Enhancing Attainment of Learning Outcomes Through Active Learning

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Abstract*— This paper presents an experimental study conducted on employing Active Learning strategies towards enhancing the attainment of learning outcomes of a course "Linear Control Systems" in the undergraduate (UG) Electrical and Electronics Engineering (EEE) programme. The existing UG programme curriculum is retrofitted into outcome-based curriculum. The Programme Outcomes (POs) for this programme are derived from the Graduate Attributes of Washington Accord (WA). In order to meet the POs, Course Learning Outcomes (CLOs) are written predominantly in the Cognitive (Revised Bloom's taxonomy) and Psychomotor (Dave's taxonomy) domains for lecture-based courses and laboratory courses, respectively and very few are written in Affective (Bloom's taxonomy) domain. In this paper, four CLOs (i) Discuss the various classification of control systems (K_2), (ii) Define the time and frequency response of the system (K_2), (iii) Derive the overall transfer function of the given Block diagram of a system (K_3) and (iv) Derive the overall transfer function of a Signal Flow Graph (SFG) of a system (K_3) are considered to measure the effectiveness of active learning methods in attaining the outcome. Active learning methods such as Jigsaw, Think-pair-share and Peer instruction, and traditional lecture-based methods were employed. In addition, ClassComm software with student interactive devices was used to measure the students' learning in the classroom and subsequently the attainment of CLOs. This study compares the effectiveness of active learning methods with the traditional lecture-based instruction method in relation to the attainment of CLOs. The overall analysis results reveal that both instructors and students received the active learning methods very well, and they are very effective in enhancing the attainment of learning outcomes. However, instructors are of the view that the duration of the contact period should be at least two hours.

***Keywords*—** active learning, Bloom's taxonomy, concept map, control systems, learning outcomes,

I. INTRODUCTION

In the last two decades, one might have seen unimaginable technological advancements from household to industrial operations in all walks of life. These revolutionary changes, by and large, caused attitudinal/behavioural changes in every individual's life. Educational processes, wherein faculty and students are major constituencies, are not exceptional. Though many engineering institutions have been attempting to bring reforms in curriculum and teaching-learning, quite a few only have achieved it at the international level. In India, the National Board of Accreditation (NBA) changed its accreditation process based on the attainment of learning outcomes and became a signatory member of the Washington Accord (WA) in 2014. After that, Universities and autonomous colleges in India that go for accreditation started implementing Outcome-Based Education (OBE) because of which changes in curriculum and teaching-learning take place. In the OBE system, the major modules, namely curriculum design, instructional means and assessment, are anchored with learning outcomes that portray what students know and be able to do upon successful learning of relevant concepts. Of the three, the instructional modes, so-called content delivery methods, play a pivotal role in attaining learning outcomes. Though learning abilities of the students and faculty course competency are excellent, faculty teaching competency-primarily decides the attainment of learning outcomes.

Analytic report of Control Engineering course of past five years revealed the following. Students in regular size classrooms are (i) daydreaming, (ii) attending casually to the lecture, (iii) chatting with neighbours, (iv) drawing pictures in the notebook, or (v) going outside for nonsense reasons. Very few students only visibly engaged in taking notes during a lecture in the classrooms. The majority of the students have mindsets that they will be getting lecture notes, PowerPoint slides and other learning resources. This notional belief came into the students' minds strongly because course faculty are under pressure to achieve their pass percentage target in their respective courses more than student learning. A team of five senior faculty members reviewed and analysed course-analytic reports of previous years and has come up with the solution to employ active learning strategies in the classrooms to enhance the attainment of learning outcomes. As a first step, seven active learning classrooms were established. They were equipped well with ICT facilities, including student response hand-held remotes with ClassComm software. Faculty members have been trained to practice active learning methods through workshops.

II. ACTIVE LEARNING METHODS – RELATED WORK

The lecture method is a relatively poor instructional approach for maintaining student attention (Bligh, 2000). It involves transferring information from the lecturer's notes to the student's notes without passing through either's minds. In addition, research findings suggest that student concentration during lectures begins to decline after 10-15 minutes (Stuart & Rutherford, 1978). A summary of the different types of evidence offered to support this assertion is provided by Bligh (2000). Over the years, scholars, researchers and national reports have also discussed the importance of employing active learning instructional strategies to maximize student learning in the college or university classroom (Crawley et al., 2014).

(Fusic S J et al., 2018) investigated how to use Active learning tactics to transform student entertainment such as games, riddles, quizzes, peer-to-peer learning, and demonstration into teaching methods. The active learning surveys, student activities, and experience with the activities are discussed using case studies by comparing the performance of two batches of students (2014 & 2016 – electrical machine course) with and without the activities utilising active learning approaches.

(R. Suganya et al., 2020) have confirmed that students are delighted with learning based on the Jigsaw technique. Based on feedback, Jigsaw activities are presumed to have helped students learn self-learning, teamwork, and collaborative learning. This case study proves that active learning is the best methodology for improving student understanding and performance on exams.

(Asok D et al., 2016) used ALE (Authentic Learning Experiences) tactics such as Role Play, Jigsaw, Brainstorming, Debate, Mind Mapping, and others for Concept Understanding and Group Assignments, Combined Mini Projects, Topic Discussions, Quizzes, and Puzzles for Concept Applying and also used a variety of learning tactics and evaluated the results of the students to achieve HOTS (Higher Order Thinking Skills). HOTS is attained by developing software or products that promote interpersonal skills and lifelong learning abilities. The effectiveness of ALE among engineering students is demonstrated by significant improvements in their academic performance, placement record, and research interests.

