooms level, accordingly identifying individual learning path and their track. Also, these are the vital parameters for enhancing the employment and improved education percentage in higher educational institutes. This grading provides self-awareness and it helps improve students abilities.

Assessment driven learning helps to improve learning experience. It also identifies different levels of student competencies, their cognitive ability level and to prepare them for their careers in industry, higher studies career opportunities, entrepreneurship-related knowledge, skills etc., as presented by Authors (Senay Purzer, etc., Winter 2016). Gap identified in this work is the correlation and analysis of continuous assessment components to developing problem solving skills, entrepreneurship skills and innovation skills.

Authors (Amol C. Adamuthe and Sandeep U. Mane, 2016), proposed outcome-based assessment methodology for the laboratory course. It claims of strengthened students learning and teaching quality but does not have the proper analysis approach as proposed assessment components have not been mapped to experiments or design problem. Instead, mapping assessment components directly to laboratory course outcomes have been observed. Here the gap has been identified in the limitations of assessment components with respect to course outcomes. Course outcomes are defined based on the curriculum or list of experiments, so mapping of these experiments needs to be done with respect to course outcomes instead assessment components.

From the aspect of quality assurance, teaching-learning process, assessment and evaluation are important phases of student development to acquire higher cognitive ability. The study by Authors (Tamer El-Maaddawy and Christopher Deneen, 2017) suggested the evaluation of students be done more specifically to the frameworks and intentions of change and innovation. Gathering evidence of student's perceptions of the outcome-based learning experience and their achievement proved meaningful. Problem finding in this paper includes all the stakeholders and all disciplines with generalized assessment method in OBL framework.

Critical theoretical frameworks are necessary to understand self-sustaining factors influencing the study of persistence in higher education institutes research as presented by Authors (Joel Alejandro Mejia, etc.,2018). How engineering education research could influence critical pedagogy using critical theoretical frameworks has been highlighted. This work lacks in the empirical validation in research, innovation and entrepreneurial practices. It is important to engage in critical reflection while the researchers, innovators and entrepreneurs engage in their respective work activities.

To encourage, motivate and foster young students and faculty, universities have increased entrepreneurial activity for the development of student and faculty entrepreneurship perspectives. Authors (Cory Hixson and Marie C Paretti, 2018) found the gap in entrepreneurial mindset and ecosystem in the university campuses. Also, they have been able to identify reasons why faculty and students believe entrepreneurial knowledge, skills, attitudes and competencies add value to higher education campuses.

To create a vibrant innovation based ecosystem, supporting scouting of ideas, pre-incubation of ideas and development of better cognitive ability in students, authors (Jose Ramon Morales-Avalos, & Yolanda Heredia-Escorza, 2018) have analysed efforts like labs network. The association between the institute and industry importance has been highlighted which leads to developing learning skills, innovation skills and research competencies.

Authors (Goldie Gabrani, et.al., October 2016) aims to highlight some of the contemporary practices practiced in the teaching-learning process that make better learning experiences. Innovative teaching - learning methodologies like Innovation by Innovating, Learning by Teaching, keeping up with the world, Interest based learning, Flipping the class and the power of peer have been implemented and analysed for learning experiences. These methodologies have resulted in efficient delivery, enhancement of learning and personalized learning styles.

Laboratory component is vital to develop hands on experience, critical thinking skills, enquiry based learning and problem solving along with trouble shooting. Authors S.S. Rathod and D.R. Kalbande (April 2016) have shown several ways to make the laboratory sessions interesting, increased student & faculty involvement in laboratories and implementations of appropriate assessment rubrics. In this paper, faculty development plan for adopting emerging technologies, continuous assessment to drive students learning, and their contributions for course outcomes attainment have not been explored.

A case study on the use of exit surveys for assessing students learning levels as well as students learning based on of engineering education on students learning levels on outcome based education has been proposed by authors (U.P Kulakarni etc., October 2017).Findings of this paper are true implementation of continuous assessment , outcome based education ecosystem and stakeholders involvement in process driven environment could be explored to address most of the concerns pointed.

Author (B M Naik, January 2017) has highlighted answers to few issues like future of higher education institutions, effective models for addressing current problems and way to create innovators and their necessity. Also, he mentions about the ways and means through which Institutions can do better by enhancing employability, Innovation and Entrepreneurship. Our findings in this paper are, there is a necessity to create a process and methodology in the institution to drive and improve issues brought here.

