Use of Active, Collaborative and Problem based Learning Strategies in the Digital Circuits Course of Electronics and Communication Engineering

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***Abstract*— The two well notable constraints faced by the engineering instructors are sustaining learner engagement and motivation. This paper inspects the potential usage of active, problem based and collaborative learning strategies in the digital circuits course of electronics and communication engineering department at Anurag University where in a class there will be wide diversified students coming from rural & urban areas, different medium of study in school education, different thinking & grasping abilities. Despite many researchers substantiated that different learning strategies are conducive in enriching learning momentum, motivating learners, improved skills of applying the knowledge gained to perform a specific task/application, making the learners feel the sense of purpose, relevancy to learning, enriched individual and team accountability, there is a need to develop exceptional techniques for the learners with different backgrounds. The various strategies that are implemented for this course of learners includes Concept Mapping Test (CMT), Think-Pair-Share (TPS) as a part of active learning, Simulation based Test (ST), Model Design (MD) as a part of problem based learning, Jigsaw & Problem Solving through Group Discussion (PSGD) as a part of collaborative learning. The detailed course of plan, execution & reflection report of each strategy is mentioned in the paper. Results showed that these approaches are found to be very effective in resolving the afore said constraints enriching the learning spirit among the students and improvement in regularity of attending classes by learners.**

Keywords—Active learning, Collaborative learning, Problem based learning, Learner engagement

I. INTRODUCTION

The lecturing, a time tested and revere teaching strategy, remains the most common mode of instruction in education sector all over the globe. Engineering education has progressed based on the solicit of pedagogical practices that place the learners as proponent of learning momentum with the use of various teaching and learning strategies. So as to make the learners to get more engaged in the learning momentum, one should add on verbal sort of learning style with active, sensorial, sequential, problem based, visual and collaborative based learning strategies.

Generally the students acquire & process the information in their own style which is mostly incompatible with the profile of school of engineering, which really makes the learners suffer with motivational issues. Hence, there is a need to transform the classroom environment to dynamic so that the students gets involved in the class, solve the problems, work in teams, improves critical thinking and communication skills. The correct use of teaching methodologies and motivation are the key components of curriculum learning and shaping the education pursuant to the learners learning style is very important to develop study skills. Hence, it is necessary to make use of effective teaching practices which promotes student engagement and make them get motivated and feel responsible towards the studies. Before introducing any type of learning strategy, it is good for instructors to specify their expectations and to spotlight that these strategies used in the classroom will be reflected in tests, assignments and examinations which really motivate the students to pay much more attention towards learning and practicing the things. This paper describes the various active learning, problem based learning and collaborative learning strategies that are implemented for Digital Circuits course of Electronics and Communication Engineering (ECE) department for II Year B.Tech students at Anurag University.

II. INDEX OF LEARNING STYLES

The learners have divergent strengths, mindset and preferences in the way they take the information and process it. This quantifies that they have different learning styles. Some learners prefer to learn via basic principles & theories, mathematical models, while others incline towards concrete data like facts, experimental information. Some prefer to learn by doing the things, check and analyze what happens, rather than simply grabbing the facts and some learn by visual appearances like flowcharts, pictorial representations, block schematics etc., and other tries to acquire data from conventional verbal elucidations. When there is a mismatch in teaching style of the teacher and learning style of the student, then they feel bored, become inattentive in class, get dishearten about the course, performs poorly in tests, dissatisfaction about the curriculum and themselves and in certain cases drop out the institution. Hence, there is a need to identify the learning momentum of the students in a class.

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Felder, R.M and Silverman, L.K. (1988) formulated a learning style model (FSLSM- Felder Silverman Learning Style Model) which is used to assess the preferences of learning momentum of the students on four dimensions shown in Fig.1. The Index of Learning Styles (ILS) is an online instrument with 44 questions that assesses the preferences of students on the four dimensions of learning and is free to use. The same is shared to the students of II Year B.Tech of ECE department with a class size of 75 and the results of the questionnaire are shown in table 1. Contrary results have been seen in various learning dimension, hence the balanced group is included as described by Jesus, G.C (2024) & Cardozo (2024). The dimensions/models of learning and teaching styles are shown in Fig.2.