In a digital logic and computer organisation/assembly language course sequence, the frequent usage of simple Active Learning such as Think-pair-share (TPS), minute paper, and pair programming were employed. Exam results from the current semester were compared to those from previous semesters, with Grade point average (GPA) serving as a control variable. In both courses, exam scores were much higher during the active semester. Renee M. (Clark et al. 2018) evaluated techniques indirectly through content analysis of student interviews using a research-backed coding scheme; the vast majority of students thought the techniques were beneficial to their learning, with the majority citing the ability to converse and collaborate with their classmates to solve problems as one of the most important benefits.

(Werdiningsih et al. 2018) used a quantitative descriptive research design to examine students' mathematics learning achievement through the think-pair-share (TPS) model and science, technology, engineering, and mathematics (STEM) approach. The results showed that students using the STEM method in the TPS model had superior mathematics learning achievement in geometry than students who used the TPS model. Furthermore, pupils who used the TPS approach performed higher in geometry than those who used direct learning.

From the literature review, it is inferred that the active learning methods will certainly improve the students' learning. The active learning methods discussed from the reported works are effective and highly recommended. Also, it is confirmed that the active learning methods promote better understanding than the traditional methods. At this juncture, it is worth to study the effectiveness of active learning methods over traditional methods vis-à-vis enhancing the attainment level of course learning outcomes. Hence, an experimental study was conducted on employing Active Learning strategies towards enhancing the attainment of learning outcomes of a course "Linear Control Systems" in the undergraduate (UG) Electrical and Electronics Engineering (EEE) programme. Three active learning methods such as the Jigsaw method, Think-pair-share and Peer instruction are employed in this work in addition to the traditional lecture with discussion.

(Jung Hyun et al., 2017) investigated the effect of active learning pedagogies on students' satisfaction of learning processes in Active Learning [ALC] and Traditional Classrooms [TCs]. Each student had to answer the questionnaire focusing on the class in which the survey was administered, the negative effects appeared minimal. According to the findings, active learning pedagogical activities are important factors in increasing students' engagement with their individual and group learning processes. Furthermore, active learning pedagogical activities in both TCs and ALCs favorably increased students' satisfaction with their learning processes.

(Tiia Rüütmann, 2019) This article presents the philosophy and basics of Engineering Pedagogy Science - the key to science-based, effective, interactive, and motivating engineering teaching, shaping the foundation of engineering faculty teaching competencies, and ensuring relevantly one of the prerequisites of the quality of engineering education in general. This paper presents the foundational questions shaping the philosophy of Engineering Pedagogy Science, as an analytical ground for effective course design and further course development based on informed decisions, the didactical pentagram, and the basic didactical model of Engineering Pedagogy Science. The didactical pentagram of Engineering Pedagogy Science serves as the foundation for engineering faculty's core pedagogical competences, as well as specialist competencies, ensuring effective engineering instruction.

(Henna Vilppu et al., 2019) The study explores whether short online pedagogy courses can have an effect on university teachers' interpretations of teaching–learning situations. Pedagogical training should be offered already at the early stages of teaching careers. Learning and content focused approach Using video clips with written interpretations as a method for studying conceptions of teaching. To study teachers' conceptions of teaching, selected video assessments to avoid problems related to self-report measures.

(Chadia A. Aji et al., 2019) This paper investigates the effect of active learning on academic success of students from underrepresented groups in STEM in introductory mathematics and aeronautical engineering courses. The "flipped classroom" is one way to freeing up class time for active learning. Lower-level math and aeronautical engineering classes used active-learning methodologies. A comparison of active-learning (flipped) and regular classrooms revealed that the active-learning approach had a beneficial influence. Students in the active-learning classroom outperformed those in the traditional classroom, with 64% attaining an A-grade compared to 36% in the traditional classroom. According to the findings, active-learning (with flipped delivery) in lower level math and aeronautical engineering courses resulted in not only better success rates but also higher academic performance of students.

III. Proposed Work

Learning outcomes are statements that portray what learners will know or be able to do due to a learning activity. Outcomes are abilities usually expressed as knowledge, skills, and attitudes. CLOs are written for courses. Learning outcomes are derived from a need assessment. The need assessment should determine the gap between the present and expected levels of knowledge, skills, or attitudes. Learning outcomes represent the solution to the identified need or issue. They provide direction in the planning of a learning activity and help focus on the learner's behaviour that is to be changed, serve as guidelines for content, instruction, and evaluation, identify precisely what should be learned and convey to learners exactly what is to be accomplished. In this paper, four CLOs are considered for the various topics in the Linear Control Systems course. Focus questions portray both

Facilitator and learners to identify the concepts to attain the specific CLO. CLOs 1&2 and 3&4 are at understanding (K_2) and applying (K_3) levels respectively in the cognitive domain of revised Bloom's taxonomy. Complexity for CLO 1 and 2 is (K_2), while complexity for CLO 3 and 4 are (K_3). The effectiveness of active learning methods is examined using a combination of methods. To measure the extent of effectiveness of active learning methods, two sections of 30 students each are taken. Table 1 shows that the Jigsaw technique and the Lecture with discussion approach were used for Section A, whereas, for Section B, Peer Instruction and Think-pair share were used. The focus questions pertaining to the chosen CLOs with learning concepts and concept maps (hierarchical interconnection among the concepts towards the attainment of learning outcome) are given below.

