

LATERAL THINKING COURSE IMPLEMENTATION IN CDIO BASED UNDERGRADUATE PROGRAMMES

Thiruvengadam S J, Venkatasubramani V R

Dean (Academic Process), Thiagarajar College of Engineering, Madurai
Assistant Professor, Electronics and Communication Engineering, Thiagarajar College of Engineering, Madurai

ABSTRACT

Thiagarajar College of Engineering (TCE), Madurai, India has adapted CDIO curriculum for all undergraduate Engineering programmes in 2018 to address the increasing gap between scientific and practical engineering demand and to meet the global requirements of Professional Engineer. In alignment with CDIO syllabus goals and mission of the institute, new courses were introduced in the CDIO curriculum. The course on 'Lateral Thinking' offered at second semester aims to provide a conceive type experience. The purpose of thinking is to collect information and to make the best possible use of it. Vertical thinking is concerned with proving or developing concept patterns. Lateral thinking is a deliberate process closely related to restructuring such patterns – insight and humour; and provocation of new patterns - creativity. Although the emphasis in Indian education has always been exclusively on vertical thinking, the need for lateral thinking arises from the limitations of the behaviour of mind as a self-maximizing memory system. Like any other skill, Lateral thinking skills can be learned, practised and used. The course provides a platform for students to practice lateral thinking under different scenarios such as generating alternatives, challenging assumptions, suspending judgements, innovations, analogies, brainstorming, etc. In this paper, we exhibit the pedagogical structure, evaluation and grading methods developed for the 'Lateral Thinking' course. The evaluation was carried out based on Lateral Thinking ability tests/puzzles, worksheets, and practising lateral thinking skills applied to in real-world projects being aware of the limitation of established patterns. From the formal course exit survey and informal interviews with the students, significant students' engagement was observed in the course individually as well as through teamwork. Students have experienced thinking and practising in a different way with active involvement, in a humorous classroom environment. It is also observed that the lateral thinking course has changed the attitude of students to look at the thing as a useful pattern but not unique or absolute. Students attempt to challenge the assumptions and try to put things together in different ways, creating a different, yet useful pattern. Performance analysis on course implementation has confirmed significant improvement in technical, personal and interpersonal skills of learners. Inclusion of case studies in problem-based learning served as an efficient pedagogical to promote students' engagement in self and reflective learning.

KEYWORDS

Lateral Thinking, CDIO Curriculum, Creative Thinking, CDIO Standards: 1, 2, 4, 5, 7, 8, 9, 10, 11

1. INTRODUCTION

The main objective of any engineering programme is to graduate engineers with ability to conceive-design-implement-operate complex value-added engineering systems in a modern team-based environment (Crawley, 2001). Graduating Engineers should be able to escalate the process of engineering and contribute to the development of products and systems for the advancement of society. However, the recent report on National Employability Skills Report

(Aspiringminds, 2019) shows that 80% of engineers in India are not meeting the requirement for employability in the knowledge economy. The employability trend in India has not improved significantly for the past nine years. In alignment with this, annual review of Internal Quality Assurance Cell in our institute shows that 90% of our students have been offered placement only in software industries for the past decade. This means, the percentage of graduates getting employed in core companies is getting reduced. Practical, personal and interpersonal skills are not up to the expectation of core engineering industries. Though engineering is an applied discipline, the increasing gap between engineering education and engineering practice has driven engineering education towards being more theoretical. Engineers are not sufficiently exposed to conceive-design-implement-operate experiences during the period of their graduation.

Education in India has always focussed exclusively on vertical thinking, until now. Vertical thinking deals with the development and utilisation of ideas while Lateral thinking is concerned with the generation of new ideas. Edward de Bono originated the term *Lateral Thinking* in 1967 in his book 'The Use of Lateral Thinking'. According to Edward de Bano, "Lateral Thinking is a set of processes that provides a deliberate, systematic way of thinking creatively that result in innovative thinking in a repeatable manner". One cannot dig a hole in a different place by digging the same hole deeper (Edward de Bano, 1970). Analogically, Vertical thinking is digging the same hole deeper while Lateral thinking is digging the hole somewhere else. The objective of both is effectiveness. Current education believes in only vertical thinking because lateral thinking has always been seen as redundant or a difficult course to teach (Shlomo Waks,1997). It has been taken for granted that nothing can be done about the generation of new ideas except wait for arousal of such opportunity. Due to such attitude, skill in vertical thinking has developed to a very high degree while skill in lateral thinking remains poor.

