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Enactment and impact analysis of active learning strategies utilized for the basic science courses in the evaluation of engineering students

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Abstract**—** The new era of teaching learning process demands more clearance of theoretical aspects utilizing visual strategies. Accordingly, this research focuses on usefulness of student team achievement division (STAD) and project based learning (PjBL) as active learning strategies for comprehensive understanding of basic science courses. The study revealed increased effectiveness of learning, encouraging equal participation, active engagement and supportive learning environment for better understanding of concepts in basic science courses. The usefulness of active learning strategies has been studied by conduction of STAD & PjBL activities for the Engineering Mathematics and Engineering Chemistry courses respectively. The appropriate evaluation and comparative analysis done before and after activity allows to elaborate the efficacy of visual strategies utilized for understanding theoretical concepts.

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1. Introduction

Currently, the way educational system is implemented needs to change with technological improvements, new forms of communication and rising expectations from highly skilled students. Teamwork is one of the key components of student engagement since it encourages students to develop their social and intellectual skills for lifelong learning, which is undoubtedly necessary in technical education (Karge et al., 2011; Mulongo, 2013). The importance of active learning techniques in the teaching and learning of science and mathematics has been well established. The understanding, beliefs, self-efficacy, practices, and problems of active learning among science and math teachers were examined in variety of ways (Freeman et al., 2014; Dole et al., 2016).

In a cooperative learning technique called student teams-achievement divisions, small groups of students with various levels of ability work to accomplish a common objective (Ziziumiza et al., 2022). When properly executed, the group project technique of teaching and learning can result in students performing better and remembering more information than when they work individually (Tran, 2014; Yussop et al., 2021; Goodsell et. al. 1992). The idea of improving the educational process, which entails the introduction of some project-based skill mastering formats, has gained significant attention in the educational world during the past few years. It became vital to have systems in place for involving academics and students in project-based activities (Thomas, 2007; Raker et al., 2021).

A rubric is helpful in quantifying all aspects of active learning tools evaluation and enables a uniform way of objectively comparing various students. A rubric also offers an object that can serve as documentation for the choice of a particular tool and as a convenient reference in the activity. Enhancing active learning, repetition, and feedback in the classroom all crucial components of encouraging student learning can be difficult in large university classes.

Various active learning tools utilized for better learning of subject matter but their impact analysis is also important. The strategy defined to gather feedback also plays crucial role. Giving and receiving feedback in the classroom is crucial for supporting learning and academic success. Students acquire information about their present performance as well as information through the process of feedback. Students frequently overestimate how much they know and remember, so feedback gives them the chance to monitor their learning progress, identify their strengths and weaknesses, and choose what they need to focus on (Hattie et al., 2007; Agarwal et al., 2019, Schneider et al., 2017). With the present study, we tested a teaching of Engineering Mathematics and Engineering Chemistry utilizing student team achievement division (STAD) and project based learning (PjBL). The feasibility of strategies and interrogation of activities done through rubrics, as well as student pre-survey and feedback.

2. Purpose of Employing Active Learning Strategies

A student-centered pedagogy involves active learning tools that combines a dynamic practical approach for previously acquired theoretical or experimental concepts with hands-on experience that help students for better understanding of the subject matter. The project-based learning approach aims to inspire students to create, develop their problem-solving skills, and enhance their management abilities to conduct independent research. Moreover, STAD will raise their awareness about the significance of the mathematical concepts that enables them to integrate various principles and skills as well as motivate them to improve communication abilities.

3. Strategic Steps for Impact Analysis

The algorithmic approaches of for impact analysis of active learning strategies are as given below;

A. The Pre-survey Stage- This stage deals with different pre-surveys conducted in order to gather information or facts regarding enhancing effectiveness of theory sessions by utilizing active learning strategies.
B. Implementation of active learning strategies- In this stage depending on pre-survey analysis two active learning strategies for basic science courses were implemented. For Engineering Chemistry PjBL activity and for Mathematics STAD activity.
C. Feedback analysis In order to access the intention of students about PjBL and STAD activity we float same questionnaire as feedback. Moreover analysis of feedback clearly indicated the effect of activities.
D. Comparative analysis of pre-survey and feedback Comparative analysis of pre-survey and feedback was carried out in order to assess in depth of impact for employed strategies.
E. Overall feedback about active learning strategies- In the final step overall feedback about active learning strategies was taken.

