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Effectiveness of Think Aloud Pair Problem Solving and Case Study based Active Learning Techniques for Engineering Classroom

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***Abstract*— Engineering and Technology is a very dynamic sector and change is very rapid. The knowledge gained in traditional classrooms, through online lectures, through search engines, online video books, and Wikipedia is just helping to understand the theoretical concepts. These information sources cannot develop abilities to apply the theoretical concept to real-world problems. This can be developed through experiential learning in workshops, industrial visits, field visits, etc. The advanced courses are not having this scope due to limited lab capacities, high instrument costs, a variety of instruments, quick revisions in technology, less number of industries, IP securities, and many more reasons. The Automobile sector is a vibrant one and the Automobile Engineering department is always facing these issues. This study presents the teaching-learning experience of the course Automotive Control Engineering which faces the above issues. The study was conducted for T.Y.B.Tech Automobile Engineering students for the years 2018-19. The aim of the study was to increase the concept implementation ability of the students. The theoretical knowledge that was being received through books, lectures, and search engines were used to correlate the working of advanced technology. Think Aloud pair problem-solving technique (TAPPS) and case study presentation of the real-world system tools have been used for the course delivery. The course attainment level of the experimental group increased by 11%. The students have shown enhancement in competencies like problem-solving, application of theoretical concepts, critical thinking, lifelong learning, etc. Learning from peers and in groups also improved classroom engagement and the joy of learning.**

***Keywords*— Active learning; Control Engineering; Life-long learning; OBE; Problem based learning; Think Aloud Problem Solving Technique.**

***JEET Category*— Research**

I. INTRODUCTION

Automotive is ever changing field of Engineering and technology. The control system plays a key part in efficient and safe working of an automotive system. It becomes inevitable to learn concepts of automotive control for Automobile Engineering students. Automotive control and allied industries are the most fascinating pocket for an automotive engineer. Teaching Control Engineering course to Automobile Engineering students is a challenging task, as students have not studied the basics of electronics and the advanced, emerging technologies are complex and setting new trends day by day (Govindasamy, 2001; Shulman, 1986). This is an era of transformation and engineering education field is also started transforming from the conventional chalk and talk method of teaching learning to outcome based design, delivery, and assessment of curriculum (Jwaid, Clark, & Ireson, 2014; Archambault & Barnett, 2010). The domain-specific engineering education is all about developing the problem solving skills by applying theoretical knowledge they learnt. Nowadays various cooperative and collaborative active learning techniques like think-pair-share, jigsaw, project-based learning, STAD, puzzle-based, and problem based learning are used to make classroom learning more effective so that students themselves demonstrate the skills by active participation. Various task-based activities with proper planning and execution make classroom learning more effective as they are based on 'learning-by-doing' principle (Hayne, 2011). The methods like reciprocal and modified reciprocal teaching (Alfassi, 1998; Kadam & Sawant, 2020) are effectively used as peer learning techniques.

There are many evidences in literature in which different concepts are worked out and experimented for delivery of control engineering course (Govindasamy, 2001). The Technological Pedagogical Content Knowledge (TPACK) method of learning has been used which helped to communicate fresher with specialist (Chilukuri, 2020). The Visual literacy aids like the intuitive approach adopted and implemented successfully some specially designed tracks for better learning of this course are documented (Bencomo, 2004; Krathwohl 2002; Pantoya, Hughes, & Hughes, 2013). Problem solving technique and case study approach have been also implemented for enhancing course delivery and classroom engagement of engineering courses (Johnson & Chung, 1999; Kani & Shahrill.

2015; Pate & Greg, 2011) as well as science and technology allied courses (Ogundele, Umar, Ma'aji, & Idris, 2022; Nufus & Arnawa, 2018; Pate, Wardlow, & Johnson, 2004). This research work presents Think aloud pair problem solving and case study presentation tools for improving concept applicability of the students of T.Y. B. Tech Automobile Engineering for the academic year 2018-19.

TAPPS technique is one of the cooperative learning techniques to enhance problem-solving skills, further resulting in the development of reasoning and analytical skills of learners. As per the title, it is a peer-learning technique focusing on thinking aloud and problem solving. The review of the literature shows that this technique can be implemented for all disciplines such as Mathematics (Kani & Shahrill. 2015), Chemistry (Noh, Jeon, & Huffman, 2005), and even in career and technical education courses (Pate & Miller, 2011). The technique is effective in language classroom to help students to strengthen their analytical skills in comprehension (Lochhead & Whimbey, 1987).

Case study as an active learning tool is used in disciplines where students explore their theoretical knowledge by demonstrating or applying it in real life situations. This is a problem-solving tool. Case studies are in the form of open-ended question or solution for any problem.

