Revving Up Education: A Case Study on Active Learning in Automotive System Design for B. Tech Students

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ABSTRACT

This study explores the implementation of active learning techniques in a mathematics and design-intensive Automotive System Design (ASD) course to enhance student engagement and learning outcomes. The strategies employed include Think-Pair-Share (TPS), Think-Aloud Pair Problem Solving (TAPPS), Teams-Games-Tournament (TGT), Quizzes, and Puzzles. TPS and TAPPS facilitated collaborative learning, fostering critical thinking and problem-solving skills. TGT introduced gamification, increasing motivation and conceptual mastery, while quizzes and puzzles reinforced knowledge retention in an engaging manner. The results indicate a significant improvement in student performance, participation, and conceptual understanding**.** This study highlights the effectiveness of active learning methodologies in promoting deeper comprehension and engagement in complex, mathematics-driven design courses.

***Keywords*—Cooperative learning, Team Game Tournament (TGT), TPS, TAPPS, Puzzles, Automotive System Design**

I. INTRODUCTION

The evolving landscape of education has seen a shift towards innovative teaching methodologies that enhance student engagement, understanding, and participation (Serfass, 2014). Among these, active learning techniques have gained prominence for their ability to foster critical thinking, collaboration, and deeper comprehension. This paper explores five key active learning strategies that have transformed traditional classroom dynamics: Think-Pair-Share (TPS), Think-Aloud Pair Problem Solving (TAPPS), Teams-Games-Tournament (TGT), Quizzes, and Puzzles. These methods not only inject vitality into the learning process but also cater to diverse learning styles, making education more interactive and effective (Canavesi & Ravarini, 2024).

- *Think-Pair-Share (TPS):* TPS encourages students to reflect on a question or topic, discuss their thoughts with a partner, and then share their insights with the class. This technique promotes critical thinking, collaborative learning, and diverse perspectives.
- *Think-Aloud Pair Problem Solving (TAPPS):* In TAPPS, students work in pairs, with one verbalizing their thought process while solving a problem and the other providing feedback. This method enhances problem-solving skills, analytical thinking, and communication.
- *Teams-Games-Tournament (TGT):* TGT integrates gamification by dividing students into teams for academic competitions. This approach fosters healthy competition, teamwork, and content mastery through structured tournaments.

- *Quizzes:* Quizzes provide a quick and effective assessment of knowledge retention. Available in various formats (multiple-choice, short-answer, true/false), quizzes offer timely feedback, helping both students and teachers identify areas for improvement.
- *Puzzles:* Incorporating puzzles such as crosswords, word searches, and jigsaw activities makes learning engaging and intellectually stimulating. Puzzles promote problem-solving, vocabulary acquisition, and memory recall.

Each of these strategies contributes to a dynamic and interactive learning environment, encouraging students to actively engage with course material, collaborate with peers, and apply their knowledge in meaningful ways. By integrating these techniques, educators can create enriched learning experiences that not only improve student performance but also equip them with essential lifelong skills for academic and professional success (Dijkstra et al., 2019).

II. IMPLEMENTATION PLAN

Automotive System Design (ASD) involves the design and analysis of various automotive components, making the integration of active learning strategies a unique challenge. Careful planning is essential to maintain a steady teaching pace while allowing students sufficient time for hands-on practice. Table 1 outlines the structured implementation of active learning activities across different topics.

TABLE 1
IMPLEMENTATION PLAN

Sr. No.	Activity	Topic	Lecture No.
1.	Quiz Competition	After every chapter	L6, L12, L18, L24, L30, L36
2.	Puzzle	Design of Clutch, Design of Gearbox, Design of Brake System	L8, L15, L27
3.	Think-Pair-Share (TPS)	Design of Clutch, Design of Suspension System, Final Drive	L10, L22, L33
4.	Think-Aloud Pair Problem Solving (TAPPS)	Design of Suspension System	L17, L32
5.	Teams-Games-Tournament (TGT)	Design of Suspension System	L24, L25

III. IMPLEMENTATION OF ACTIVITIES

1) Quiz Competition

Quiz competitions are conducted at the end of each chapter using interactive online platforms such as Kahoot and Slido. Students are grouped into teams at the start of the course, with each team selecting a unique name. These groups remain constant throughout the semester, competing in quizzes after every chapter.