TABLE.I
DATA OBTAINED FROM THE STUDENTS REGARDING LEARNING STYLE PREFERENCES

Learning Style	Preferences of Students (%)
Visual (Vi)	**42.9**
Verbal (Ve)	**18.7**
Balanced Vi/Ve	**25.7**
Sensorial (Se)	**71.2**
Intuitive (In)	**2.8**
Balanced Se/In	**16.8**
Sequential (Seq)	**49.8**
Global (Gl)	**8.4**
Balanced Seq/Gl	**31.3**
Active (Ac)	**58.9**
Reflective (Re)	**34.5**
Balanced Ac/Re	**37.9**

These results imply that the active and team based learning are suitable for this class of students. The mean dimension scores of learning styles of II Year B.Tech students of ECE department is shown in Fig.3

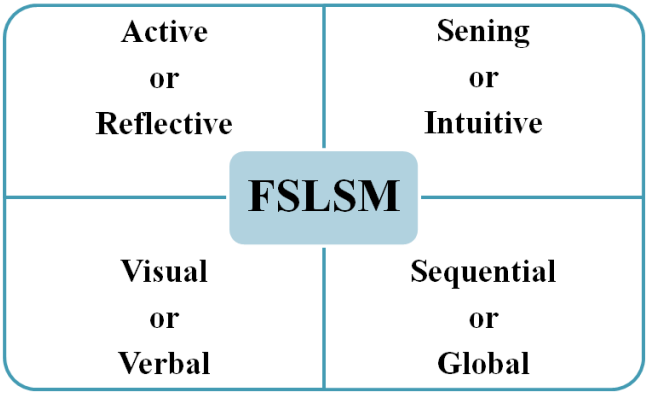

Fig.1 Felder-Silverman Learning Style Model: A Path to Personalized Learning

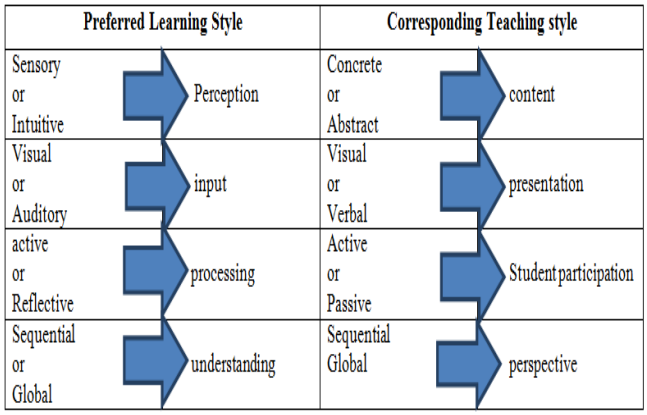

Fig.2: Dimensions of Learning and Teaching Styles

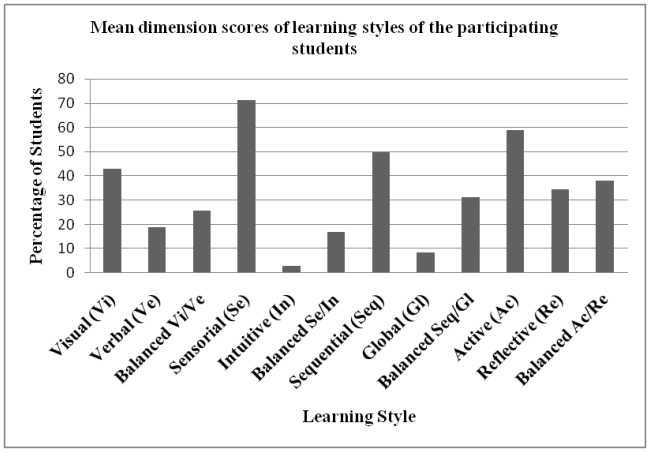

Fig.3 Overall distribution of learning style preferences among the II Year B.Tech students of ECE department

III. ACTIVE LEARNING STRATEGIES

Active Learning (AL) is one of the key elements of "learning centered" or "student centered" teaching (Weimer, 2002). A great number of inquiry studies suggest that if the teacher/instructor who aches to increase learner engagement in learning should espouse active learning. It mainly focuses on two important elements: "doing" and "reflecting". Bonwell, C.C., & Eison, J.A. (1991) defined AL as "Involving learners in doing the things and thinking about what they are doing." In practice, AL alludes to strategies/activities that are instigated into the classroom and is a contrast to traditional classroom where the learners receive the information passively from the teacher. The AL activities/strategies are the precise one which takes around seven to ten minutes to accomplish. Concept Mapping Test (CMT) and Think-Pair-Share (TPS) were the AL activities implemented in the classroom.