The present paper aims at identifying the effectiveness of TAPPS and case study approach on problem solving skills of students in Control Engineering.

The course learning objectives were as follows,

1. Explain various control systems.
2. Model the control system mathematically for the formation of a Block diagram.
3. Apply linearization technique to non-linear control systems.
4. Analyse control systems using different mathematical tools.
5. Verify stability of given control system using different techniques.
6. Represent control systems using state space technique.

An attempt has been made to improve the involvement of student in the class and to empower them to correlate the book knowledge with the actual new technologies in the market. The course delivery is done using two techniques Think Aloud Pair Problem Solving and Case study presentation. This has not only improved classroom engagement but also facilitated stress-free in semester evaluation of the course. The CO attainment at the End semester examination is significant and remarkable.

II. METHODOLOGY

There were total 70 students in classroom. The students have been divided into two groups of 35 students each, the Experimental Group and the Control Group. Care has been taken during formation of groups for equal intellectual level of the group and has been purely based on CPI of students. Group details are as given in Table I.

TABLE I
STUDENT DISTRIBUTION IN GROUPS

CPI	**Experimental Group**	**Control Group**
8-9	5	5
6-8	15	15
5-6	10	10
Less than 5	5	5

The Control group was taught through conventional chalk and talk approach and Experimental group went through active learning experiences. The course teacher was same, number of hours' engagement and notes shared with both the group were same. Only the difference in experimental group and Control group was that TAPPS and case study presentation active learning tools were implemented to experimental group for course delivery and ISE assessment.

A. Think Aloud Pair Problem Solving:

The control engineering course involves more mathematical and electronics part, the conventional monotonous teaching lack in maintaining interest of students in classroom. Even students having a strong vocation in this field might find themselves uninterested (Sorribes & Noguera, 2020). In TAPPS Technique students are supposed to apply the theoretical concept to solve the problems of control engineering course. This is modified problem solving technique in which active learning and in semester evaluation simultaneously have been executed. The student needs to solve problems in group of 4-5 members. The group formation was done such that average CPI of this subgroup was maintained 7.

The problems were given to students. The students were solving problems in groups. One student from each group was guiding the group members by initiating the thought process to solve problem stepwise. The members were expressing their thoughts and different methods in front of group to solve the problem. The leader used to guide the members for easy and fast method of getting answer. The role of the instructor was observer, timekeeper and evaluator at the same time

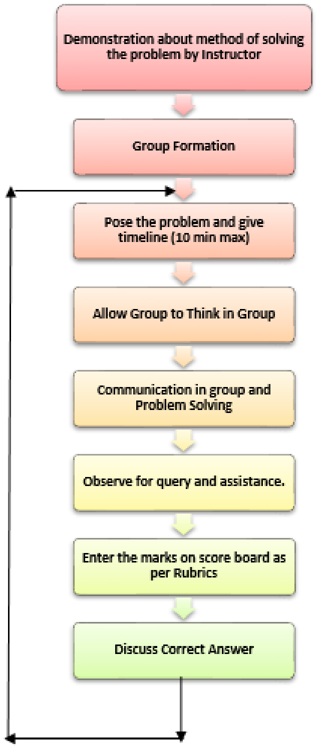

Fig. 1 Phase-I Flow chart of TAPPS activity.

As per Fig. 1 implementation of the TAPPS activity was started by demonstrating problem solving through TAPPS and concluded with discussion on correct answers.

Following are the steps followed in classroom TAPPS activity:

1. Demonstration about method of solving the problem with application based examples.
2. Group Formation.
3. Pose the problem and give a timeline (10 min max)
4. Observe for query and assistance.
5. Enter the marks on scoreboard as per responses.
6. Solve the problem stepwise and discuss the solution on blackboard for more clarity.

The rubrics used for evaluation of TAPPS are given in Table II. Such four problems were taken in a lecture of 60 minutes. This activity is conducted for 4 times in a semester. Each time the instructor observed rise in smoothness of conducting the activity, student enthusiasm and student engagement in classroom.

TABLE II
RUBRICS FOR EVALUATION OF TAPPS ACTIVITY

Criterion	**2 Marks**	**3 Marks**	**4 Marks**	**5 Marks**	**Marks out of 5**
Correctness of Answer	All steps are wrong	Only few steps are correct	Only final step is wrong	All answer is correct with units	
Time Required to Solve the Problem	Not completed half problem in 10 min	Not completed problem in 10 min	Completed problem in 10 min	Completed problem before 10 min	
Group Culture	No communication within group members	Poor willingness and communication within group member	Good communication and willingness within group members	Best group culture and communication, leadership approach	
Problem Assistance	Require frequent instructor assistance	Require occasional instructor assistance	Require rare instructor assistance	Does not require instructor's help to solve the problem	

Fig.2 Glimpses of Classroom at the time of TAPPS activity.

