IMPACT ANALYSIS OF ACADEMIC REFORMS FOR CDIO IMPLEMENTATION: CASE STUDY

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ABSTRACT

Thiagarajar College of Engineering (TCE), Madurai, India is a member of Worldwide CDIO Initiative and has been practicing CDIO based curriculum from the academic year 2018-19.. The self-assessment of CDIO standards has been carried out meticulously by the CDIO group members of the institute in the academic year 2017-18 and a detailed action plan has been evolved for enhancing CDIO skills. As a first step, the curriculum of undergraduate programmes has been revamped to promote Design–implement Experience and Integrated Learning Experience. New courses like Engineering Exploration, Lateral Thinking, Design Thinking, Project Management, System Thinking and Capstone Projects are offered to promote technical, personal and interpersonal skills. As a second step, to enhance Faculty Teaching Competence, exclusive in-house training programmes on CDIO skills and pedagogical training programmes in association with international experts have been successfully conducted. Successful implementation of Engineering Projects in Community Services (EPICS) Program at TCE has resulted in 164 prototypes to address location-specific community problems. A new framework has been developed to introduce a wide variety of assessment methods to assess technical, personal skills and interpersonal skills of learners. An in-house customized web application for effective assessment of learning outcomes has been developed. This article presents the impact analysis of the academic reforms made in the curriculum, content delivery and assessment at TCE in enhancing the rating scale for the CDIO standards namely Design - implement experiences, Integrated Learning Experiences, Active Learning, Enhancement of Faculty Teaching competence and Learning Assessment. It can be observed that there is great positive impact of these academic reforms not only in improving the ratings of CDIO standards but also in getting national level accreditation and in improving the ranking of the Institute.

KEYWORDS

CDIO implementation, Active Learning, Integrated Learning Experience, Faculty Teaching Competence, CDIO based Curriculum Design, Standards: 5, 7, 8, 10, 11

INTRODUCTION

During the 60th year of establishment of our institution, the Internal Quality Assurance Committee of TCE revisited the academic, research, industry interface and extension activities so that the institution can be moved to the next level. It is observed that, in the past two decades, 90% of the graduates are getting employment in software industries. With the emerging opportunities in core engineering disciplines, students are not able to meet the stringent requirements of core engineering industries such as hands on skills and system approach.

Though we have been following outcome based education framework, the hands-on practices, system design thinking leading to product development approach and interpersonal skills have not been much emphasized in the curriculum. Further, many of the students who get placed in software industries also want to switch over to core engineering jobs. By becoming the member of the CDIO Initiative, we hope to adopt and share the best practices and standards from other CDIO member institutions. TCE membership in the CDIO Initiative has enhanced the opportunity for faculty exchange and global student contest. We are convinced that, by adopting the CDIO framework, we could meet the global requirements of the professional engineer. This paper presents the various activities carried out in TCE for exclusively for bringing improvement in the CDIO Standards 5, 7, 8, 10 and 11 respectively

RESEARCH QUESTIONS

The motivation of this experimental study is supported by the following Research Questions (RQ):

RQ1: What is the impact of the curriculum revamp and newly introduced CDIO based courses in enhancing design implement experiences and integrated learning experiences?

RQ2: What is the impact of exclusive training programs on pedagogy and CDIO implementation in promoting active learning, faculty teaching competence and learning assessment?

IMPACT ANALYSIS OF ACADEMIC REFORMS ON CDIO STANDARDS

During the initial phase of incorporating CDIO as the education framework at TCE in the academic year 2017-18, an exclusive working group for promoting CDIO initiatives at TCE has been constituted with representatives from all the departments. The self-assessment of CDIO standards has been carried out meticulously by the CDIO group. A detailed action plan has been evolved for improving the quality of the academic process with the prime focus on enhancing CDIO skills. This section explains various reforms and initiatives in the context of CDIO implementation and its subsequent effects in the improvement of rating in CDIO standards.