A. Concept Mapping Test (CMT):

It is an effective and easy strategy/activity in order to get instant feedback from the learners after completing the lecturing about the content covered in the class. Initially, the student is asked to represent or summarize the concept covered in the form of a tree diagram or noting of key points or formula involved in the concept. This improves the

retrieving capabilities of the learners about the concept. The time allocated for summarizing is 1-2 minutes, and then a multiple choice question(application based on the concept taught)with four distracting options (A, B, C & D) which reflect misinterpretations is posed to the learners and are asked to think & respond and the time allocated for this is 1-2 minutes. Then the students are asked to show their solutions with the given set of cards printed with one of the options (A, B, C & D). The responses against each of the option specifies the instructor that how well the concept is understood and do they require any further inputs or clarifications on the concept taught. At last, the activity is concluded by the instructor by specifying what is the correct answer for the question posed and why the other options are incorrect. This sort of activity provides scope for the learners to relate the learnt concept to the real time world applications. CMT can be taken in the beginning of the class based on the previous lecture or at the end of the class on the current lecture. The instant learning momentum of the students is greatly increased with this activity.

B. Think-Pair-Share (TPS):

i) Topic for the TPS activity:

Minimization of Switching functions in Sum of Products (SOP) form using Karnaugh (K) Maps.

ii) Justification for choosing TPS for the topic:

This topic involves grouping the given min-terms correctly following the rules of grouping mechanism (Octet or Quad or Pair or Single) to simplify the given switching function in SOP form.

Initially the students need to think individually about the question(s) posed by the instructor and then pair up with neighbors & share ideas or perspectives regarding on how to minimize the switching function enriching collaborative spirit and critical thinking. The student thoughts can foster new ways of thinking, resulting in constructive and unconsidered insights of the concept.

iii) Time allotted for the activity:5-8 Minutes

iv) Detail plan for implementing the activity:

Before beginning of the activity, the instructor describes the purpose, specifying the discussion guidelines/ ground rules and time limits.

Purpose:

Analyzing how K maps can be used to minimize a switching function in SOP form.

Discussion Guidelines/Ground rules:

For the smooth conduct of the discussion, certain rules are framed. During discussion every student should:

- Listen actively & respectfully without interrupting.
- Criticize the ideas, not the individuals.
- Allow everyone in team to share their views.
- More commit to learning, not debating.

Time limits:

Phase-1: Thinking on the question posed by the instructor individually (1-2 Minutes)

Phase-2: Discussion in groups (2-3 Minutes)

Phase-3: Sharing the team views (2-3 Minutes)

Plan for implementing the activity:

The activity is implemented in three steps.

Step 1- (Think)

Initially the students are asked to take a moment and think out the questions posed by the instructor regarding minimization of switching function in SOP form using K Maps.

The question includes: Simplify the switching function F (a, b, c, d) = Σm (2, 3, 5, 7, 9, 10, 11, 15) and realize the same using logic gates?

The students need to think & address about the following:

Which variable K Map is suitable to simplify the above Boolean expression?

How grouping of min-terms can be done in the K Map?

Which logic gates are used to realize the simplified Boolean expression?

This process is given 1-2 minutes. In this step every individual writes or note down their perspectives of addressing the above posed questions and are ready to discuss further in pairs.

Step-2 (Pair & Discussion)

In this step, the students are asked to pair up who are next to them in the bench and share the answers they came up with by strictly following the guidelines/ground rules. While the in-class activity is under execution, the instructor moves around the class and observe the students who are active or inactive in discussing the things, if necessary. This process is given 2-3 minutes.

Step-3 (Share)

In this step, the students are asked to share their views and thoughts in minimizing a switching function in SOP form, how grouping of min-terms is done and which logic gates are used to draw the logic finally. In this step, it's better to provide opportunity for the quiet students in certain teams to speak out on the things as a token of encouragement or asking students to share their partner's perspective in simplifying the Boolean expression & logic realization. This process is given 2-3 minutes. At last, as a glance the instructor take a moment & specifying the answers for the posed question and get back to the normal lecture for the other topic.

v) Success of the activity:

The activity has been executed exceptionally well. The three phases of the activity namely posing of question by the instructor & allowing students individually to think of it (Think Phase), after that the students paired up who are next to them in the bench and started discussing about the question posed adhering to ground rules (Pair & Discussion Phase) and finally the students are asked to share their thoughts & views

on the question posed (share Phase). The execution of TPS activity is shown in Fig.4.