The project-based learning pedagogy impact and its outcomes have been analysed through rubric based assessment by the authors (Anitha D, etc., October 2018). This paper does not address how creativity can be enhanced in a fixed period or with one teaching pedagogy. So, it's very important to have best practices at the early stages of student's learning in both theory and laboratory subjects. Also, continuous assessment of these parameters with well-defined rubrics applicable for all courses will definitely help to improve outcomes qualitatively and quantitively over a period of time.

The use of ICT to enhance delivery method, transparency in the assessment and few pedagogy initiatives to improve students' competencies have been analysed by the authors (Maruti R Jadhav, etc., January 2018). Observations from this paper are, exclusive methodology and process to improve program outcomes and program specific outcomes of students have not been addressed. Also, resources utilization and their new additions not been addressed.

Importance of identifying learner prerequisites, competencies and plan to implement effective way of teaching-learning process have been highlighted by the authors (Akhil Sachan, etc., July 2019). Limited teaching interventions, objective based test in the assessment and criteria to identify groups could have been extended for the findings with their recommendations. Also, alternative methods to identify gain in learning and misconception could have been analysed.

Industry and Institute interaction to minimize the industrial gap in the Academic Institutes is very essential. This has been highlighted with measures, means and way forward by authors (Balasubramani R, July 2019). Curriculum development issues, practical limitations of Industry expert's participation, budgetary considerations and regulatory norms constraints can be further explored with larger data set.

Authors (G.S. Durga Prasad, etc., April 2019) have proposed solutions to improve the Quality Assurance of Higher Technical Education in Indian context for the TIER-I and TIER-II category Institutions with accreditation. Also, they have brought out the shortcomings in the policy rating scheme following outcome based education by NBA, Curriculum, Infrastructure and Quality manpower. Our findings indicate that, what is important for Accreditation in Higher Technical Educational institutes are what kind of Infrastructure/ facilities, Faculty, Students and Curriculum do they have.

The enhancement modes and initiatives of Engineering Education for best Enrolment Ratio, Academic Performance Index and Success Index have been highlighted by author (R. Senthil, July 2020). Also, the case study on active learning to show case improvement of these parameters has been analysed. Formative and summative assessments outcomes have been compared to identify student's involvement in learning and performance enhancement.

3. Proposed Model

A model of OBE Laboratory Assessment Components (OLAC) has been proposed and developed to measure competencies by considering graduate attributes defined by Washington Accord.

Proposed Lab Assessment Components (AC's) are

AC1: Written Work, AC2: Fundamental Knowledge to conduct Experiment, AC3: Questions Answered, AC4: Interaction during conduction of Experiment, AC5: Punctuality

Table 1: Assessment Components Marks Data Entry

SN	Roll No	Experiment No.1					Experiment No.2					..	Experiment No. 10				
		AC 1,1	AC 2,1	AC 3,1	AC 4,1	AC 5,1	AC 1,2	AC 2,2	AC 3,2	AC 4,2	AC 5,2		AC 1,10	AC 2,10	AC 3,10	AC 4,10	AC 5,10
1																	
2																	
3																	
4																	
. . .																	
N																	
		S_{AC11}	S_{AC21}	S_{AC31}	S_{AC41}	S_{AC51}	S_{AC12}	S_{AC22}	S_{AC32}	S_{AC42}	S_{AC52}		S_{AC110}	$S_{AC2,10}$	S_{AC310}	S_{AC410}	S_{AC510}

Assessment Component Grading:

Marking scheme for assessment Components: 0 for Absent,1 for Very Weak,2 for Weak,3 for Moderate,4 for Strong, and 5 for Very Strong.

Example: AC1,1 : (0-5) Marks of assessment component 1 for experiment 1, AC2,1 : (0-5) Marks of assessment component 2 for experiment 1. AC5,1 : (0-5) Marks of assessment component 5 for experiment 1

Similarly, same procedure is adopted for all experiments

Average assessment component for each experiment of the class where

$$S_{AC1,1} = \sum(AC1,1)/N, S_{AC1,2} = \sum(AC1,2)/N, ..., S_{AC1,10} = \sum(AC1,10)/N$$

$S_{AC1,1} = \sum(AC1,1)/N$, $S_{AC1,2} = \sum(AC1,2)/N$ .....
$S_{AC1,10} = \sum(AC1,10)/N$

Where N is number of students in the class, SAC1,1: Average of Assessment Component 1 evaluation of experiment 1 (obtained value will be between 0 and 5). Similarly, same procedure is adopted for all experiments to calculate Average of Assessment Component.