- The winning team of each quiz receives a reward, while all participants receive small tokens of appreciation (e.g., chocolates, pens).
- At the end of the course, the team with the highest overall performance is declared the winner and honored with certificates in a felicitation ceremony.

2) Puzzle Activity

Puzzles are designed to assess students' comprehension of key automotive systems and their components (Akdemir &Arslan,2012). Three different puzzles are tailored to topics listed in Table 1.

- Students are encouraged to solve these puzzles independently without external assistance.
- Peer assessment is used to evaluate the puzzle-solving process, creating an interactive and collaborative learning environment.

3) Think-Pair-Share (TPS)

TPS activities are implemented for selected topics where students analyze automotive system images and answer thought-provoking questions (Michaelsen et al., 2002).

- Students first think individually, then discuss with a partner before sharing their insights with the class.
- This activity enhances critical thinking, peer interaction, and presentation skills, helping students develop confidence in articulating their ideas.

4) Think-Aloud Pair Problem Solving (TAPPS)

TAPPS is used for problem-solving exercises in gearbox and propeller shaft design.

- Students work in pairs, alternating roles—one solves the problem aloud, while the other observes and provides feedback.
- Each pair then presents their thought process to the class, promoting reflective learning and interactive discussions.
- This method enhances analytical thinking, problem-solving, and communication skills in an engaging manner.

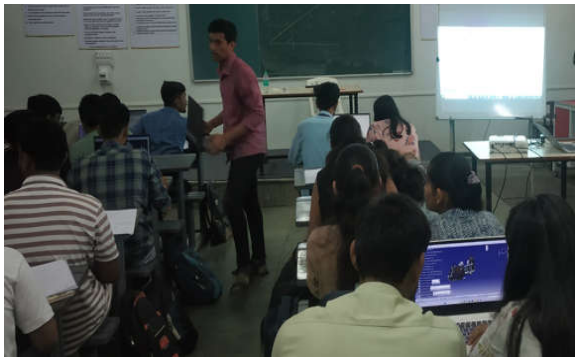

Fig.1.Pairs working on modeling task

5) Teams-Games-Tournament (TGT)

TGT introduces a tournament-style learning experience, where students compete in teams on selected topics (González et al., 2014)

- The class is divided into balanced teams based on academic ability.
- Teams compete against each other, reinforcing concepts through friendly competition.
- Since team performance depends on individual contributions, members are encouraged to collaborate and support one another.
- At the end of the activity, the winning team is awarded certificates of appreciation.

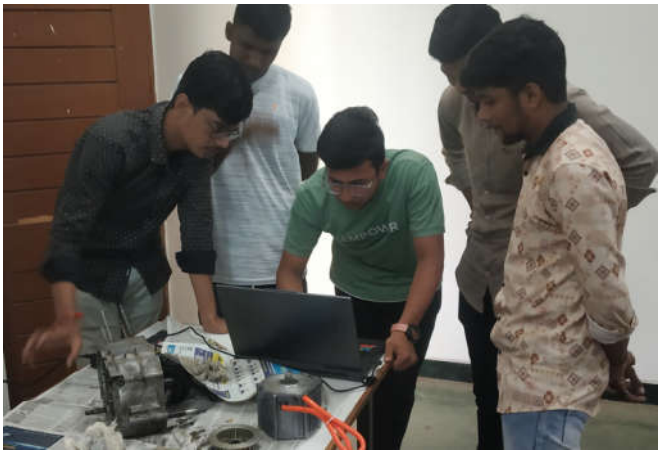

Fig.2.Teams working on task

IV.IMPACT ANALYSIS

The impact of active learning techniques was evaluated using four key parameters:

1. *Student Grades*
2. *Student Participation*
3. *Student Feedback*

1) Student Grades

A comparative analysis of student grades from the 2023-24 and 2022-23 academic years was conducted to assess the effectiveness of active learning strategies. The grade distribution is illustrated in Fig.3**.**

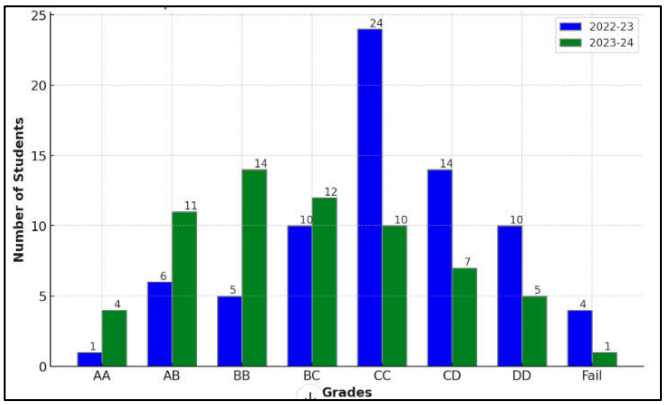

Fig.3 -Comparison of Grades of AY 2022-23 & AY 2023-24

Comment on Student Grades

The graph indicates a notable improvement in student performance following the implementation of active learning techniques. Key observations include:

- A significant increase in the number of students achieving higher grades **(**AA, AB, and BB**).**
- A decline in the number of students in the lower grade categories **(**CC, CD, DD, and Fail**).**

This trend suggests that active learning strategies positively impacted student outcomes**,** leading to higher overall academic performance**.**

2) Student Participation

Fig.4 illustrates the expected versus actual student participation in various active learning activities.

- Quiz Competitions**:** Conducted six times; highest participation, with a minor shortfall of 14 students**.**

- Puzzles & TPS**:** Conducted three times each; participation was strong, missing only a few students**.**
- TAPPS: Conducted twice; participation slightly lower than expected, with a shortfall of 6 students**.**
- TGT: Conducted once; met full expected participation, indicating strong engagement.

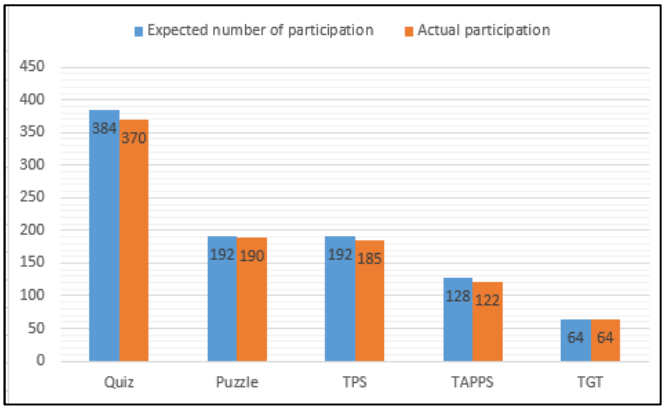

Fig.4. - Student Participation

Comment on Student Participation

The data suggests that students were highly engaged**,** with participation rates aligning well with expectations. Minor variations in attendance may be attributed to scheduling conflicts or individual preferences.

3) Student Feedback

A structured feedback survey was conducted, consisting of five key questions assessing engagement, activity effectiveness, understanding, challenge level, and recommendations for future courses.

Q.1. How would you rate your overall engagement level during the active learning activities in this course?

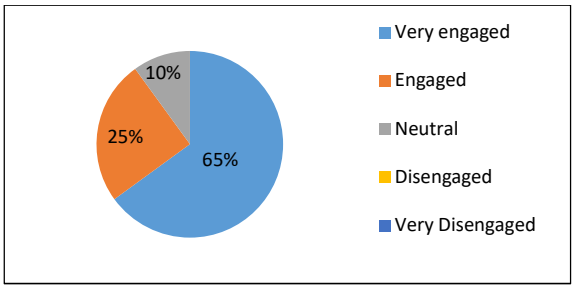

Fig.5- Student Response to Q.1

Q.2. Which active learning activity did you find most effective for your learning?

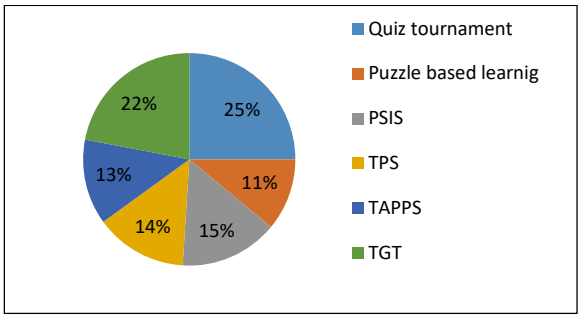

Fig.6- Student Response to Q.2

Q.3. How well do you think the active learning activities helped you understand the course material?