TABLE 1
CLOs with Bloom's taxonomy levels and active learning methods

CLO	**Pedagogy**		
	Cognitive level (Bloom's taxonomy)	***Section A***	***Section B***
CLO 1	Understanding (K_2)	Jigsaw	Peer Instruction
CLO 2	Understanding (K_2)	Lecture with Discussion	Think-pair-share
CLO 3	Applying (K_3)	Jigsaw	Peer Instruction
CLO 4	Applying (K_3)	Lecture with Discussion	Think-pair-share

Topics: Introduction to Control System - Basic classification of Control system – Open-loop and closed-loop systems – Examples – Definition of time and frequency response of system; CLO - 1: Discuss the various classification of control systems (K_2); Focus Questions: 1.1 How will you distinguish linear and nonlinear systems with examples? 1.2 How are systems classified? Explain with examples; Learning Concepts Set: System, Linear and Non-linear, Control system, Classification, Time-Variant, Time-Invariant, Open and Closed-loop, Manual Automatic, Servo and Regulatory, Analog and digital. The concept map for CLO - 1 is shown in Fig. 1.

Topics: Transfer function - Definition of time and frequency response of a system; CLO - 2: Define the time and frequency response of the system (K_2); Focus Questions: 2.1 What do you mean by the time response of a system? Explain with examples.
2.2 Why do we need the frequency response of a system? Learning Concepts Set: Response, Transfer function, Laplace transform, Standard test signals, transient response, steady-state response, time response, initial value theorem, final value theorem, sinusoidal signal, Amplitude, frequency, phase, frequency response, bandwidth, stability. The concept map for CLO - 2 is shown in Fig. 2.

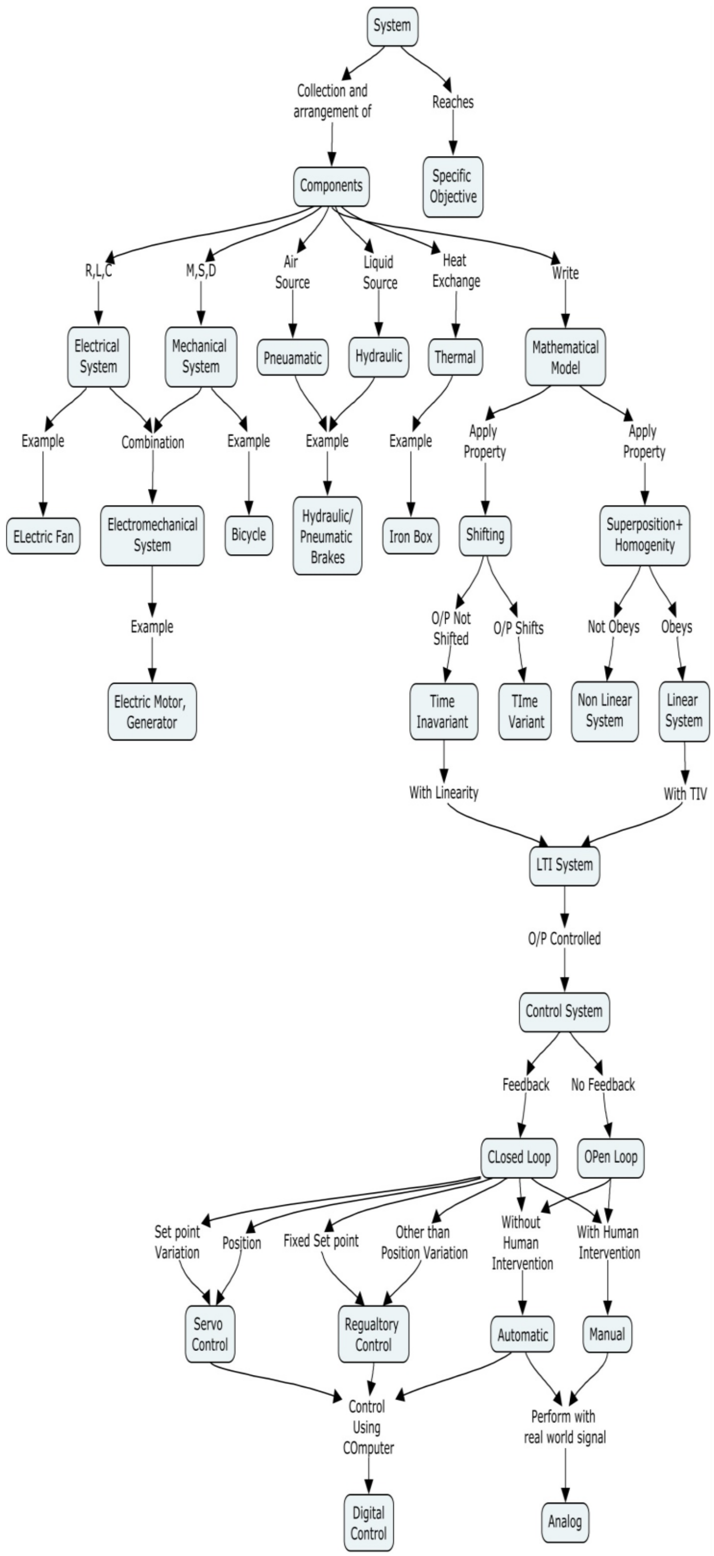

Fig. 1: Concept map for CLO - 1 (K_2)