Calculation of Final Assessment Components:

TAC1 = (SAC1,1 + SAC1,2 +……….SAC1,10)/10
(obtained value will be between 0 and 5)
TAC2 = (SAC2,1 + SAC2,2 +……….SAC2,10)/10
(obtained value will be between 0 and 5)
TAC3 = (SAC3,1 + SAC3,2 +……….SAC3,10)/10
(obtained value will be between 0 and 5)
TAC4 = (SAC4,1 + SAC4,2 +……….SAC4,10)/10
(obtained value will be between 0 and 5)
TAC5 = (SAC5,1 + SAC5,2 +……….SAC5,10)/10
(obtained value will be between 0 and 5)

Mapping of Assessment Components with COs: For the mapping of Assessment Components with CO's, form a table as shown in Table-2.

Now check which assessment component contributes to which CO's and accordingly checks that particular cell. Suppose that CO1 is achieved with AC1, AC3 and AC5 then evaluation for CO1= (TAC1+ TAC3+TAC5)/3, and target for each CO will be 50% i.e. 2.5

Let the calculated values of TAC1, TAC2, TAC3, TAC4, and TAC5 be 2, 4, 5, 1 and 0 respectively.

Table -2: Example to show mapping of Assessment Components with COs.

	CO1	CO2	CO3	CO4	CO5	Obtained T_{AC} values
T_{AC1}	√		√		√	2
T_{AC2}		√	√	√		4
T_{AC3}	√	√	√			5
T_{AC4}		√	√			1
T_{AC5}	√		√	√		0

Calculations: As an example, in the Table-2, CO1 is achieved by lab assessment component 1, 3 and 5 (TAC1, TAC3 and TAC5). So, the value for CO1 will be equal to

CO1= (2+ 5+0)/3 = 2.33 Target not achieved
CO2= (4+5+1)/3 = 3.33 Target achieved
CO3= (2+4+5+1+0)/5 = 2.4 Target not achieved
CO4 = (4+0)/2 = 2 Target not achieved
CO5 = 2/1 =2 Target not achieved

Mapping of COs with POs and PSOs:

Finally, to map COs with POs, form the Table-3. Check the cells where the PO is achieved by a particular CO. Suppose that PO1 is achieved by CO1, CO3 and CO4, the evaluation for PO1 = (CO1 + CO3 + CO4)/3

For example, suppose that
PO1 is achieved by CO1, CO3 and CO4.
PO2 is achieved by CO1, CO3, CO4 and CO5
.
PO12 is achieved by CO3 only
Similarly
PSO1 is achieved by CO2,CO3
Let the values of COs be same as that obtained from Table-2

Table 3: CO – PO Mapping Example

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	PO1	PO2	....	P12	PSO1	....	PSOn	Obtained CO values
CO1	√	√						2.33
CO2					√			3.33
CO3	√	√		√	√			2.4
CO4	√	√						2
CO5		√						2

Calculations:
PO1 = (2.33 + 2.4 +2)/ 3 = 2.24
PO2 = (2.33 + 2.4 +2+2)/ 4 = 2.18
.
.
PO12 = 2.4/1 = 2.4
Similarly, PSO1 = (3.33+2.4)/2=2.86

The steps to implement OLAC proposed methodology are
1.Prepare a list of practical's that the student will perform in the laboratory classes.
2.Map the practical's with the CO's.
3.Map the CO's with PO's for the evaluation.
4.On the very first class in the lab, explain the relevance of the practical's and the expected outcome to the students.
5.Divide the students in the groups.
6.Distribute the list of practical's, mapped with CO's to the students.
7.Distribute the practical's to the students and ask them to come prepare with their respective practical.
8.On the day of practical, ask the students to complete the file after performing the practical and get it verified by the faculty in charge.
9.The faculty in charge will then follow the procedure to evaluate the performance in the laboratory as laid down on the same day.
10.Faculty in charge will then distribute the next practical to the student and will ask the student to come prepare in the next turn.
11.On the next turn the faculty member will provide the marks as per the procedure for the previous practical and these marks are the marks for performance in the lab.
12.Repeat the process.
13.Prepare the final excel sheet of the marks scored by the students during different laboratory as shown in the procedure.

4. Results and Discussion

Table 4. 2nd Year Academic Performance Index of OLAC students.