IMPACTON DESIGN IMPLEMENT EXPERIENCE

In the academic year 2018-19, curriculum of all the undergraduate programmes in TCE have been revamped exclusively to promote design implement experience. Unique features of the CDIO based curriculum at TCE has been presented in Figure 1. New courses pertaining to CDIO standards have been introduced to create Design- Implement experience namely, Engineering Exploration, Lateral thinking, Design thinking, System thinking, Engineering Design project and capstone project contributing 20% of the total credits.

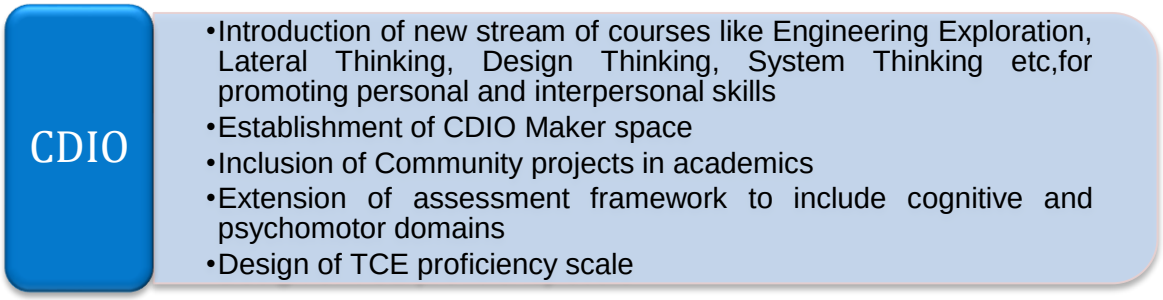


Figure 1 Features of CDIO curriculum @ TCE

Table -1 Uniqueness of CDIO Curriculum @TCE

Total Number of New courses offered	733
Total Number of New Core Courses offered	476
Total Number of New Elective Courses offered	257
Total Number of Industry Supported Courses	113
New Audit Courses for UG Engineering Students	Environmental Science Constitution of India Essence of Indian Knowledge
New Audit Courses for PG Engineering Students	Professional Authoring Value Education

Faculty members have been trained in these areas and have been assigned as faculty guides to train the students. Also, 205 faculty members have been trained in CDIO based curriculum design during May to June 2020 and the feedback given by the faculty members are illustrated in Figure 2. To promote design thinking (Donne, 2018, Sarah, 2019), a special program, Engineering Projects in Community Service (EPICS) has been initialized to understand the lifestyle of the local community partners and to identify their potential problems. Among 43 projects carried out during 2019, 5 projects have been successfully made their way with the prototypes. The projects include Agricultural support systems, Blended learning application for village students and Assistive technologies for autism affected children. The work has been presented in the paper (Thiruvengadam et al, 2020b) as an outcome of Design-implement Experiences in the host institution. The major milestones in the EPICS project at TCE are depicted in figure 3. Photographs of the exhibits of the outcomes of EPICS and review of EPICS project are presented in figure 4. Significant outcomes of the design thinking course includes 164 conceptual prototypes of real-world location-specific community problems. Satisfaction index of the students is improved mainly because of experiential learning. Use of the rubrics for periodic reviews served as an effective instrument for assessing personal and interpersonal skills of the students. Many of our students have extended their projects of design thinking and exhibited their implementations in national level contest like Smart India Hackathon and IUCEE-EPICS Design contest and received good recognition and rewards.The above mentioned initiatives have taken the CDIO self assessment for the standard Design Implement Experience from Level 1 to Level 4 as shown in figure 5.