Fig.2 shows the active participation of students in TAPPS activity, which is indirectly reflected in the group dynamism and communication skills of students.

B. Case Study

In Automobile there are many control systems like acceleration, braking, steering, headlight, exhaust, inside temperature, and ventilation control. Many advancements in these systems are going on. To cover these technologies with the theoretical base is the most challenging part for the instructor. On the other side if it is not covered during instruction, students are unable to correlate theoretical concepts (like development of transfer function, block diagram, feedback loop and control of system through mathematical modelling) with these new technological advancements in the system. Case study presentation was found to be a best tool in this situation (Noguez & Neri 2019; Garg & Varma, 2007; Yadav, Shaver, & Meckl, 2010) for the same class and same course as it works on analytical, problem solving, and decision-making skills of learners.

A month before the presentation, the instructor circulated the google form to enter the topic of case study as per student's choice. The instructor had taken care that the topics should not repeat. After finalization of list of topics one-month time was given to study the advanced system, make a presentation of five slides, and present as a case study. The role of the instructor for this activity was facilitator. The students took instructor's guidance and help for the same.

Following are the instructions for students for case study based active earning session:

1. Select any one system from the following automobile components:

Engine Control system, Cruise control system, Steering System, Window and Door Operating of Car, Automobile A/C, Automatic Transmission System, Rear glass clarity, Rear Camera based parking system, Direction Indicator, Automobile Lightning System, Emission system Information system (e.g. catalytic converter failure),

2. Draw block diagram of the system.
3. Explain the need of linearization of particular parameter in the system and explain which type of controller it is (P/I/D/PID/ any other)
4. Draw nature of transient response of the system. (Also mention type of Input you need.
5. This exercise of the course needs to be presented as a case study in front of peers and instructor as a part of in semester evaluation.
6. Open discussion on the case presented

The assessment rubrics were shared with the students at the time of the declaration of this activity. In the last week of instructional activity, case study presentations were planned and conducted. The time allotted for presentation was 7 minutes followed by 2 minutes question-answer session. The instructor gave the marks as per the rubrics given in Table. III.

TABLE III
RUBRICS FOR CASE STUDY EVALUATION

Criterion	2 Marks	3 Marks	4 Marks	5 Marks	Marks 5
Selection of Topic	Selected Conventional Technology	Selected conventional system with Complicated architecture	Selected fairly advanced and complicated system	Selected highly advanced technology	
Implementation of Theoretical Concept	Not implemented any theoretical concept taught in class	Implemented few theoretical concepts taught in class	Implemented all Theoretical concepts taught in class	Implemented all theoretical concepts taught in class and knowledge beyond the class	
Presentation and Communication	No satisfactory communication and presentation	Poor presentation and communication	Good presentation and communication	Best presentation and communication	
Question Answer	Not answered single question or asked any question to others	Answered few questions but not asked any question to others	Answered all questions and asked few questions to others	Did not take instructor's help to solve the problem	

Both the Phases mentioned above were added in the course plan and in semester evaluation plan which was shared at the start of semester only. Fig. 3 shows the case study presented in the classroom as a part of in semester evaluation.

Fig. 3 Photos of Classroom at the time of Case Study Presentations.

III. ASSESSMENT

The effectiveness of both these active learning techniques has been investigated by direct and indirect methods. In direct analysis method Rubrics were used for each phase separately. The rubrics of TAPPS and Case study based active learning technique were shared on the moodle portal before the execution of Phase. In Phase I time required to solve the problem, correctness of answer, group culture, and problem assistance were the parameters of evaluation in rubrics. In rubrics of phase two evaluation timely submission, selection of system, application of the theoretical concept, and comprehensions of the studied part had been considered for evaluation. In both phases evaluations marks were combined and mapped with course outcomes.

The researcher used rating method for indirect evaluation of the effectiveness of implementation of TAPPS and case study as shown in Table IV. To collect anonymous feedback from students for further improvement, 4 questions were given to students and asked them to give ratings as strongly disagree, disagree, neutral, agree, or strongly agree.

TABLE.IV
RUBRICS FOR INDIRECT EVALUATION

Q. No	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	I feel , I can correlate physical system with Theoretical concept taught in class					

2	The Case study based learning helped me to confidently talk with subject experts					
3	I have gone through number of documents beyond syllabus book while preparing case study presentations					
4	I feel peer learning and self-learning through TAPPS and case study activities helped me for better understanding					

IV. RESULTS AND DISCUSSION

As both active learning techniques Viz TAPPS and case study based learning were planned not only as active learning but also for active and joyful assessment (Wang, Zhang, Wu, Xu, & Tong, 2016; Elamvazuthi, Lee, Ng, Song, Tiong, Parimi, & Swain, 2015) of the learning. The marks of the rubrics become part of the CO attainment. The result of direct evaluation is represented in the form of CO attainment graph in figure 4. The direct attainment of CO from marks has been represented for both experimental and control group. The in semester evaluation marks of the experimental and control group are represented in percentage. Here the activities were planned in such a way that both the techniques implemented in class above were contributing to all course learning outcomes.