In TCE, only a small number of faculty members have exposure to industry standards. Therefore, adopting industrial practices and procedures are limited to a few academic courses and projects. Though we have been following outcome-based education framework (All India Council for Technical Education, 2018), practical skills, lateral thinking skills, design thinking skills, system thinking skills, personal and interpersonal skills have not been much emphasized in the curriculum until 2018. To build faculty competence in design and product building skills and to enhance the emphasis on personal and interpersonal skills in the curriculum, our institution has adopted CDIO curriculum framework addressing the four sections of CDIO syllabus (Edward F. Crawley, 2011). Hence, special courses with appropriate refinements which includes Engineering Exploration, Lateral Thinking, Design Thinking, Project Management and System Thinking have been introduced in TCE CDIO curriculum since 2018. This article reports an experimental study on the impact analysis of Lateral Thinking course offered at TCE. The motivation for this study is supported by the Research Question: What is the impact of the course on 'Lateral Thinking in promoting the 21st century skills namely Creativity, Critical thinking, Collaboration and Communication?

The rest of the paper is organized as follows: Section 2 describes the course structure, content delivery methods and assessment plan adopted for the Lateral Thinking in TCE. Section 3 presents the impact of the course in achieving the desired learning outcomes. Summary of the research discoveries and the scope for improvements are presented in Section 4.

2. LATERAL THINKING COURSE AT TCE

In India, institutions with autonomy have freedom to design and develop innovative curriculum, content delivery and assessment methodologies. In 2013, Outcome Based Education (OBE) framework was made mandatory for accrediting undergraduate engineering programmes in India. However, in reality, cognitive domain is addressed to a greater extent than affective and psychomotor domains. After attending the 11th International CDIO conference, we realized that CDIO framework would be highly suitable for improving undergraduate engineering

curriculum in addressing all 12 graduate attributes of International Engineering Alliance (IEA). The CDIO activities include projects, internships in industry and active learning in theory and practical courses in which state-of-the-art laboratories are considered as workspaces (Johan Bankel et al, 2005). CDIO curriculum was adapted for all undergraduate engineering programmes at our institution in 2018. A specialized new course was introduced at each semester of the programme to improve personal, interpersonal and system building skills of the students, in addition to disciplinary knowledge and reasoning. One among them is the course on 'Lateral Thinking' offered at second semester that aims to provide a conceive type experience to students. This course has paved a way for increasing the effectiveness of the course on 'Design Thinking', the course offered in the following semester (Thiruvengadam S. J., Saravana Perumaal S., Baskar Subramanian, Jeyamala C and Abhaikumar V, 2020).

With the practice of Lateral Thinking skills, the students investigated various case studies and brought meaningful and simple solutions to day-to-day problems. It was observed that students were enthusiastic and interested in generating innovative ideas, as an individual as well as a Team. Also, feedback obtained from the course handling faculty members shows that this course has to be a mandatory one even for school children, to kindle and improve young children level of thinking. This course has been made compulsory for students of all seven undergraduate engineering programmes at our institution.

2.1 Course Design

The expectations of the course are conceived as developing and practicing Lateral Thinking skills by virtue of identification of a societal problem, problem formulation, problem solving using Lateral Thinking, generate alternatives, challenge assumptions, suspend judgments and practice lateral thinking in design process. Apply the concept of factorization and reversal method for restructuring of patterns. Generate ideas by organizing brainstorming sessions. With these requirements, the Course Outcomes (COs) were formulated for the students' engagement in the Lateral Thinking process. The Course Outcomes (COs) of this course along with corresponding weightage in percentage are listed in Table 1. In order to deliver the course effectively, the faculty members were involved in sharing best practices in a weekly meeting organised by the Academic Process Team headed by the Dean (Academic Process). Besides, an industry-expert has delivered few guest lectures to the class on Awareness of limitation of established patterns and lateral thinking process in small projects, as case studies.