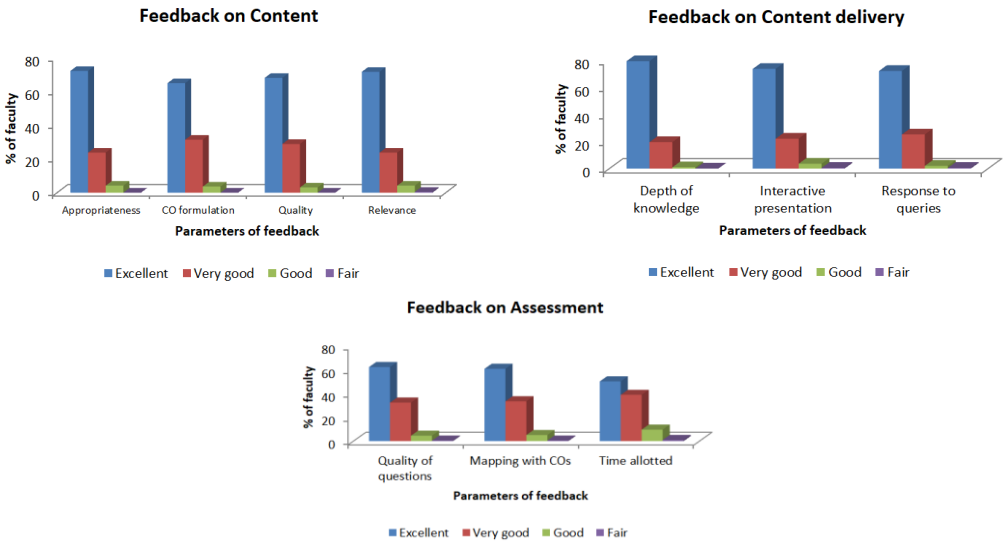


Figure 2 – Faculty Feedback on CDIO curriculum design workshops

Figure 3 – Milestones in EPICS Project

Figure 4 – Exhibits and Review of outcomes of Design Thinking

Scale	Criteria
5	The design-implement experiences are regularly evaluated and revised, based on feedback from students, instructors and other stake holders
4	There is a documented evidence that students have achieved the intended learning outcomes of the design – implement experiences
3	At least two design implement experiences of increasing complexity are being implemented
2	There is plan to develop a design implement experience at basic and advanced level
1	A needs analysis has been conducted to identify opportunities to include design implement experiences in the curriculum
0	There are no design implement experiences in the engineering program

Figure 5 – Progress in Design Implement Experience

IMPACT ON INTEGRATED LEARNING EXPERIENCE

According to CDIO standard 7, Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, product, process, system, and service building skills. Acquisition of disciplinary knowledge shall be observed from the academic performance of the students whereas personal and interpersonal skills are connected with their communication skills and teamwork skills. After getting a detailed feedback from the student after the experience, analysis of the feedback is made. The design-implement experience in EPICS projects are related to integrated learning experience. As the major components of integrated learning experience are Knowledge acquisition, personal & interpersonal skills and system building skills, the feedback of students are taken to account to find whether the efforts are bringing positive results. The feedback is collected after the learning experience with a likert scale of 1-4 in the learning experience gained by the students with the given parameters as in Table 2. 520 students in the fourth semester in the academic year of 2019-2020 participated in the survey and presented their views. The responses of the students have been presented in figure 6. It can be inferred that majority of the students have given top two ratings thereby demonstrating high satisfaction index.

Table 2. Feedback parameters after the learning experience

Parameters of Integrated Learning Experience	**Sub parameters considered for getting feedback**
System building skills	1.1 Identification of societal problem
	1.2 Formulation or modelling the problem
	1.3 Literature review
	1.4 Prototype development
Knowledge acquisition through development process	2.1 Specification development process
	2.2 Functional decomposition
	2.3 Final Poster presentation
Inter and intra personal skills	3.1 Communication skills
	3.2 Teamwork skills

Maker space in TCE has been established in the academic year 2018-19 with an objective to enable the students to innovate, design, build and develop prototypes of their ideas that have been conceived in engineering, science and interdisciplinary domains. Figure 7 presents the facilities of CDIO maker space at TCE. From these observations, it is evident that there is a documented evidence that there is an impact of integrated learning experiences across the curriculum. Further, it is also important to note that two of the student projects are selected as the best project posters in the event of the 7th International Conference on Transformations in Engineering Education (ICTIEEE 2020). Hence, these reforms take the CDIO self assessment for the standard Integrated Learning experience from Level 2 to Level 4 as shown in Figure 8.