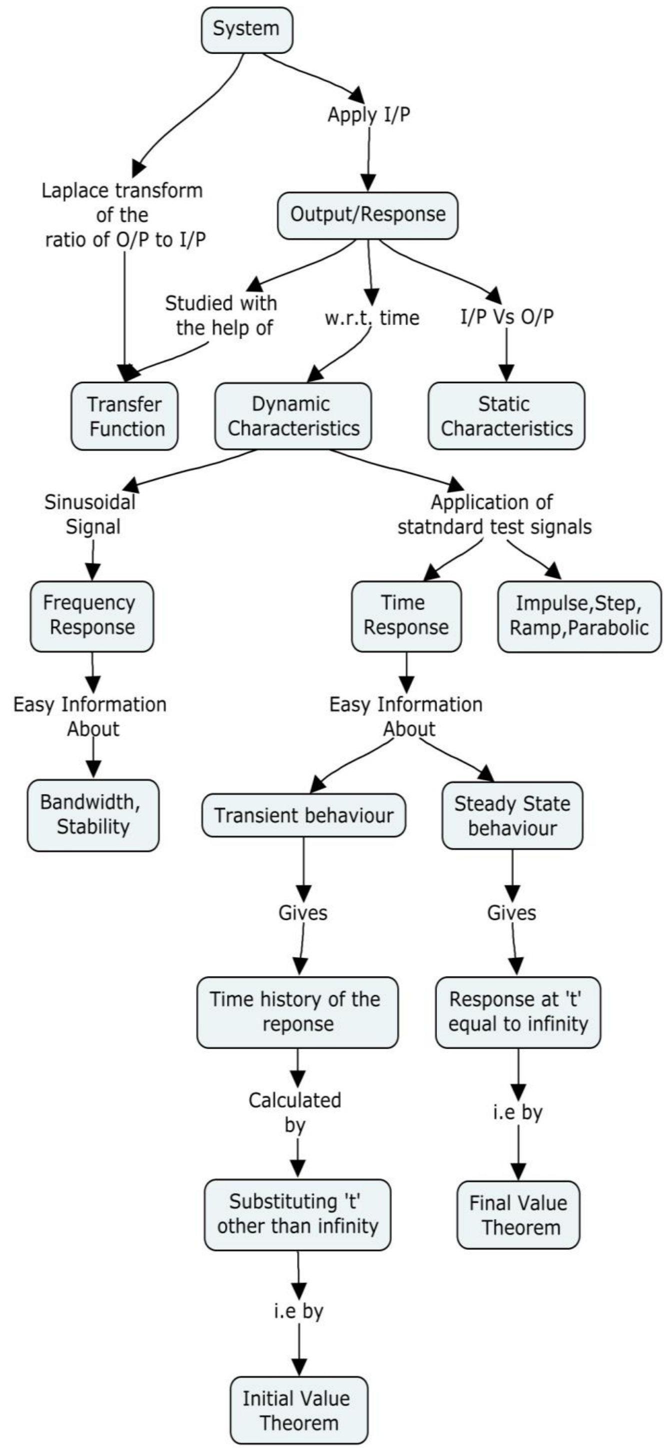

Fig. 2: Concept map for CLO - 2 (K_2)

Topics: Block diagram algebra and reduction techniques; CLO - 3: Derive the overall transfer function of a given Block diagram of a system (K_3); Focus Questions: 3.1 State the basic hierarchy of simplifying the block diagram; 3.2 If you simplify the block diagram in Figure (a) to the form in Figure (b), then the values of X, Y and Z are:

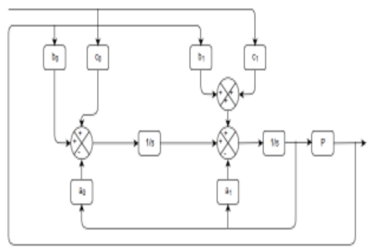

Figure (a)

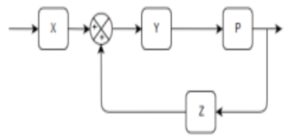

Figure (b)

a) $X=c_1s + c0$, $Y=\frac{1}{s^2+a_1s+a_0}$, $Z=b_1s+b_0$

b) $X=c_1s + c0$, $Z=\frac{1}{s^2+a_1s+a_0}$, $Y=b_1s+b_0$

c) $Y=c_1s + c0$, $X=\frac{1}{s^2+a_1s+a_0}$, $Z=b_1s+b_0$

Learning Concepts Set: Block, Input, Output, algebra, cascade block, parallel block, summing point, branch point, simplification, shifting of summing point, shifting of branch point, combining cascade and parallel blocks, simplifying canonical form. The Concept map for CLO - 3 is shown in Fig. 3

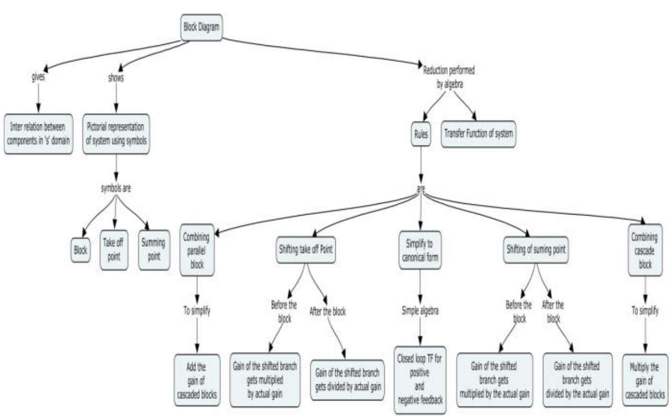

Fig. 3: Concept map for CLO - 3 (K_3)

Topics: Signal Flow Graph (SFG) and Mason's gain formula; CLO - 4: Derive the overall transfer function of an SFG of a system (K_3); Focus Questions: 4.1 Obtain the transfer function of the signal flow graph shown in the Figure c.