Table 1 Course Outcomes of Lateral Thinking Course

CO#	Course Outcome Statement
	On the successful completion of the course, students will be able to
CO1	Explain the concept of lateral thinking, distinguish it from vertical thinking.
CO2	Use lateral thinking for problem solving
CO3	Generate Alternatives, challenge assumptions and suspend judgment and Practice lateral thinking in design process
CO4	Apply the concept of factorization and reversal method for restructuring
CO5	Organize brainstorming sessions
CO6	Use PO for innovation
CO7	Aware of limitation of established patterns and practice lateral thinking in small projects

2.1.1 Course Content

The content has been evolved from the defined course outcomes. The course content with corresponding course outcomes is shown in Table 2 and the relationship established with the TCE proficiency scale (Thiruvengadam S J, Baskar Subramanian, Venkatasubramani V R and

Abhaikumar V, 2020) and CDIO syllabus version 2.0 (Edward, Johan, William, & Doris, 2011) is depicted in Table 3.

Table 2 Course Content with Corresponding Course Outcomes

Module No.	Topic	Course Outcome
1.	The way the mind works	CO1
1.1	Difference between lateral and vertical thinking	CO1
1.2	Attitudes towards lateral thinking	CO2
2.	Basic nature of lateral thinking	CO2
2.1	The use of lateral thinking techniques	CO2
2.2	The generation of alternatives	CO3
2.3	Challenging assumptions	CO3
2.4	Innovation	CO3
2.5	Suspended judgment	CO3
3.	Design	CO3
3.1	Dominant ideas and crucial factor	CO3
3.2	Fractionation	CO4
4.	The reversal method	CO4
4.1	Brainstorming	CO5
4.2	Analogies	CO5
4.3	Choice of entry point and attention area	CO5
4.4	Random stimulation	CO5
4.5	Concepts/divisions/polarization	CO5
4.6	The new word PO	CO6
5.	Blocked by openness	CO7
5.1	Description/problem solving/design	CO7

Table 3 CO Mapping with TCE Proficiency Scale (TPS) and CDIO Curriculum Framework

CO #	TPS	Learning Domain Level			CDIO Curricular Component (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	-	2.3.1, 3.2.6
CO2	TPS3	Apply	Value	-	2.4.1, 2.4.2, 2.4.3
CO3	TPS3	Apply	Value	-	2.4.1, 2.4.2, 2.4.3, 2.4.5, 2.4.6
CO4	TPS3	Apply	Value	-	2.3.1, 2.4.2, 2.4.3
CO5	TPS4	Analyse	Organize	-	3.1.1, 3.1.2, 3.2.1, 3.2.2
CO6	TPS3	Apply	Value	-	2.3.1, 2.4.1, 2.4.2, 2.4.3, 2.4.6
CO7	TPS5	Evaluate	Characterize	-	2.3.4, 4.5.1, 4.6.1

Out of the four sections of CDIO syllabus namely 'Technical Knowledge and Reasoning, Personal and professional skills, Interpersonal skills and CDIO', the Lateral Thinking course has addresses 'Personal and professional skills and Interpersonal skills and CDIO' very well. In particular, this course emphasizes the conceive part to a larger degree. Students found it interesting to apply lateral thinking skills to various issues that eventually improved their morale, self-esteem and personality, as a whole. As shown in Table 3, the mapping of COs with CDIO curricular components indicates that the the Lateral Thinking course very well addresses the cognitive and affective domain of learning. Moreover, the introduction of this course has also strengthened the mapping between course level learning outcomes and some of the so called 'usually rarely addressed' graduate attributes / programme outcomes of IEA (International Engineering Alliance, 2013). These 'usually rarely addressed' graduate attributes are: The engineer and society, Individual and team work, Ethics, Communication, and Life-long learning. Table 4 shows the mapping between Course Outcomes and these

'usually rarely addressed' graduate attributes. It can be observed that most of these graduate attributes are strongly addressed by the Lateral Thinking Course Outcomes.

Table 4 Course Outcomes and 'Usually Rarely Addressed' Graduate Attributes

CO #	The engineer and society	Ethics	Individual and team work	Communication	Life-long learning
CO1	-	-	-	-	L
CO2	-	S	S	S	S
CO3	-	S	S	S	S
CO4	-	S	S	S	S
CO5	-	S	S	S	S
CO6	S	S	S	S	S
CO7	S	S	S	S	S

S- Strong; M-Medium; L-Low

2.1.2 Assessment Plan

Three worksheets are given to students periodically after the coverage of the corresponding course outcomes. The work sheets tests the various Lateral Thinking ability skills such as the use of lateral thinking techniques, the generation of alternatives, challenging assumptions, Innovation, Suspended judgment, dominant ideas and crucial factors, fractionation, and the reversal method. Whereas the three Case Studies given towards the end of the course tests the students' capabilities on organizing brainstorming, finding analogies, choice of entry point and attention area, random stimulation, Concepts/divisions/polarization, Blocked by openness, and Description/problem solving/design in small projects. The detailed assessment plan is presented in Table 5.