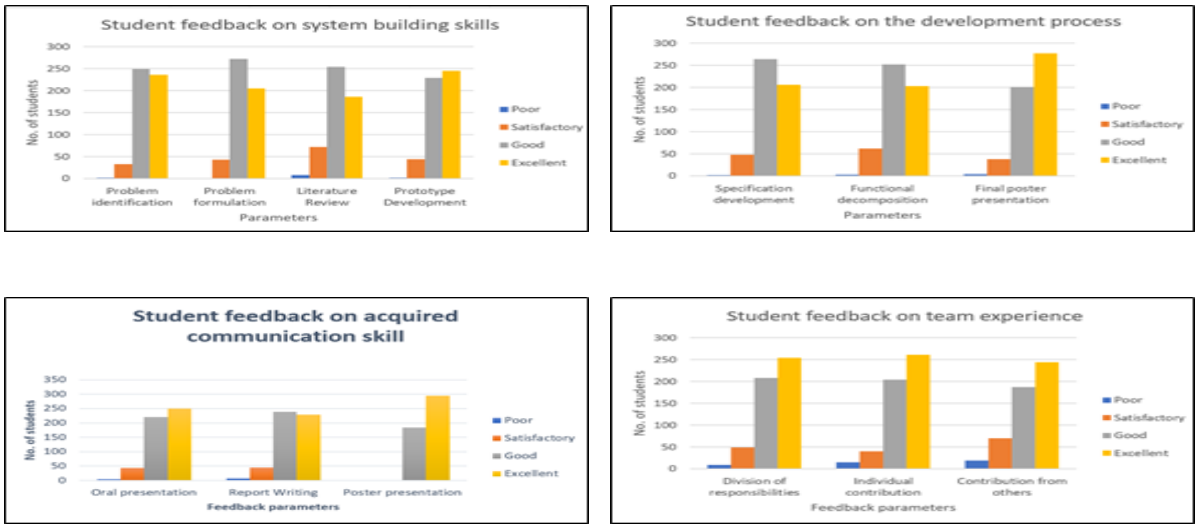


Figure 6 –Learners Feedback on system building, team work and communication skills