i) Identify the number of forward paths

a) 6 b) 4 c) 2

ii) Identify the number of individual loops

a) 3 b) 2 c) 4

iii) The transfer function of the signal flow graph shown is:

a) [g2g4g6(1 + g5h2) + g3g5g7(1 + g4h1) + g1g2g7 + g3g6g8 - g1g3g7g8h1 - g1g2g6g8h2] / (1 + g4h1 + g5h2 - g1g8h1h2 + g4g5h1h2)

b) [g3g5g6(1+g1h2) + g3g5g7(1+g3h1) + g1g6g7 + g3g6g4 - g1g3g7g8h2 - g1g3g6g8h2] / (1 + g4h1 + g5h2 - g1g5h1h2 + g3g5h1h2)

c) [g1g2g3(1 + g5h2) - g3g5g7(1 + g4h1) + g1g2g6 - g1g8h1h2 + g4g5h1h2)

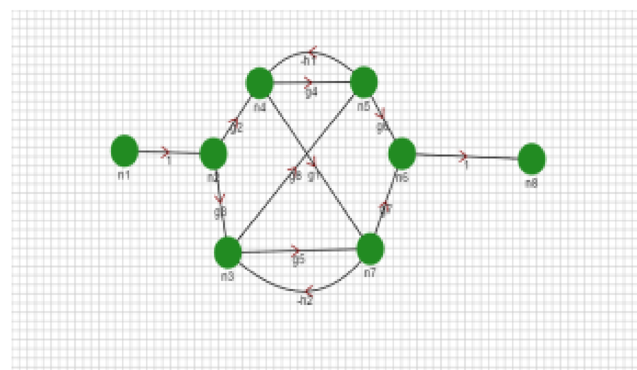

Fig. c: Signal flow graph for the focus question 4.1

Learning Concepts Set: Definition, terminologies, node, branch, path, forward path, loop, self-loop, non-touching loops, forward path gain, loop gain, Mason's gain formula Concept map for CLO - 1 is shown in Fig. 4.

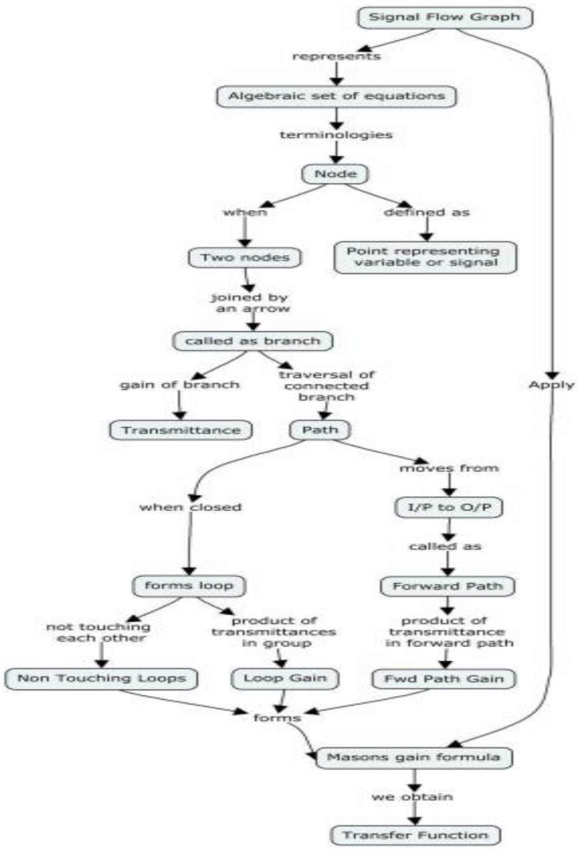

Fig. 4: Concept map for CLO - 4 (K_3)

IV..Results and Discussion

The focus questions were identified for the chosen CLO, and a Concept Map (CMap) was developed by linking various learning objects hierarchically. In addition, course instructors were trained to employ active learning strategies such as Jigsaw, Think-Pair-Share (TPS) and Peer Instruction for effective course delivery towards learning outcomes. As the traditional lecture classrooms were not comfortable for instructional delivery of courses through active learning methods, the institute established active learning spaces, so-called smart classrooms. These classrooms are equipped with reconfigurable tables for students' teams, a glass-marker board around the circumference of the classroom, a fixed display projection system for visuals, an audio system, WiFi internet connectivity and Hand-held student response devices.

The methodology adopted for the experimentation is as follows: (i) Instructional delivery was made to Section – A students employing the Jigsaw method and lecture with discussion method for attaining CLO - 1 (K_2) & CLO - 3 (K_3) and CLO - 2 (K_2) & CLO - 4 (K_3) respectively. Similarly, the Peer Instruction method and Think-pair share method were employed for Section – B students for attaining CLO - 1 (K_2) & CLO - 3 (K_3) and CLO - 2 (K_2) & CLO - 4 (K_3), respectively. There are around 60 students in each section. The prior knowledge level with respect to the Linear Control Systems course and learning abilities of the students in both sections were measured through pre-assessment. It was found that the mean prior knowledge level and learning abilities of the students in both sections are more or less the same. (ii) Assessments were conducted to measure the attainment of CLOs using ClassComm software and student response devices and (iii) Feedback was collected from students and analysed.