Table 5 Detailed Assessment Plan

Assessment Type	Deliverables	Marks	Course Outcomes
Continuous Assessment			
Worksheet - 1	Worksheet	5	CO1
Worksheet - 2	Worksheet	5	CO2
Worksheet - 3	Worksheet	10	CO3 and CO4
Case Study - 1	Technical Report	10	CO1 to CO7
Case Study - 2	Technical Report	10	CO1 to CO7
Case Study - 3	Technical Report	10	CO1 to CO7
End-Semester Examination			
Ability Test	Answer sheets	50	CO1, CO2, CO3 and CO4
Case Study (Best) Presentation and Viva-voce	Technical Report	50	CO1 to CO7
<ul style="list-style-type: none"> • Technical Reports are to be submitted at each case study presentation. The report and presentation will be evaluated based on customized Rubrics. • For End-Semester Examination, the best one among the 3 case studies shall be presented along with the corresponding technical report. Presentation and technical report will be evaluated by two faculty members nominated by the respective Head of the Department. Also, viva-voce (oral) examination shall be conducted by these faculty member. 			

As per the assessment plan, rubrics are developed and implemented for evaluating case studies. The Rubrics for evaluation of Case Studies is presented in Table 5. Also, communication skill is assessed during the presentation process.

Table 7 Assessment Rubric for Case studies

Descriptors	Exemplary (4)	Proficient (3)	Partially proficient (2)	Incomplete (1)
Motivation and Objective	Clearly stated the motivation and objective of the case study with appropriate evidences and data	Clearly stated the motivation and objective of the case study with enough evidences and data	Stated the motivation and objective of the case study with minimum evidences and data	Lack of clarity in the statements and objective of the case study with no or inappropriate evidences and data
Identification of Stakeholders	All the stakeholders are identified with their roles and responsibilities.	All the stakeholders are identified and the roles and responsibilities are identified for a only a few	All the stakeholders are identified but their roles and responsibilities are not defined.	Few Stakeholders are identified. Roles or responsibilities are not defined.
Identification of problem	Excellent and clear understanding of the scope of the problem and its objectives.	Sufficiently states the scope of the problem and is able to identify and list the objectives.	Able to identify the scope and objectives with discrepancies.	Unable to identify the scope and objectives.
The use of lateral thinking techniques	The work demonstrates confident ability in applying lateral thinking techniques with the key concepts / information / process / theory - applying or extending them to a wide variety of new problems or contexts, making predictions, recognizing hidden meanings,	The work demonstrate s adequate ability in applying lateral thinking techniques with the key concepts / information / process / theory - - applying or extending them to a wide variety of new problems or	The work demonstrates uneven and shaky ability in applying lateral thinking techniques with the key concepts / information / process / theory - - applying or extending them to a wide variety of new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences,	The work demonstrates extremely limited ability in applying lateral thinking techniques with the key concepts / information / process / theory - - applying or extending them to a wide variety of new problems or contexts, making predictions,

Descriptors	Exemplary (4)	Proficient (3)	Partially proficient (2)	Incomplete (1)
	drawing inferences, analysing patterns and component parts, communicating insightful contrasts and comparisons.	contexts, making predictions, recognizing hidden meanings, drawing inferences, analysing patterns and component parts, communicating insightful contrasts and comparisons.	analysing patterns and component parts, communicating insightful contrasts and comparisons.	recognizing hidden meanings, drawing inferences, analysing patterns and component parts, communicating insightful contrasts and comparisons.
The generation of alternatives	The work demonstrates confident ability to generate alternatives with the key concepts / information / process / theory	The work demonstrates adequate ability to generate alternatives with the key concepts / information / process / theory	The work demonstrates uneven and shaky ability to generate alternatives with the key concepts / information / process / theory	The work demonstrates extremely limited ability to generate alternatives with the key concepts / information / process / theory
Challenging assumptions	The work demonstrates confident ability in Challenging assumptions with the key concepts / information / process / theory	The work demonstrates adequate ability in Challenging assumptions with the key concepts / information / process / theory	The work demonstrates uneven and shaky ability in Challenging assumptions with the key concepts / information / process / theory	The work demonstrates extremely limited ability in Challenging assumptions with the key concepts / information / process / theory
Thinking towards Innovation	The work demonstrates confident ability in thinking towards Innovation with the key concepts / information / process / theory	The work demonstrates adequate ability in thinking towards Innovation with the key concepts / information / process / theory	The work demonstrates uneven and shaky ability in thinking towards Innovation with the key concepts / information / process / theory	The work demonstrates extremely limited ability in thinking towards Innovation with the key concepts / information / process / theory