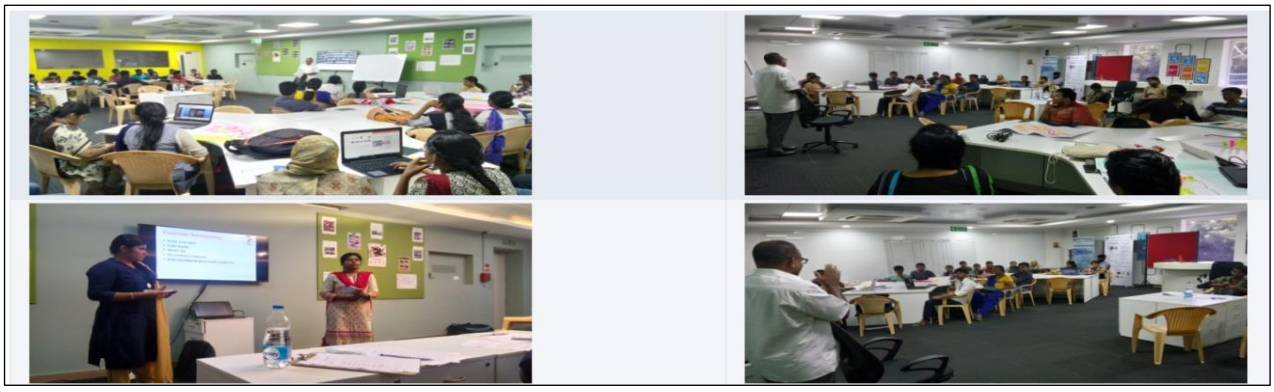


Figure 7 - CDIO Makerspace @TCE

Scale	Criteria
5	Courses are regularly evaluated and revised regarding their integration of learning outcomes and activities
4	There is evidence of the impact of integrated learning experiences across the curriculum
3	Integrated learning expereinces are implemented in courses across the curriculum
2	Course plans with learning outcomes and activities that integrate personal and interpersonal skills with disciplinary knowledge has been approved.
1	Course plans have been benchmarked with respect to the integrated curriculum plan
0	There is no evidence of integrated learning of disciplines and skills

Figure 8 - Progress in integrated learning experience

ACTIVE LEARNING

Active learning methods aim at improving the engagement of learners by involving them in problem solving activities which involve critical thinking. During the self-assessment of CDIO standards in 2017, it has been inferred that active learning methods are implemented in many of the undergraduate courses. However, no impact analysis of active learning strategies on the improvement of learning outcomes has been made and is not documented. Only a few faculty members were interested in adopting modern pedagogical practices and ICT tools in their teaching. The self-assessment for the CDIO standard on active learning is "2" in the academic year 2017-18.In order to improve the rating, a series of capacity building workshops and training programmes on Pedagogy and ICT tools for education were planned for the academic years 2018-19 and 2019-20 respectively. Around 20 faculty members have been certified in the International Engineering Educator Certification Program (IIEECP) offered by the Indo Universal Collaboration for Engineering Education (IUCEE). The program included training on the principles of learner-centered teaching, designing or redesigning a course and its elements, emphasizing learning outcomes, development of different teaching and active learning strategies, and designing formative and summative assessment tools and rubrics for outcomes assessment. The list of in-house faculty training programmes organized is presented in Table 3. Figures 9 presents the photographs of various training programmes conducted for promoting active learning.

Table 3 – List of training programmes for TCE faculty

S.No	Date	Programme	Count of Participants
1.	May – Jun 2018	Development of CDIO based Undergraduate Engineering Curriculum	20
2.	Jun – Sep 2018	Two week workshop on Pedagogy for use of ICT in Education	20
3.	Oct – Dec 2018	Two week workshop on Pedagogy for Online and Blended Teaching-Learning Process	15
4.	Feb 2019	Programme Assessment – Self Evaluation as per CDIO Standard	20
5.	May - Jul 2020	CDIO Based Curriculum Design (three batches) 1. Batch 1:27-05-2020 to 02-06-2020 2. Batch 2: 15-07-2020 to 22-07-2020 3. Batch 3: 27-07-2020 to 31-07-2020	220
6.	4-5, August 2020	Developing learner-centric online courses: Resilient Teaching Approach	40

Figure 9– Faculty Training Programmes @ TCE

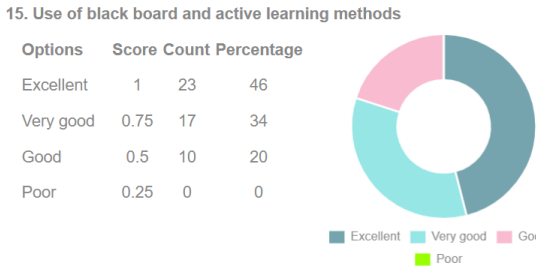
To enforce the implementation of active learning in all classrooms, a common template for instructional design has been developed and is presented in Figure 10 and a sample can be found in the link https://tinyurl.com/4azdy6p4.