The course faculty delivered topics corresponding to CLO - 1 (K_2) using the Jigsaw method to the Section – A students referring the concept map 1. Students were assessed through a set of ten questions using ClassComm software. Figure 5 shows the attainment percentage of CLO - 1 for each question. Out of ten questions, more than 75% attainment is recorded in seven questions. Similarly, the course faculty delivered topics corresponding to CLO - 2 (K_2) using traditional lecture with discussion (LWD) to the Section – A students referring the concept map 2. Again, students were assessed through a set of ten questions using ClassComm software. Figure 6 shows the attainment percentage of CLO - 2 for each question. Out of ten questions, less than 50% attainment is recorded in nine questions, and the highest attainment level for question 3 is 50% only. To make the comparison sensible, it is ensured that all the ten questions for each CLOs are at the K_2 level.

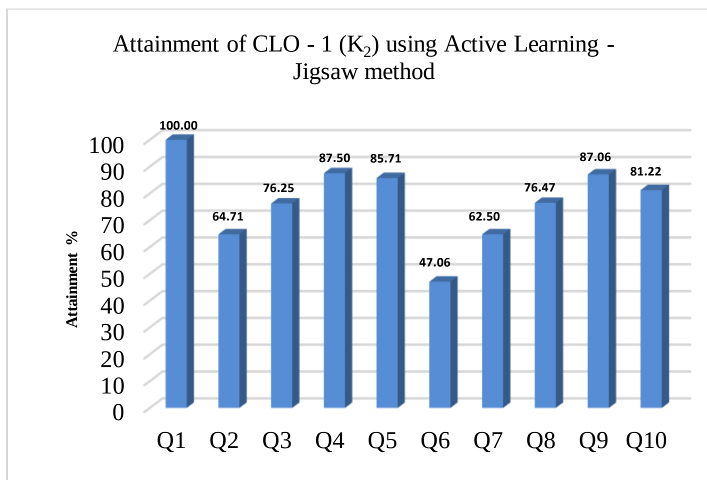

Fig. 5: Section A - Attainment of CLO - 1 (K_2) using Jigsaw method

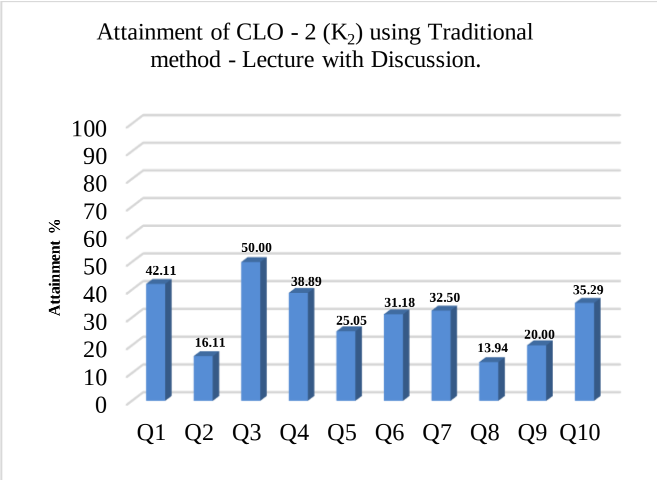

Fig. 6: Section A - Attainment of CLO - 2 (K_2) using LWD method

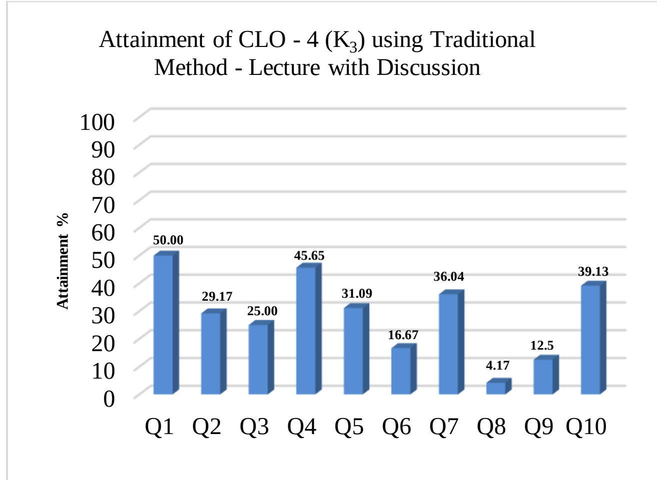

Fig. 8: Section A - Attainment of CLO - 4 (K_3) using LWD method

The course faculty delivered topics corresponding to CLO - 3 (K_3) using the Jigsaw method to the Section – A students referring the concept map 3. Students were assessed through a set of ten questions using ClassComm software. Figure 7 shows the attainment percentage of CLO - 3 for each question. Out of ten questions, more than 75% attainment is recorded in eight questions. Similarly, the course faculty delivered topics corresponding to CLO - 4 (K_3) using traditional lecture with discussion to the Section – A students referring the concept map 4. Again, students were assessed through a set of ten questions using ClassComm software. Figure 8 shows the attainment percentage of CLO - 4 for each question. Out of ten questions, less than 50% attainment is recorded in nine questions, and the highest attainment level for question 1 is 50%. To make the comparison sensible, it is ensured that all the ten questions for each CLOs are at the K_3 level.