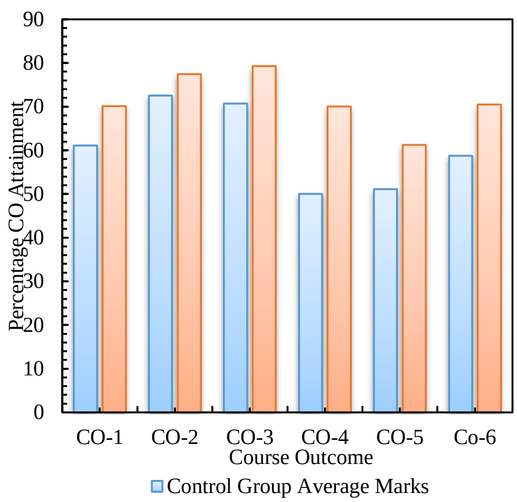

Fig. 4 Co attainment Comparison by direct assessment Method.

The graph shows that there is an average 11% rise in performance of the students of experimental group than control group. The remarkable increase in performance is found in CO 4 and 5 which addresses the higher-order skills as per the Bloom's taxonomy such as analysis and evaluation. The attainment of CO 6 represents complex problem analysis and skillful presentation of the complex control system.

The indirect assessment of technique is shown in Fig. 5. The results of rating method show that 85 % students could correlate physical system with the theoretical concept. Approximately 86 % students could discuss with experts in the sector using this terminology. Approximately 87 % students have gone through many other resources beyond the book while preparing for the case study presentation of Advanced Automotive Control System. Even to work on case study they visited automotive sectors and collected information about the system selected. About 90 % students were agreed that that the peer learning and self-learning with TAPPS and Case study helped them for better understanding of the course content. The students get confidence to use the terms used for analysis of control systems like tuning performance of P/PI/PID controller, transient response terms, and design of control system parameters so that they could discuss with experts of the sector using this terminology. The most important achievement is students had gone through out of the book data and literature to self-learn the things which were there in automotive control market and which are new and fresh things they learnt at their own. This showed lifelong learning skills of students are enhanced.

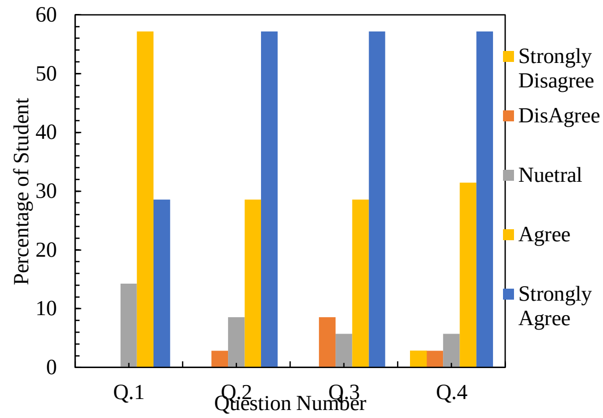

Fig. 5. Results of rating method.

Following are the outcomes of the active learning techniques used in this research work using rating method,

1. Peer learning helped to improve student's confidence of concept application and problem solving.
2. Students' hands on involvement in learning has been increased.
3. The team work and healthy competition motivated students to learn.
4. The role of instructor is observer and time monitor and helper in case of assistance which helped to reduce fear of teacher from student's mind.
5. The problem solving ability and self-learning ability of the students enhanced.
6. Observed enhancement in overall performance of student as compared to conventional teaching-learning process.

V. CONCLUSION

One of the important aspects of engineering education is to hold the interest of students in theoretical courses and empower them by motivating them to apply the knowledge they learnt in real life situations and TAPPS and case study techniques both worked for the problem solving skills of learners. TAPPS and Case Study techniques are useful for the branches like automobile engineering and mechanical engineering where the students have less exposure of electronics and electrical basics. These active learning techniques have been used here are also useful for continuous assessment. The rating method showed that students' thought process get enhanced for application of the theoretical concept. Healthy competition within group developed team work culture. Students' confidence level increased to self-learn the new things and correlated the theoretical concepts with the technologies available in the automotive market. Students' performance through these techniques reflected the positive attitude of students towards learning. The direct assessment showed average 11 % increase in performance. Both direct and indirect assessment tools have shown that there was improvement in students learning, engagement in the classroom, self-learning ability, and performance in course evaluation.

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