Fig.4 TPS Activity

Positive insights:

- Accountability in team & as individual.
- Diverse Perspectives

As per the students point of view there is more positive response regarding the activity as it is making them involved in sharing their thoughts and views enriching collaborative spirit and critical thinking. This particular activity enriched meta-cognition (thinking about thinking) and peer learning among the students. Unequal participation of students & controlling the students during discussion phase are the major challenges faced during implementation of the activity. The one minute by students on class in conventional mode & activity based mode is shown in Fig.5.

IV. PROBLEM BASED LEARNING STRATEGIES

Problem Based Learning (PBL) is a class of experiential learning which motivates the learners to learn and inculcate self-learning& exploration, critical thinking, communication and complex problem solving skills. PBL is an educative student centered strategy that entitles the students to integrate theory and practical, oversee research and put in knowledge and skills to provide a feasible solution to a specified problem (Ruan, L., 2023). Problem is the key driving component of PBL. There are various norms of PBL, which can be implemented at the level of a chapter, course or even curriculum and can be varied according to domain or area, requirements of an individual course or traditions & practices of institution. (Chen, J., Kolmos, A., & Du, X., 2020)

PBL focuses on both self-directed learning and collaborative learning momentum of the learners. As a part of PBL, the strategies/activities that were carried out for Digital Circuits course includes Simulation based Test (ST) and Model Design (MD).

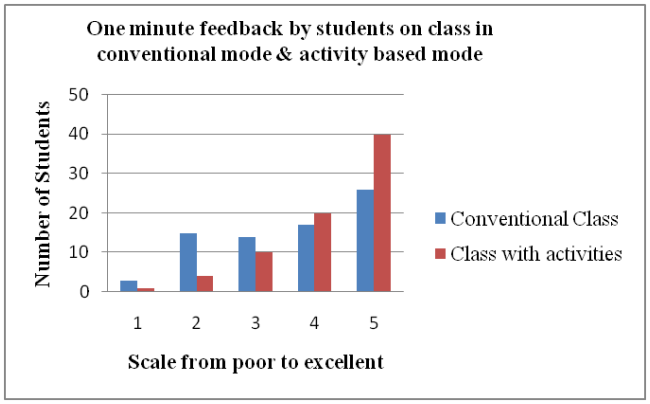

Fig.5 Feedback average scores from the conventional class and activity based class

A. Simulation based Test (ST):

Instructor poses problems with preliminary information to the learners and they work towards problem solving by their own instead of reviewing how other ones have solved the same as in a case study and are directed to perform simulation-based implementation of the same using Verilog HDL. The problems for the learners are posed on: a) Minimization of a Boolean function using K-Map & implement the same using multiplexer of suitable size. b) Minimization of a Boolean function using Tabular method & implement the same using multiplexer of suitable size. The criterion which is used to assess the learner's problem-solving abilities is: Problem Identification/Definition (2M), Analysis of the Problem (7M), Realization of the circuit using logic gates & multiplexer (7M), Verilog HDL Coding (4M). The rubric for the assessment of ST is shown in table 2.

Compared to traditional descriptive test, the students have performed exceptional well in simulation based test. The learners have implemented the minimized logic in various description levels of Verilog HDL. Some students have implemented in data flow model, some in behavioral model & some in structural level. The performance analysis of students for two academic years are shown in table 3, where simulation based test conducted during the academic year 2023-24, whereas traditional descriptive test conducted during the academic year 2022-23.

TABLE II
RUBRICS FOR THE ASSESSMENT OF ST

Criteria	Exemplary	Satisfactory	Needs Improvement
Problem Identification / Definition (2M)	Detailed and extensive explanation of problem. (2 to >1.5 Marks)	Average explanation of the problem. (1.5 to > 1Mark)	Poor explanation of problem. (1 to >0 Mark)
Analysis of the problem (7M)	The problem is clearly stated & proper k-map is used to solve the Boolean function. (7 to >4.5 Marks)	The problem is clearly stated & fails to group the terms using K-map. (4.5 to >2 Marks)	The problem is not clearly stated and fails to solve the same using K-map. (2 to >0 Mark)
Realization of the circuit using logic gates & multiplexer (7M)	Simplified Boolean function is well realized. (7 to >4.5 Marks)	Simplified Boolean function is partially realized. (4.5 to >2 Marks)	Simplified Boolean function is not well realized. (2 to >0 Mark)
Verilog HDL Coding (4M)	Developed code for the problem and design steps are clearly understood and found to be correct. (4 to > 2.5 Marks)	Partially developed code for the problem and design steps is correct and relevant. (2.5 to >1.5 Marks)	Code is not developed for the problem and design steps are correct. (1.5 to >0 Mark)