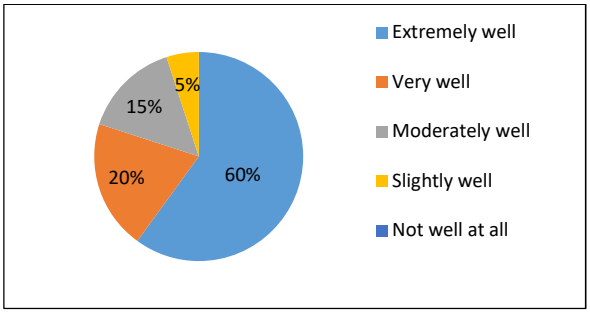

Fig.7- Student Response to Q.3

Q.4.How often do you feel challenged by the active learning activities in this course?

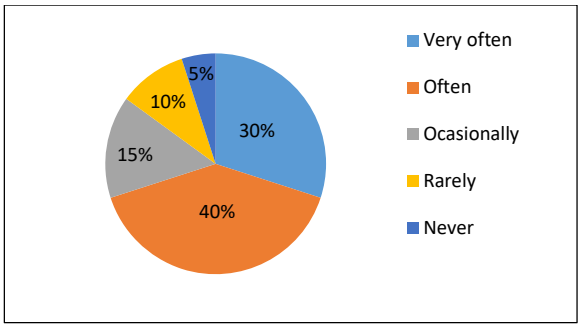

Fig.8- Student Response to Q.4

Q.5. Would you recommend incorporating more active learning techniques in future courses?

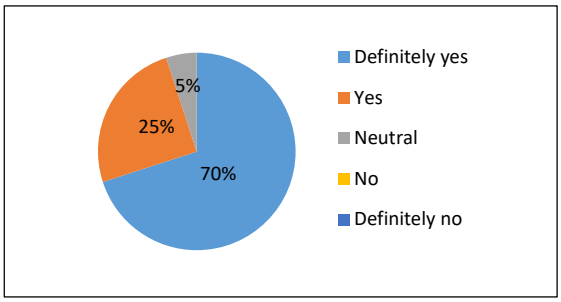

Fig.9- Student Response to Q.5

Feedback Breakdown and Analysis

1. Overall Engagement (Q1)

- 65% of students reported being "very engaged," and 25% were "engaged," meaning a total of 90% had a positive engagement experience.
- 10% remained neutral, suggesting potential barriers to engagement such as personal learning preferences, workload, or external factors.

2. Effectiveness of Activities (Q2)

- Quiz Tournament (25%) and TGT (22%) were the most favored activities, indicating a preference for competitive and team-based learning.
- Other activities received moderate preferences (11%-20%), highlighting the importance of offering diverse learning methods.
- TAPPS and Puzzle-Based Learning were less favored, suggesting potential refinements in their structure or delivery.

3. Understanding of Course Material (Q3)

- 80% of students found active learning "extremely" or "very" effective in enhancing their understanding.
- 15% rated the activities as "moderately effective", indicating a need for additional support or alternative explanations for some students.

4. Challenge Level (Q4)

- 70% of students felt "very often" or "often" challenged, confirming that the activities provided an appropriate level of difficulty.
- 30% reported feeling only occasionally challenged, suggesting that some students may need more complex tasks to maintain engagement.

5. Future Recommendations (Q5)

- 95% of students would "definitely" or "probably" recommend incorporating more active learning techniques in future courses.
- A 5% neutral response suggests a small portion of students may prefer traditional methods or have a different learning style.

Overall Analysis and Recommendations

1) Strengths

- High Engagement: 90% of students found the activities engaging.
- Effective Learning: 80% reported improved understanding.
- Student Preference for Active Learning: 95% recommended continuing these methods.
- Successful Team-Based Activities: Quiz Tournaments and TGT were highly effective.

2) Areas for Improvement

- Refining TAPPS and Puzzle Activities: Adjust the design or implementation to make them more engaging.
- Enhancing Student Challenge: Introduce differentiated tasks to ensure all students feel adequately challenged.
- Addressing Neutral Responses: Further investigation into the 10% neutral engagement responses could help tailor strategies for greater inclusivity

V.CONCLUSION

The implementation of active learning techniques in this course has led to notable improvements in student engagement, comprehension, and overall academic performance**.** This is evident from positive student feedback, increased participation, and improved grades**.** Students responded enthusiastically to the variety of activities**,** with strong support for their continued use in future courses. While the approach has been highly effective**,** further refinement of certain activities and ensuring that all students are appropriately challenged could further optimize learning outcomes.

Overall, the significant impact on both engagement and academic achievement underscores the value of active learning strategies, reinforcing their importance in enhancing the educational experience.

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