Course Plan:

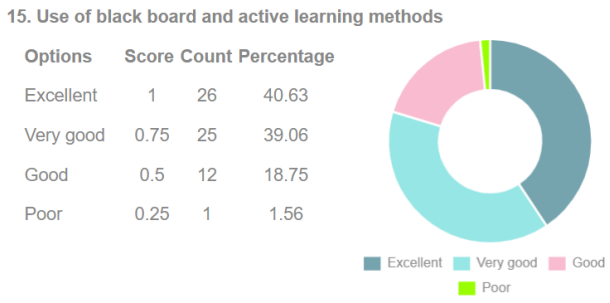
Module No.	Module Name	Cos	Duration (Hours)	Content Delivery Method	Resources / Tools required	Active learning strategy
	Course Outcome					

Figure 10–Template for Instructional Design

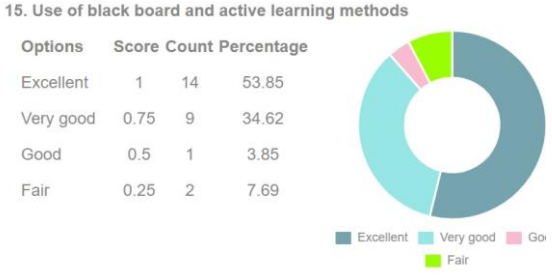
Wide usage of active learning has resulted in improved learning outcomes. Exclusive question banks have been developed to enhance higher order thinking skills of learners. Also, the experience of the learners has been recorded in course end surveys. Figure 11 represents the learner feedback on few sample courses.From these observations, it can be inferred that there is documented evidence on the impact of active learning methods on students learning. Hence, these reforms take the CDIO self-assessment for the standard on active learning from Level 2 to Level 4 as shown in Figure 12.



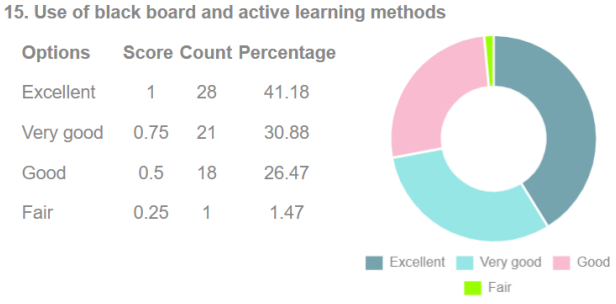
Python Programming



Information Security



Data Structures



Computer Networks

Figure 11 – Learners' feedback on Active Learning

Scale	Criteria
5	Courses are regularly evaluated and revised regarding their integration of learning outcomes and activities
4	There is evidence of the impact of integrated learning experiences across the curriculum
3	Integrated learning experiences are implemented in courses across the curriculum
2	Course plans with learning outcomes and activities that integrate personal and interpersonal skills with disciplinary knowledge has been approved.
1	Course plans have been benchmarked with respect to the integrated curriculum plan
0	There is no evidence of integrated learning of disciplines and skills

Figure 12 Progress in Active Learning

IMPACT ON FACULTY TEACHING COMPETENCE

The training programmes at regular intervals and constant support and encouragement by the management and superiors, for the use of active and collaborative learning strategies has resulted in significant improvement in the faculty teaching competence. TCE, with its strong passion for research, supports research in Engineering Education also. The faculty of TCE has participated in various Engineering Education Research (EER) courses offered by IUCEE. The impact of adopting active learning strategies has been analyzed and published in various educational conferences and journals. The increase in the publications in Engineering education has been increased to 31 for the last three academic years. Having gained expertise on the use of various pedagogical approaches and ICT Tools for education, faculty members have organized exclusive training programmes for the benefit of neighboring and partnering colleges. Sharing of best practices and knowledge sharing with other colleges has led to collective growth in the society. The list of training programmes organized by the faculty members of TCE is presented in Table 4.