TABLE III
PERFORMANCE ANALYSIS OF STUDENTS FOR TWO ACADEMIC YEARS (ASSESSMENT COMPARISON)

Parameters	Descriptive Test	Simulation based Test
Academic Year	2022-23	2023-24
Average Score of the Students	12.21/20	17.48/20

B. Model Design (MD):

As an extension to simulation based test, the students are asked to explore about various Electronic Design Automation (EDA) tools to design various combinational and sequential circuits. Once the exploration is done by the students about the tool, then the instructor provides the problem on which they need to work on & design the circuit model. This sort of activity really helped the students to think & solve the problems in a research perspective as they first perform survey on various EDA tools available and selects suitable one to design the digital circuits which makes the students to work on beyond the course syllabus.

V. COLLABORATIVE LEARNING STRATEGIES

Collaborative Learning (CL) is normally used as a super type to epitomize an activity/strategy whereby the learners are provided with a scope to work in small groups to fulfill a shared learning goal. This differs from traditional lecture delivery practiced in higher educational institutions. It drives the learners to take an active role in self-learning& discussing the same with peers in the teams and become critical thinkers (Barkely, Elizabeth, Patricia Cross, K., Major, C., 2014). CL strategies/activities are very potent for thorough learning and accomplishing graduate attributes like interpersonal communication, group building and life-long learning. Research studies ratifies that often learners learn superior from their peers than from the teachings delivered by the instructor. Jigsaw and Problem Solving through Group Discussion (PSGD) were the CL activities implemented in the classroom.

A. Jigsaw:

i) Topic for the Jigsaw activity:

Minimization of Switching functions using Karnaugh (K) Maps.

Subtopics:

1. Minimization of Switching functions in Sum of Products form (SOP).
2. Minimization of Switching functions in Product of Sums form (POS).
3. Minimizations of switching functions in SOP with don't care combinations.
4. Minimizations of switching functions in POS with don't care combinations.

Learning Objective: At the end of the class/session, the students can be able to simplify a Boolean Expression represented either in Sum of Product (SOP) or Product of Sum (POS) with and without don't care combinations using K-Maps.

ii) Justification for choosing Jigsaw activity for the topic:

Students have already learnt how to represent the switching functions either in SOP or POS with and without don't care combinations using K-Maps. With the current topic, students will be able to apply the same on how to simplify Boolean expression by grouping the min terms or max terms following the rules of grouping mechanism (Octet or Quad or Pair or Single) to simplify a switching function given either in SOP form or POS form with or without don't care combinations. In this activity, the students share ideas or perspectives regarding on how to minimize the switching function enriching collaborative spirit and critical thinking. The student thoughts can foster new ways of thinking, resulting in constructive and unconsidered insights of the concept. This quantifies the suitability of the Jigsaw activity for this topic. This particular activity enriches meta-cognition (thinking about thinking) and peer learning.

iii) Time allotted for the activity: 40-45 Minutes

iv) Detail plan for implementing the activity:

Before beginning of the activity, the instructor describes the purpose, specifying the discussion guidelines/ ground rules and time limits.

Purpose:

Analyzing how K-maps can be used to minimize a switching function either in a SOP or POS with and without don't care combinations

Preparations before the activity:

- The student teams are formed randomly using a computer (Random number generator) and the same is informed to the students earlier to the activity so that they can sit in pre-arranged teams before the commencement of the activity to save time.
- Preparing the students for the activity & making them excite about the team work by clearly stating the learning objective & specifically mentioning of how important the concept is? and providing of any learning material in advance if necessary.
- Creating a questionnaire to take feedback from students. (Questions are posed in terms of reflecting the affective dimension of the student's learning experience).

Time limits:

Phase-1: Creation of Expert Groups & Discussion (15 Minutes)

Phase-2: Reporting back to the original teams & Consolidation of reports (20 Minutes)

Phase-3: Feedback (2-3 Minutes)

Plan for implementing the activity:

The activity is implemented in three steps.