4. Methodology for Implementation of Activities

The detailed discussion of methodology utilized to implement the active learning strategies was done in this section. The STAD and PjBL activities were completed by first-year B. Tech students in the Mechanical and Civil Engineering programme who were taking Engineering Chemistry and Engineering Mathematics courses.

A. STAD

STAD is an instructional strategy used in the classroom to promote cooperative learning and improve student performance (Adesoji et.al., 2009). The steps involved in complying of STAD strategy are given below;

1) Conduction of Quiz

The teacher taught a lesson to the students in the class. Further quiz is conducted and students were graded individually for their performance.

2) Group formation

In second step, the students are placed in small heterogeneous groups containing 4 to 5 students based on slow learners, advanced learners, gender, and ethnicity.

3) Topic Assignment

Each group is given a topic by the teacher, along with study materials and a set of problems. Next students work in teams and ensure that they have mastered the lesson. The students take individual quizzes on the assigned topic, during which they may not help each other. Further, their scores are compared to previous scores and points are awarded based on the degree to which students meet or exceed their own earlier performance. It encourages the students to take up responsibility for other members in their group as well as themselves.

4) Report and Presentation

On the basis of the given material and topic, students prepare the report and submit as group. Finally, all members give presentations. This ensures that all group members, regardless of their different levels, are equally motivated to do their best. The details of group formed and presentation of activity is as shown in Figure 1a.

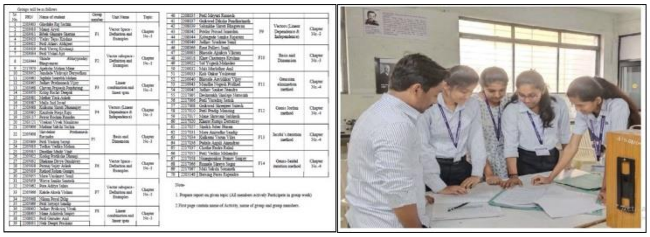

Figure 1a. Active participation of students for STAD

B. PjBL

The PjBL activity for Engineering Chemistry was potable water analysis. Normally, students during practical sessions of the Engineering Chemistry course typically work with the same water sample to determine various water quality parameters. The PjBL activity, however, enables students to conduct experiments using various water samples from their native places. The detailed methodology utilized for the conduction of PjBL activity was as mentioned in previous article (Kurane et.al. 2022). Further, the Figure 1b shows active participation of students with collection of water sample, presentation of activity and copy of front page for prepared report.

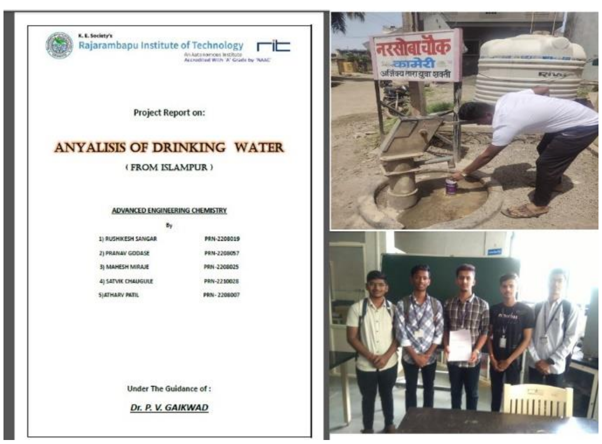

Figure 1b. Active participation of students for PjBL

5. Analysis of Data

A. Pre-survey

A survey was conducted for faculty members teaching basic science courses such as Physics, Chemistry and Mathematics using a Google form. The intention was to discover more about the difficulties associated with conducting theory sessions using a simple lecture method for basic sciences courses. The questionnaire designed for survey and graphical representation is as shown in Figure 2 a, b and c.