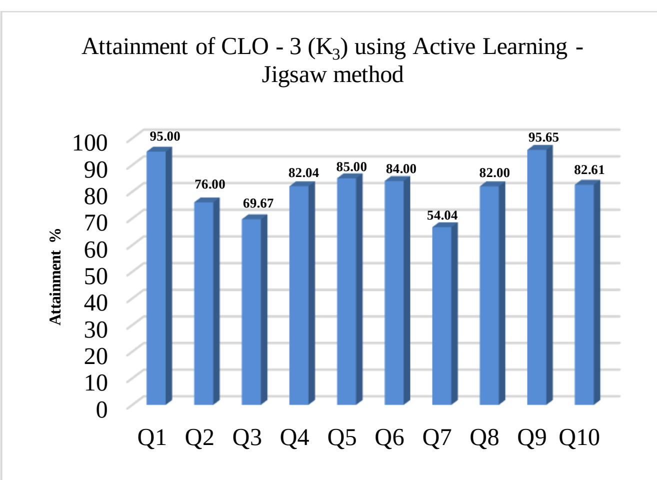

Fig. 7: Section A - Attainment of CLO – 3 (K_3) using Jigsaw method

The same experiments were conducted similarly for Section – B with Peer Instruction and Think-Pair-Share methods. Figure 9 shows the attainment percentage of CLO - 1 for each question using the Peer Instruction method. Out of ten questions, more than 50% attainment is recorded in three questions only. Figure 10 shows the attainment percentage of CLO - 2 for each question using the TPS method. Again, out of ten questions, more than 50% attainment is recorded in seven questions, and the attainment level for question 5 is as high as 78%. To make the comparison sensible, it is ensured that all the ten questions for each CLOs are at the K_2 level.

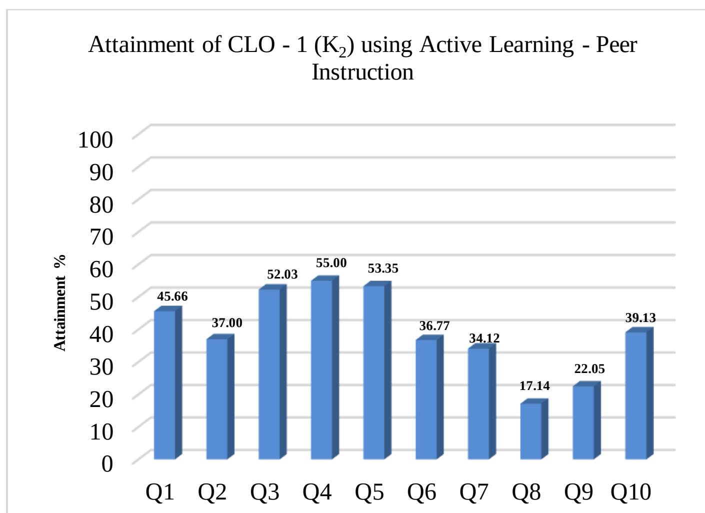

Fig. 9: Section B - Attainment of CLO - 1 (K_2) using Peer Instruction method

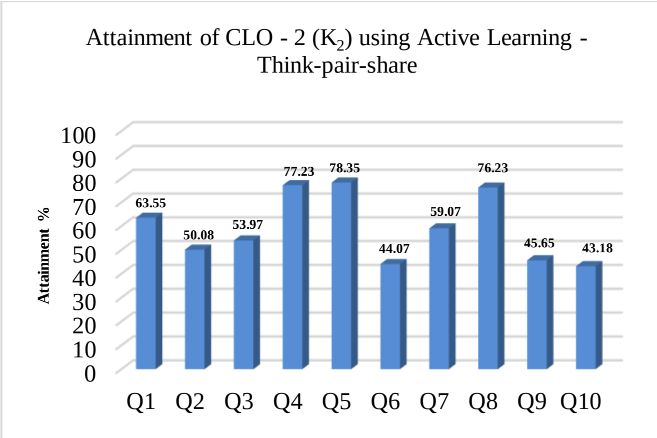

Fig. 10: Section B - Attainment of CLO - 2 (K_2) using TPS method

Figure 11 shows the attainment percentage of CLO - 3 for each question using the Peer Instruction method. Out of ten questions, less than 50% attainment is recorded in eight questions. Figure 12 shows the attainment percentage of CLO - 4 for each question using the TPS method. Out of ten questions, more than 50% attainment is recorded in nine questions, and the attainment level for question 1 is as high as 92%. To make the comparison sensible, it is ensured that all the ten questions for each CLOs are at the K_3 level.