Step 1- Creation of Expert Groups & Discussion (15 Minutes)

Initially the students pick a sub topic among the 4 subtopics named as A, B, C & D. All A's from different teams group together & start discussing about their sub topic. Similarly all B's, C's and D's do the same. Every student acts as an Expert for the chosen subtopic. The students are allowed to use various resources like usage of internet, learning material etc.

During discussion, every student needs to take notes so as to report the same to their original team.

Step 2- Reporting back to the original teams & Consolidation of reports (20 Minutes)

After thorough discussion in the stipulated time, the students return back to their original teams and prepare a report covering all the subtopics. In this phase, each and every student needs to contribute for the subtopic selected by them in order to finalize the report.

Step3- Evaluation

As a part of evaluating the activity, the teams are given choice to choose either a set of questions to solve (4 problems) or can write a small report on the topics learnt clearly explaining the procedure with examples.

The assessment of assignment / report will be evaluated team wise for 4 Marks based on the following criterion shown in table 4.

Date of submission regarding assignment / report will be informed to the students and they need to upload the copies of assignment or report in the Google classroom. The instructor can take the help of previous year students who excelled in the course to evaluate the same & provide audio feedback to save the time. The best two of the same is presented to the students for quick over view of the concept & the same will be shared to all for future reference.

TABLE IV
THE RUBRICS FOR THE ASSESSMENT OF ASSIGNMENT/REPORT IN JIGSAW ACTIVITY

Criteria	Exemplary (4 to >2.5Marks)	Satisfactory (2.5 to >1Mark)	Needs Improvement (0M)
Analysis of the problem & problem solving.	The problem is clearly stated & proper k-map is used to solve the Boolean function	The problem is clearly stated & fails to group the terms using K-map	The problem is not clearly stated and fails to solve the same using K-map.

Feedback is taken from the students through a Google form regarding the collaborative learning through Jigsaw activity (2-3 Minutes). The questionnaire includes:

i) Have you enjoyed the Jigsaw activity?
ii) How's your experience regarding collaborative learning of the topics?
iii) Will you need to have much more collaborative activities?
iv) What do you think was the central point communicated during discussion?
v) Choice of submission for grading the activity.
   a) Assignment (Solving of problems)
   b) Report
vi) Any other information.

A buffer of 7 minutes is allocated for cover up any deviations in the implementation phases of the activity.

v) Success of the activity:

The activity has been executed exceptionally well. The three phases of the activity namely creation of expert groups & allowing the students individually to express their views on the subtopic opted, after that the students report back to the original team (parent or home group) and discuss the various subtopics & consolidate a report of their views & thoughts and finally the students are asked to fill the Google form shared by the instructor to take feedback on the collaborative learning of the concepts.

Phase-1: Creation of Expert Groups & Discussion.

Phase-2: Reporting back to the original teams & Consolidation of reports.

Phase-3: Feedback.

Positive insights:

- Active listening & effective communication.
- Excellent report submission

As per the students point of view there is more positive response regarding the activity as it is making them involved in sharing their thoughts and views enriching collaborative spirit and critical thinking. Double discussion phases both in expert

group & in parent or home group made the students to feel of taking ownership on the topic opted & in delivery brining lots of confidence individually. Consolidated report of the feedback on jigsaw activity is shown in table 5. The feedback & execution of jigsaw activity is shown in Fig.6 & 7 respectively.

TABLE V
CONSOLIDATED REPORT OF THE FEEDBACK ON JIGSAW ACTIVITY

S.No	Question posed	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
1	Have you enjoyed the Jigsaw Activity?	66	26	6	2	0
2	Did Jigsaw method generated interest in learning the topic?	72	22	4	2	0
3	Did Jigsaw method enabled in depth understanding of the topic?	56	36	8	0	0
4	Did Jigsaw method enhance your referral habits, communication skills, analytical ability, and opportunity to share your views among the team members?	54	36	8	2	0
5	Will you need to have much more collaborative activities in future?	60	32	6	2	0