Q. 1 Do you feel any difficulty while conducting theory courses with only lecture method?
a) Yes b) No

Q. 2 Do you experience any difficulty in demonstration of experiment based concepts with lecture method?

Q. 3 Are you able to engage the students during theory sessions with only lecture method?

Q. 4 Whether utilizing active learning tools in between theory sessions will boost learning of students?
a) Yes b) No

Q. 5 Are you able to effectively conduct theory courses without any active learning tools?

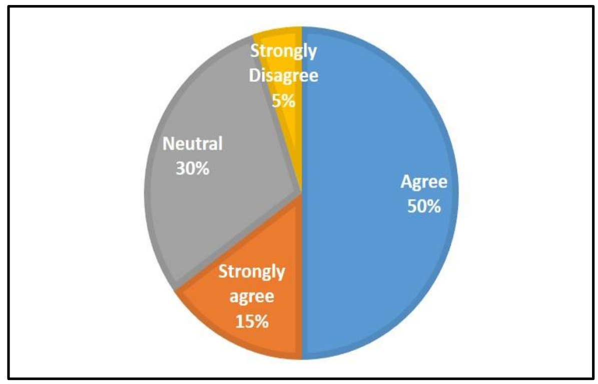

Figure 2a. Graphical presentation for question 2

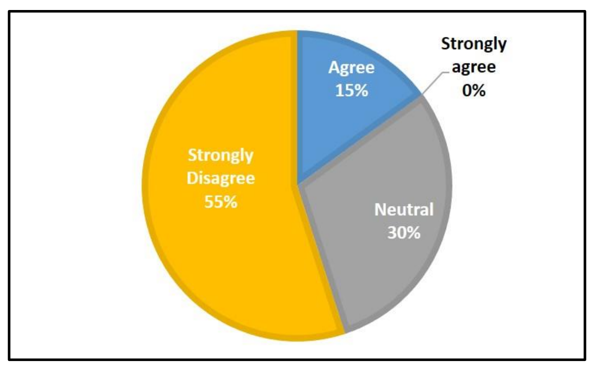

Figure 2b. Graphical presentation for question 3

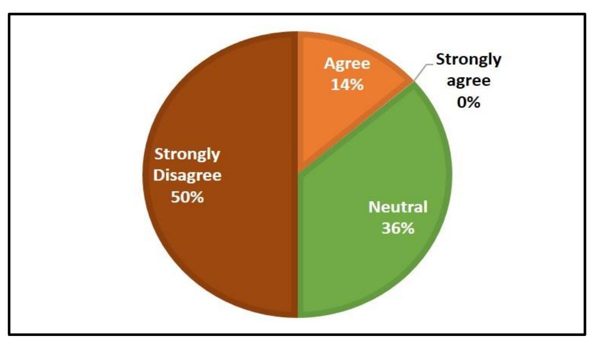

Figure 2c. Graphical presentation for question 5

The findings from faculty survey are about 84% (Yes) instructors face difficulty while conducting theory courses with only lecture method. Whereas up to 65 % course instructors face difficulty in demonstration of experiment based concepts with lecture method. Moreover, 85% instructors feel use of active learning tools in between theory sessions will boost learning by the students.

The concept of conduction theoretical lectures without employing active learning tools or strategies was then put to the students as a survey to gather their opinions. The questionnaire designed for Pre-survey and feedback are identical as given below and the graphical analysis was shown in Figure 3a and 3b.

Questionnaire to students for Engineering Chemistry course

Q. 1 I feel confident in my ability to contribute to class discussion in Engineering Chemistry.

Q. 2 I feel confident in my abilities in Engineering Chemistry.

Q. 3 I enjoy sharing my thoughts and observations during class discussion in Engineering Chemistry class.

Questionnaire to students for Engineering Mathematics course-

Q. 1 I feel confident in my ability to contribute to class discussion in Engineering Mathematics.

Q. 2 I feel confident in my abilities in Engineering Mathematics.

Q. 3 I enjoy sharing my thoughts and observations during class discussion in Engineering Mathematics class.

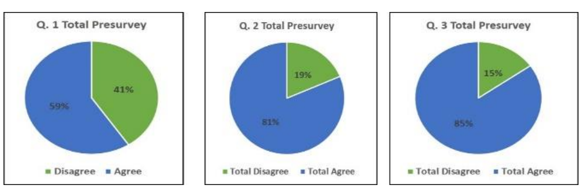

Figure 3a. Student Pre-survey for Engineering Chemistry course

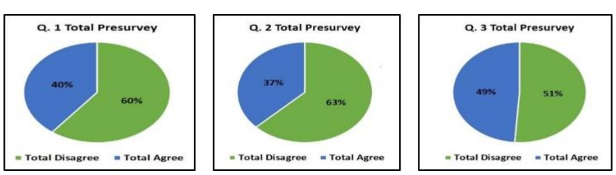

Figure 3b. Student Pre-survey for Engineering Mathematics course

B. Activity Analysis for STAD and PjBL

The active involvement in the STAD activity was evaluated using five-point scale rubrics. The rubrics fabricated with three criteria's as team work, content accuracy and oral presentation. The Figure 4a specifies that more than 70% students have achieved 4 and above point rating in grades allotted using developed rubrics. Moreover, the presentation and report writing abilities of all groups, the active involvement in the water analysis activity was assessed using five-point scale rubrics (Brookhart, 2019; Zemel, 2021). The Figure 4b states that more than 70% students have achieved 4 and above point rating in stage daring, presentation skill, communication skill and concept understanding. The project reports from five out of the fifteen groups received the highest ratings because they were precise, well-structured, and had a strong feeling of completeness.