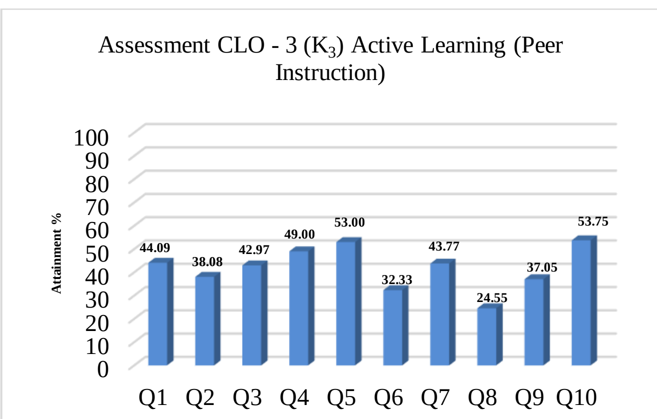

Fig. 11: Section B - Attainment of CLO - 3 (K_3) using Peer Instruction method

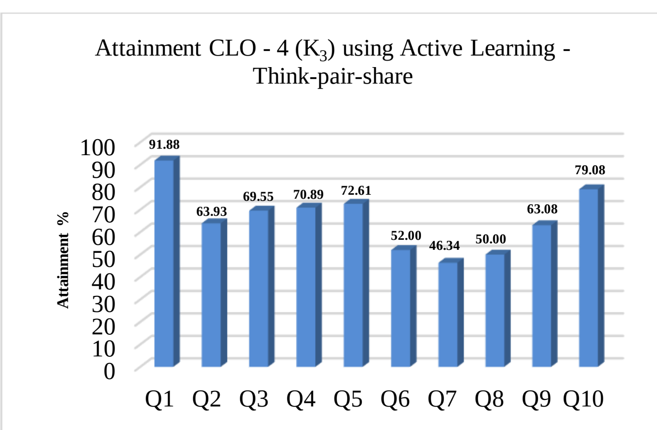

Fig. 12: Section B - Attainment of CLO - 4 (K_3) using TPS method

Figures 13 & 14 show the performance comparison of active learning methods such as Jigsaw, TPS and Peer Instruction over the traditional lecture with discussion method for four CLOs at two different levels (K_2 & K_3). It is observed from figures 13 & 14 that the increasing order of performance of the methods is as follows: Jigsaw, TPS, Peer Instruction and Lecture with Discussion. Interestingly, active learning methods are much more effective and efficient for higher-level learning outcomes CLO - 3 (K_3) and CLO - 4 (K_3) than lower-level learning outcomes CLO - 1 (K_2) and CLO - 2 (K_2).

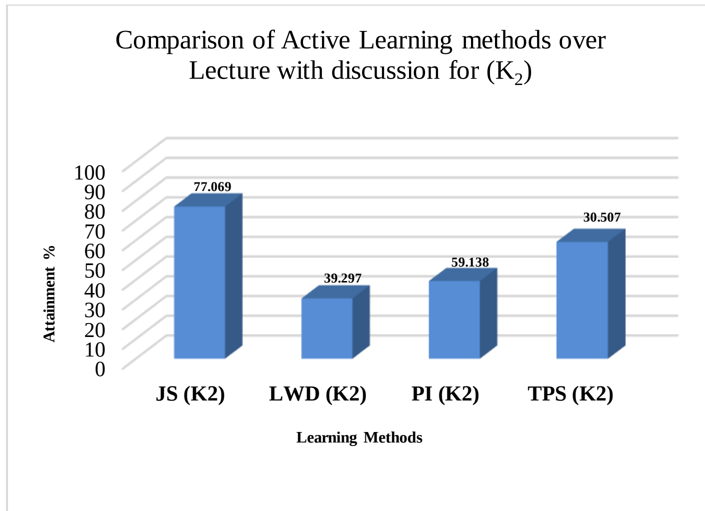

Fig. 13: Performance comparison of active learning methods over LWD method towards attainment of CLO - 1 (K_2) and CLO - 2 (K_2)

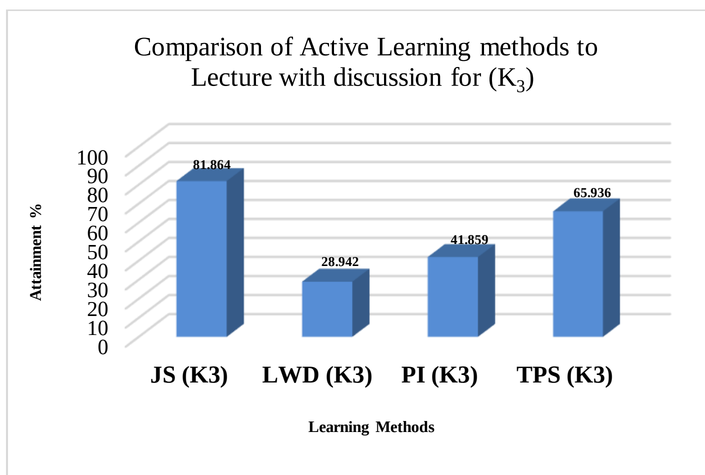

Fig. 14: Performance comparison of active learning methods over LWD method towards attainment of CLO - 3 (K_3) and CLO - 4 (K_3).

V. Conclusion

Though we struggled to overcome the faculty inertia in implementing active learning techniques during the initial stage, more than 40% of faculty are utilizing the facilities to a greater extent now. To encourage the involvement of faculty practicing and to bring more faculty into this initiative, in this work, an attempt was made to record the effectiveness of active learning methods over traditional lecture - based instruction. The Linear Control System course of the B.Tech Electrical and Electronics Engineering programme is chosen for conducting the experiments. The experiments include three active learning methods such as Jigsaw, TPS and Peer Instruction, four course – learning outcomes with two different cognitive levels (K_2 & K_3) and two sections of students with more or less the same mean prior knowledge and learning abilities. Assessments were conducted, and results were analyzed using ClassComm software. It is concluded that the Jigsaw method outperformed others for both K_2 and K_3 level CLOs. Next to Jigsaw, TPS and then Peer Instruction. The results of the analysis revealed the following: (i) Attentiveness, receptiveness and involvement of the students were found to be good, (ii) Better learning was ensured, (iii) Students answered well for applying level questions, (iv) Improvement in interpersonal skills observed (v) Preparation of learning materials by course faculty for chosen active learning method consumed more time and (vi) Course and teaching competency of faculty need to be improved. Students' satisfaction vis-à-vis learning, measured through feedback questionnaire, clearly portrays that the cultural, attitudinal and technological changes during this generation inevitably forced the faculty to change their role from traditional teachers to the facilitator of students' active learning. In this study, the CLOs at LOTS - Lower Order Thinking Skills (K_2 – Understand and K_3 – Apply) level were considered and experimented employing active learning methods. The same can be extended for the CLOs which are at HOTS - Higher Order Thinking Skills (K_4 – Analyze, K_5 – Evaluate and K_6 – Create) level not only with the methods considered in this work but also with other active learning methods.

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