Academic Year	N	Mean	Standard Deviation	P-Value
2015-16	600	6.78	0.21	0.09
2016-17	600	6.86	0.07	0.07
2017-18	600	7.23	0.05	0.07
2018-19	600	7.29	0.05	0.07
2019-20	600	7.33	0.04	0.06
AVG	600	7.10	0.08	0.06

Table 5. 3rd Year Academic Performance Index of OLAC students.

Academic Year	N	Mean	Standard Deviation	P-Value
2015-16	600	6.89	0.17	0.1
2016-17	600	6.90	0.27	0.09
2017-18	600	7.02	0.2	0.08
2018-19	600	7.10	0.18	0.07
2019-20	600	7.29	0.17	0.1
AVG	600	7.04	0.20	0.09

Table 6. Success Index of OLAC students.

Year	N	Mean	Standard Deviation	P-Value
2015-16	600	0.96	0.015	0.1
2016-17	600	0.95	0.036	0.09
2017-18	600	0.98	0.006	0.09
2018-19	600	0.98	0.005	0.1
2019-20	600	0.99	0.006	0.1
AVG	600	0.97	0.01	0.10

Table 7. PHE Data of OLAC students.

Academic Year	N	Mean	Standard Deviation	P-Value
2015-16	600	0.52	0.18	0.13
2016-17	600	0.54	0.04	0.1
2017-18	600	0.61	0.11	0.07
2018-19	600	0.62	0.10	0.07
2019-20	600	0.62	0.10	0.07
AVG	600	0.58	0.11	0.09

Table 8. Program Attainments of OLAC students.

Year	N	Mean	Standard Deviation	P-Value
2015-16	600	1.58	0.29	0.15
2016-17	600	1.60	0.35	0.13
2017-18	600	1.67	0.33	0.13
2018-19	600	1.68	0.31	0.16
2019-20	600	1.76	0.31	0.16
AVG	600	1.65	0.32	0.15

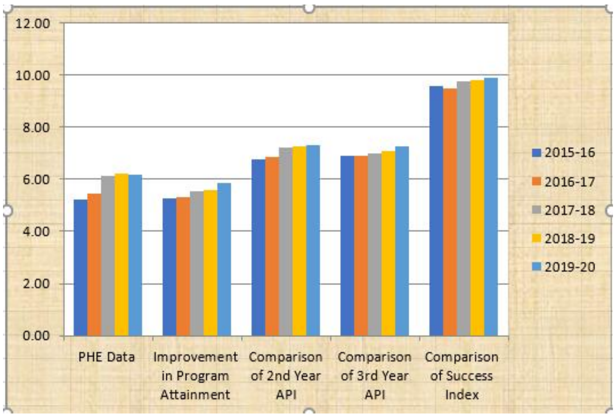

Fig. 1 Comparison of the OLAC method improvement parameters

The results obtained for the Five Academic Years have been Tabulated in Table 4 and Table 5 for 2nd Year Academic Performance index and 3rd Year Academic Performance index respectively. Inputs are considered from seven Engineering Programs with the data set of 4300 students for each Academic Year. Mean values around 70 percent and standard deviation below 0.20. P-value is compared with null hypothesis of 100 percent achievement. P -value is greater than 0.05 for all the Academic Years of 2nd & 3rd Year Academic Performance Index. Table 6 shows the Success Index of around 97 percent for the same data set.

PHE data improvement is observed in Table-7. This has been contributed for the Global visibility as many students are qualifying examinations to pursue Higher Studies in world class universities. Its standard deviation is little high but still there is a scope of further improvement is required. The stable and continuous improvement of rank of students is admitted. This indicates that OLAC proposed model contributed in PHE data improves. Program attainments data is shown in Table-8. Continuous improvement has been achieved for the five academic years for the same data set for each academic year. The Fig.1 shows each parameter under consideration in OLAC method which shows further improvement. These have been contributed for Quality Assurance in the Academy.

5. Conclusion

Proposed OLAC model results contributed for the enhancement of higher order levels competencies, soft skills and quality assurance in the Institute. Practice of this model contributed in enhancing Academic performance index around 90 percent, Success Index around 97 percent, and PHE data around 70 percent. These outcomes have contributed in the enhancement of Teaching-Learning Resources, Graduation Outcomes and Research & Innovation ecosystem with the accolades of Ministry of Education Institutions Innovation Golden Star Ranking, NIRF Band Ranking and Accreditation of various programs. Further, the proposed model in this work can be enhanced and improved further with the help of Artificial Intelligence techniques by tracking individual students learning, Individual Competencies identification and Industry required skills for early adoption in the graduation.

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