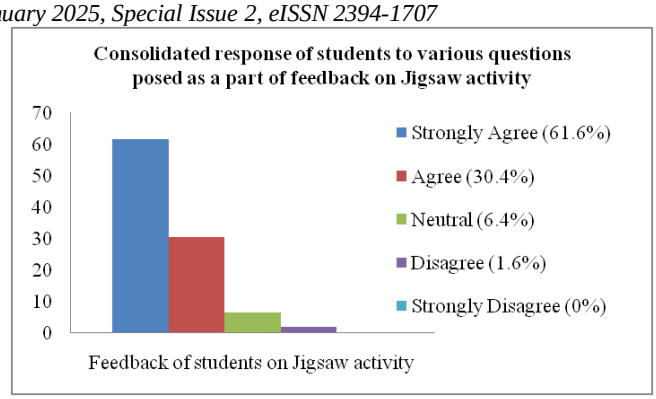

Fig.6 Feedback of students on Jigsaw activity

Fig.7 Jigsaw Activity

B. Problem Solving through Group Discussion (PSGD):

For PSGD activity, heterogeneous teams were formed and the same is informed to the students in advance to the activity. Each team is given a set of 4 questions based on the concept taught which include half solved problems, L.H.S=R.H.S prove based problems, linking based questions (In order to solve the 3rd question, the students need to solve the 1st question initially, as the output of 1st question acts as input to 3rd question) and test case based questions. Initially the teams

are given 20 minutes of time to discuss and solve the problems collaboratively. After that, the scripts are interchanged among the teams and they start evaluating the solutions provided by other teams as a group and award the marks. The time allocated for this is 10 minutes. After that, the instructor explains in brief about the given problems so that every student will get chance thrice of solving a particular problem which really helps the students to assess in self where the things went well & where the things didn't worked well. This particular activity really helped students to expose to various models of problem solving and feels responsibility as an evaluator too. This makes the students to act as both problem solver & problem inquirer. The collaborative learning assessment of PSGD activity is shown in Fig.8, where x-axis quantifies the range of scores secured by the students for different problems & y-axis specifies the number of students. Majority of the students performed exceptionally well in solving the problems in a collaborative spirit than in an individual norm. The overall feedback on Active Learning (AL), Problem based Learning (PBL) and Collaborative Learning (CL) is shown in Fig.9, which quantifies that the student learning momentum, involvement and motivation are greatly improved compared to conventional mode of teaching & learning.

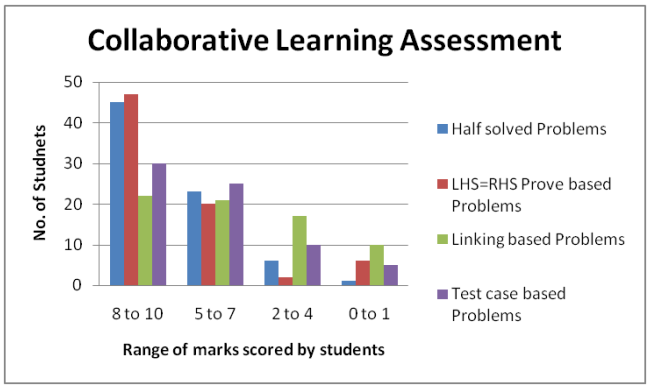

Fig.8 Collaborative Learning Assessment (PSGD Activity)

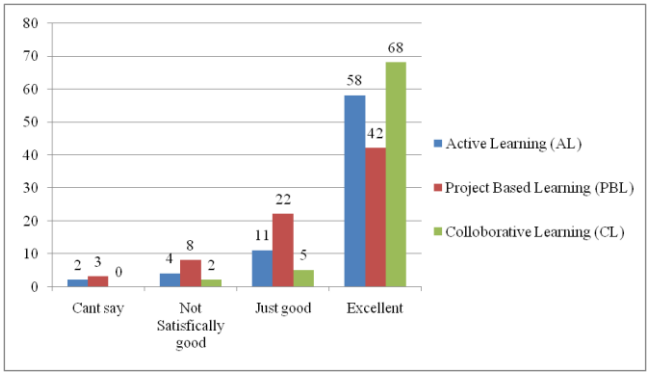

Fig.9 Overall feedback on AL, PBL & CL

CONCLUSION

The transformation of conventional classrooms in to a dynamic one by incorporating various learning strategies like active, problem based and collaborative based learning has resulted in drastic improvement in student engagement& motivation. The regularity in attending the classes and enthusiasm by the students also greatly increased underline the value of such strategies in addressing the conventional challenges in engineering education. Future research can focus on integration of technology like AI driven learning platforms, virtual labs and augmented reality to improve engagement. Long term studies haply conducted to assess the sustained impact of these methods on learner's performance, professional growth, along with ability to solve complex problems across diverse disciplines of engineering, can provide informative perceptions for adorning educational practices.

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