Descriptors	Exemplary (4)	Proficient (3)	Partially proficient (2)	Incomplete (1)
Use of Fractionation / The reversal method / Analogies	The work demonstrates confident ability in Fractionation / The reversal method / Analogies with the key concepts / information / process / theory	The work demonstrate s adequate ability in Fractionation / The reversal method / Analogies with the key concepts / information / process / theory	The work demonstrates uneven and shaky ability in Fractionation / The reversal method / Analogies with the key concepts / information / process / theory	The work demonstrates extremely limited ability in Fractionation / The reversal method / Analogies with the key concepts / information / process / theory
Organize Brainstorming	The work demonstrates confident ability in organizing brainstorming	The work demonstrate s adequate ability in organizing brainstorming	The work demonstrates uneven and shaky ability in organizing brainstorming	The work demonstrates extremely limited ability in organizing brainstorming
Presentation Slides	Slides support the presentation, are easy to read and understand, key words are used effectively.	Slides are easy to read and understand	Slides are easy to read and understand in most of the slides.	Slides are difficult to read and understand spelling/grammar errors are evident.
Communication Skill	Effectively and creatively delivers the information while staying on the topic and considering the audience, uses voice variations, seems confident and delightful ending on time.	Adequately delivers the information while staying on the topic, considers the audience, speaks clearly and ends on time	Delivers the information while staying on the topic, considers the audience, speaks somewhat clearly, trying to end on time	Demonstrates inconsistent command of English language

3. IMPACT ANALYSIS

The Lateral Thinking course was offered to 880 undergraduate students belonging to Civil Engineering, Mechanical Engineering, Electrical and Electronics Engineering, Electronics and Communication Engineering, Computer Science and Engineering, Information Technology and Mechatronics programmes. In our institution, Electronics and Communication Engineering students of the current batch were more diversified with respect to location, gender, and ability. Hence, study was conducted to analyze the Electronics and Communication Engineering students' engagement in this course and their perceptions on learning experiences and professional skills of 21st century learning skills (creativity, critical thinking, collaboration, and communication). A survey with a 4-point Likert scale from Fair (coded as 1) to Excellent (coded as 4) has been conducted to determine the effectiveness of the course. Students' learning

experiences in the Lateral Thinking process, team experience, professional communication and assessment were performance measures of this online survey. 51 (out of 51) responses were received. The distribution of the responses is presented in Table 7.

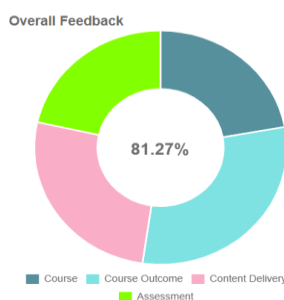
Table 7 Students' Response on Effectiveness of Lateral Thinking Course

*Values are in percentage

Response Scale Description	4 (Excellent)	3	2	1 (Fair)
1.0 Learning Experience on Lateral Thinking Process				
1.1 Identification of Stakeholders	45.8	47.5	6.3	0.4
1.2 Identification of Problem	42.3	50.5	6.9	0.3
1.3 The use of lateral thinking techniques	38.5	49.1	11	1.4
1.4 The generation of alternatives	51.2	42	6.4	0.4
1.5 Challenging assumptions	49.2	43.4	7	0.4
1.6 Thinking towards Innovation	50.8	39.3	9.4	0.5
1.7 Use of Fractionation / The reversal method / Analogies	41.2	47.9	10.3	0.6
1.8 Organize Brainstorming	48.1	44	7.5	0.4
2.0 Team Experience				
2.1 Roles and responsibilities assigned	48.9	44.3	6.4	0.4
2.2 Opportunities to contribute individually	50.2	41.8	7.4	0.6
2.3 Contribution of other members	49.1	34	14	2.9
3.0 Experience in professional communication				
3.1 Oral Presentation	48.1	42.8	8.5	0.6
3.2 Report writing experience	44.7	48.5	5.4	1.4
3.3 Developed listening experience	55.5	36.8	6.6	1.1
3.4 Drawings/sketches in idea generation and communication	56.3	37.4	5.2	1.1
4.0 Assessment				
4.1 Guidance of Assessment rubrics in the execution of the project	55.3	38.4	5.1	1.2
4.2 Satisfaction level in assessment	39.4	50.8	9.4	0.4
4.3 Worksheets – Continuous Assessment	49.5	34	14	2.5
4.4 Case study presentation – Continuous Assessment	47.4	44	8.3	0.4
4.5 Case study presentation – End Semester Examination	52.3	39.6	7.1	1.0
4.6 Confidence in presentation	51.6	41.2	6.2	1.0