Table 4 – List of training programmes by TCE faculty

S.No	Event	Beneficiary
1.	TEQIP Twinning programme on Effective implementation of Outcome Based Education, Mar 2018	Harcourt Butler Technical University, Kanpur
2.	ICT Tools for Effective Teaching, Jan 2019	Faculty from colleges in Tamil Nadu
3.	AICTE QIP sponsored Two week STTP on Effective implementation of Outcome Based Education, Mar 2019	Faculty from colleges in India
4.	AICTE QIP sponsored One week STTP on Pedagogical innovations and Research Directions in STEM Education, Feb 2019	Faculty from colleges in India
5.	Aligning Curriculum Design and Development, content delivery and assessment, Sep 2019	GMR Institute of Technology, Vishakapatnam
6.	Sharing of CDIO practices with the academic community: Best practices in the context of TCE are shared to the academic community through IUCEE Webinar Series – 4 Lectures	IUCEE consortium Members
7.	Best Practices in TCE Academic Process	Jain University, Bengaluru
8.	Typical Curriculum in Engineering and Technology	Faculty from colleges in India

	Organized by CII Southern Region, at Sathyabama University, Chennai and at Mysore	
9.	Unified Academic Processes For Higher Education by Octoze Technologies Pvt.Ltd, Chennai	Senior Faculty Members In India

The faculty members of TCE are presently involved in creating 39 online courses for the benefit of the student community. The courses are selectively designed to improved transition rate, to enable skill development and to promote interdisciplinary research. Based on these observations, it can be inferred that the collective faculty is competent in teaching, learning and in assessment methods. Figure 13 represents the progress in the CDIO standard on Active Learning from level 2 to level 4.

Scale	Criteria
5	Faculty competence in teaching, learning and assessment methods is regularly evaluated and updated where appropriate.
4	There is evidence that the collective faculty is competent in teaching, learning and assessment methods.
3	Faculty members participate in faculty developmet in teaching, learning and assessment methods.
2	There is a systematic plan of faculty development in teaching, learning and assessment methods.
1	A benchmarking study and needs analysis of faculty teaching competence has been conducted.
0	There are no programs or practices to enhance faculty teaching competence.

Figure 13 – Progress in Faculty Teaching Competence

LEARNING ASSESSMENT

The implementation of competency based education in 2008, followed by outcome based education in 2014 and the inclusion of CDIO in 2018 has helped us to update the course contents and improve content delivery significantly. To take it to the next level the academic team felts the need to revise assessment pattern that can given an opportunity for learners to demonstrate or display their depth of learning. Hence, interim assessment is designed that requires students to exhibit their knowledge and skills at various levels. Interim assessment is considered as a part of continuous assessment test and is composed of three categories:

- Category 1 - Knowledge/ concept level (25% weightage) will help to evaluate the conceptual knowledge of the students which can be carried out using quiz, poster presentation, worksheets etc.
- Category II - Presentation/communication skill (25% Weightage)is designed to enable students to demonstrate their presentation skills through seminars, comprehensive viva, video lectures etc.
- Category III - Professional skill – (50% Weightage) is again another activity based assessment to assess the higher cognitive levels. Here students will be evaluated using mini project, Concept test at HOTS, Journal reviews, case analysis etc.

The developed Interim assessment is student centric and helps to engage the students effectively during the course. It helps to them to think and act beyond text books/classroom and students were able to perform well in higher cognitive levels.

An in-house web application TCENeT-Gen3 has been developed to measure course outcomes and program outcomes effectively. The tool is capable of accommodating a wide variety of assessment strategies and measures the intended learning outcomes. A snapshot of the functionalities of TCENet is represented in figure 14. The assessment of learning outcomes in TCENet is represented in figure 15.