It can be observed that so called 'usually rarely addressed' graduate attributes / programme outcomes of IEA are almost addressed with significant correlation level.

2019-20 Even: 18ES290 [4] Lateral Thinking: Statistics



Total count: 51, Response count: 51

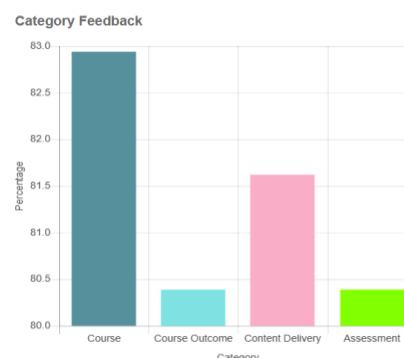


Figure 1. Overall and category-wise students' feedback of Lateral Thinking course

The overall students' feedback and category-wise students' feedback of Lateral Thinking course is shown in Figure 1 and the highlights of course exit survey for Lateral Thinking course is shown in Figure 2. The involvement of students in Lateral Thinking course is really encouraging. This course has changed the way they habitually think and this is the reason that they involved in the various activity in the class with eagerness and enthusiasm.

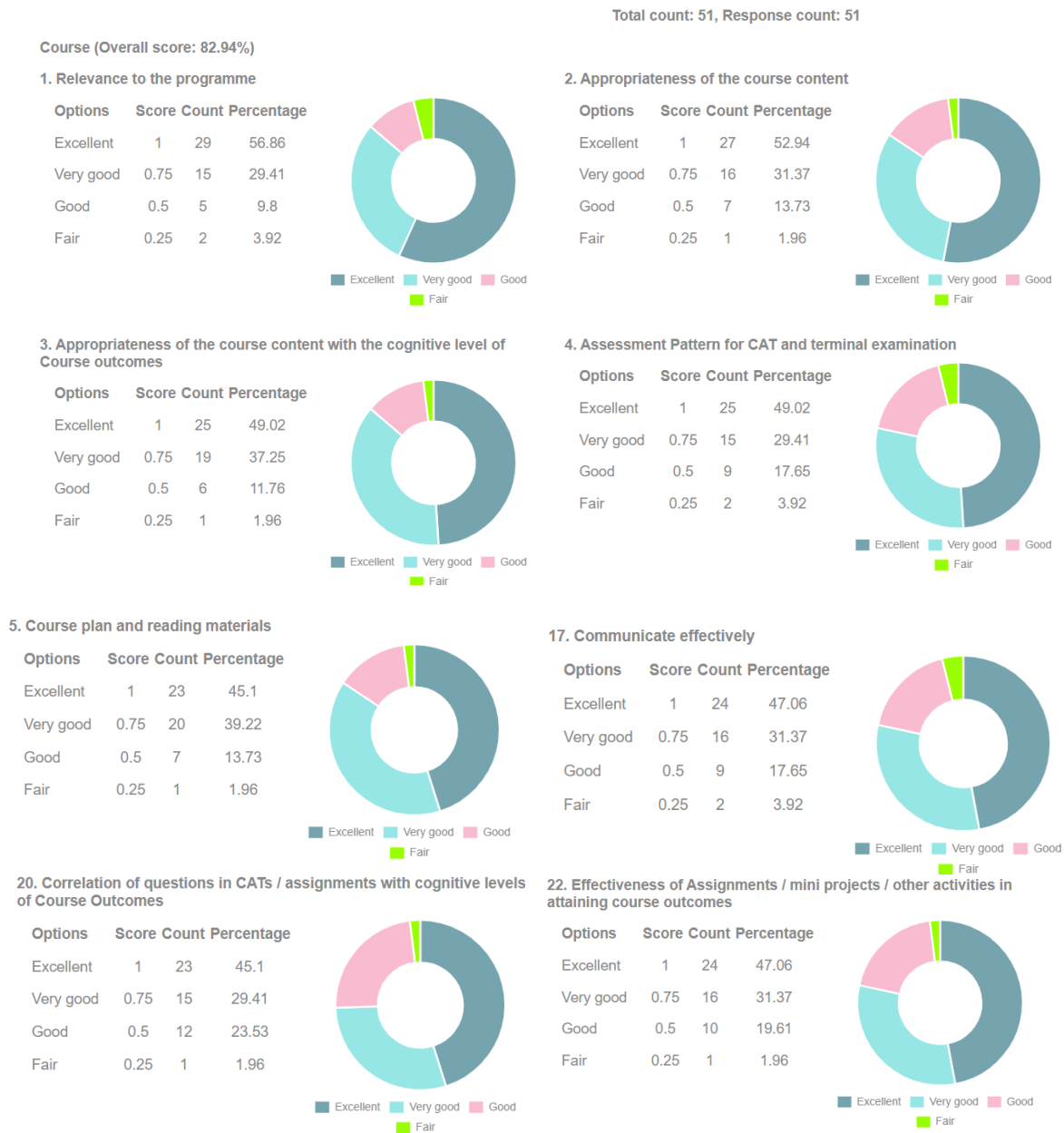


Figure 2. Course exit survey

Also, the students demonstrated their Lateral Thinking skills and showcased their ability in conferences and International Hackathon, for which they won awards and laurels. A student named Arunaggi Pandian was declared as winner for 'Designing the cities of tomorrow', a 24-hour Hackathon for innovation minds in WEEF (World Engineering Education Forum) and GEDC (Global Engineering Deans Council) 2020 Virtual Conference, 16-19 November 2020. This was a Team effort with 3 diversified international student members in the Team. In an interview with him, he specified the usefulness of Lateral Thinking course and how Lateral Thinking techniques helped him to complete the contest with limited time space.

4. CONCLUSION

TCE is the first institution in India to adapt CDIO curricular education framework for seven undergraduate engineering programmes in alignment with guidelines by the Indian regulatory authorities. In this curriculum, a new specialized course was introduced at each semester of the programme to improve personal, interpersonal and system building skills of the students, in addition to the disciplinary knowledge and reasoning. In second semester, Lateral Thinking course is offered to all the students of all seven undergraduate engineering programmes. The Lateral Thinking course very well addresses the cognitive and affective domain of learning. Moreover, this course also strengthened the mapping between course level learning outcomes and some of the so called 'usually rarely addressed' graduate attributes. Survey on Students' Response on Effectiveness of Lateral Thinking Course and Course exit reveals that the students found it enthusiastic to apply lateral thinking skills to various issues that eventually improved their overall personality. Use of rubrics for case study presentation served as an effective instrument for assessing personal and interpersonal skills. Based on the feedback from faculty and students and as a part of continual improvement, few refinements in the pedagogy of Lateral Thinking course are in progress. Continual efforts are in place for faculty training on Lateral Thinking for providing innovative and quality solutions that are not so obvious, to community problems.

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BIOGRAPHICAL INFORMATION

Thiruvengadam. S.J. holds Doctoral Degree in the field of Signal Processing for Communications. He carried out postdoctoral studies at Stanford University, USA in the area of MIMO Wireless Communications. He has completed many sponsored research projects in the area of Signal Processing for Defence Laboratories and Industries. 11 students were awarded Doctoral Degree under his guidance. He has completed IUCEE Engineering Education Certification Programme with Distinction and got IUCEE Engineering Educators Award for the year 2017 and IUCEE Institutional Leadership Award for the year 2019.

Venkatasubramani.V.R. holds Doctoral Degree in the field of Elliptic Curve Cryptographic Hardware Implementation. His expertise covers Engineering Education, Computer Arithmetic, and Cryptographic Algorithms Implementation in Hardware. He has completed IUCEE Engineering Education Certification Programme. He is also a CDIO Core Group Member in TCE.

Corresponding author

Thiruvengadam S J
Dean (Academic Process) and Professor,
Department of Electronics and
Communication Engineering, Thiagarajar
College of Engineering, Madurai – 625015.
Tamil Nadu, India
sjtece@tce.edu



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