Figure 14 – TCENet – Gen 3 Functionalities

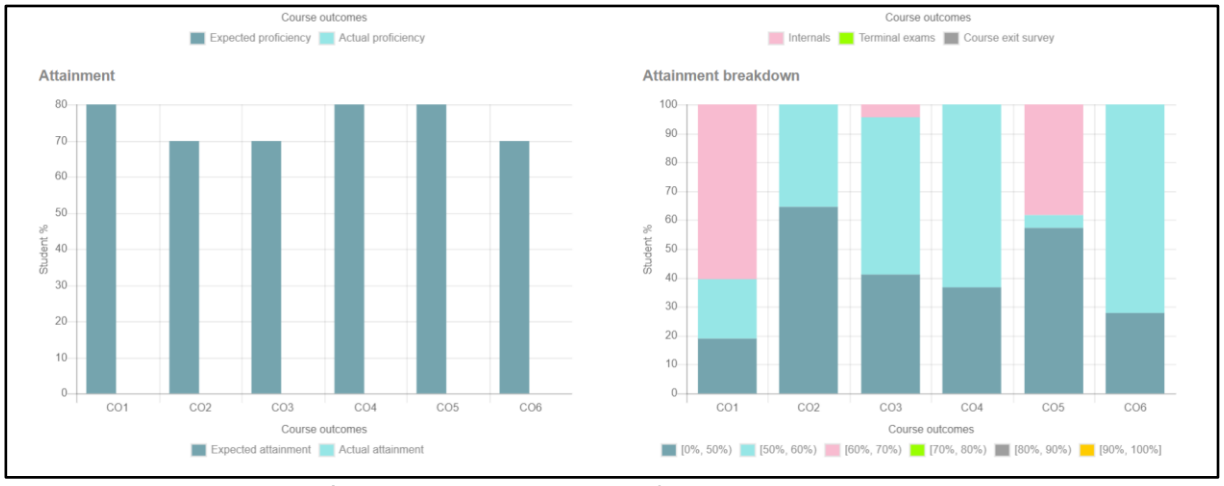


Figure 15 – Assessment of Course Outcomes

An internal academic audit is also conducted every semester to measures the effectiveness of teaching learning and provide feedback and guidance for continuous improvement. Based on the above evidence, it can be inferred that there is progress in the CDIO standard on Learning outcomes and is presented in Figure 16.

Scale	Criteria
5	Evaluation groups regularly review the use of learning assessment method and make recommendations for continuous improvement
4	Learning assessment methods are used effectively in courses across the curriculum.
3	Learning assessment methods are implemented across the curriculum
2	There is a plan to incorporate learning methods across the curriculum
1	The need for the improvement of learning assessment methods is recognized and benchmarking of their current use is in progress.
0	Learning assessment methods are inadequate or appropriate.

Figure 16 – Progress in Learning Assessment

CONCLUSION

The various refinements in the academic process of TCE has brought many laurels to the institute.Various parameters such as quality of projects, placement records, students' participation in national/international competitions and Hackathons, publications in conferences/journals, course exit surveys were used as evidences for assessing the impact of the academic reforms at TCE. National Board of Accreditation (NBA), Government of India recognized TCE as a nodal centre for conducting training programme on Outcome Based Education and Accreditation for faculty members in Engineering Institutions and Universities. TCE has become a member in a Worldwide CDIO initiative in April 2019. TCE has also been recognized by Indian Institute of Technology, Madras (IITM) as "Best Partnering Institute" for active participation in Quality Enhancement in Engineering Education (QEEE) programmes. The institute has also received special appreciation from IITB for "Best Contribution to Learning Repository". Faculty members have received awards under the category of Institutional leadership and leadership in Community Project Based Learning. Students have won prizes in Smart India Hackathons and in contests organized by higher learning institutions. Seven faculty members have received International Engineering Educator Awards (Ing.Paed.IGIP) from International Society for Engineering Pedagogy, Austria. The academics team presently focuses on developing online value-added courses to enhance graduate outcomes and provide improved interdisciplinary learning opportunities for the students of TCE and other institutions and establishing technology-based learning environment for enhancing graduate outcomes of 21st-century learners.Journey of TCE Academic Process continues with its motto "Duty is life" and its principle "Quality and ethics matter"

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BIOGRAPHICAL INFORMATION

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