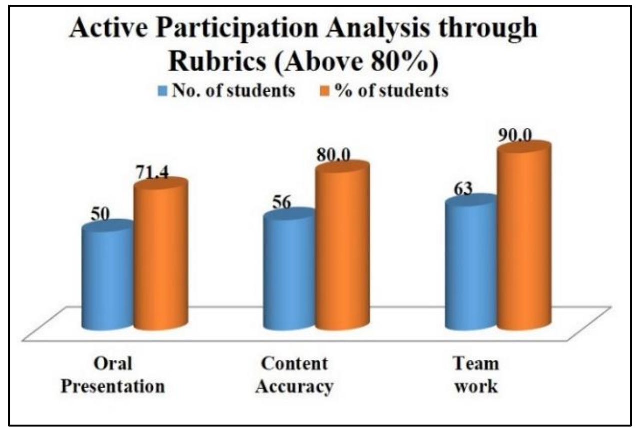

Figure 4a. Active participation analysis through rubrics for STAD

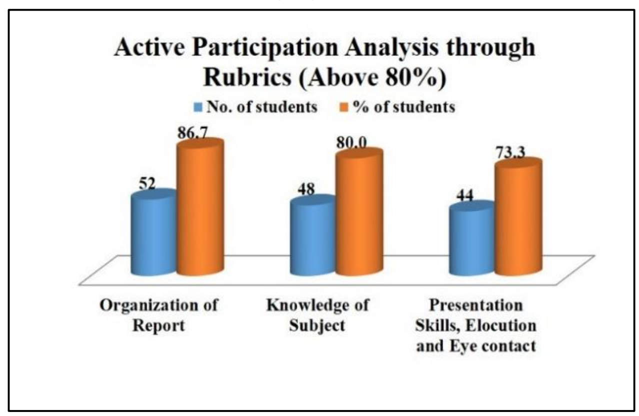

Figure 4b. Active participation analysis through rubrics for PjBL

C. Feedback

At the last of activity, in order to access the intention of students about PjBL and STAD activity we float same questionnaire as feedback. The graphical analysis was shown in Figure 5a and 5b for Engineering Chemistry and Engineering Mathematics respectively.

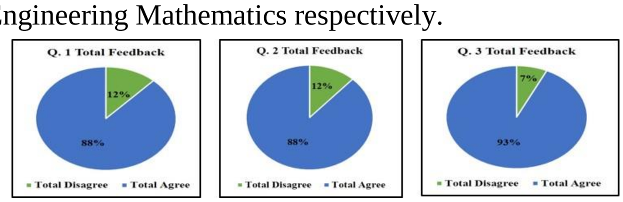

Figure 5a. Student feedback for Engineering Chemistry course

Figure 5b. Student feedback for Engineering Mathematics course

D. Comparison

Student's participation in class and level of confidence was also quantified at the beginning and end of PjBL and STAD activity in order to examine the effects of these learning approach (Marquez et.al. 2023). The Figure 6a, 6b and 6c compare the responses of students provided for the pre survey and feedback for Engineering Chemistry.

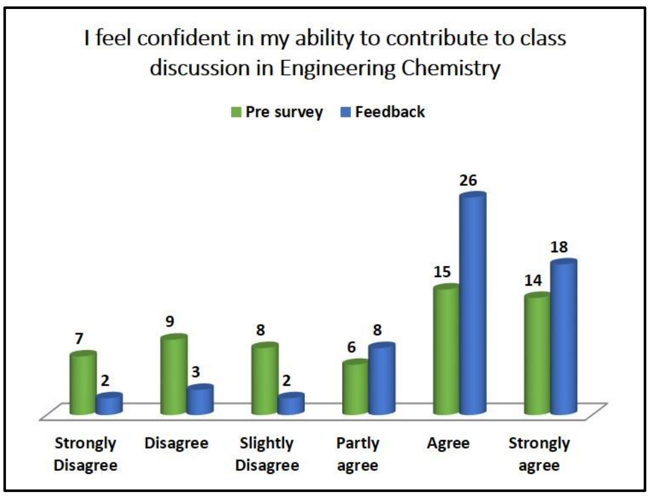

Figure 6a. Comparison of pre-survey and feedback for question 1 Engineering Chemistry

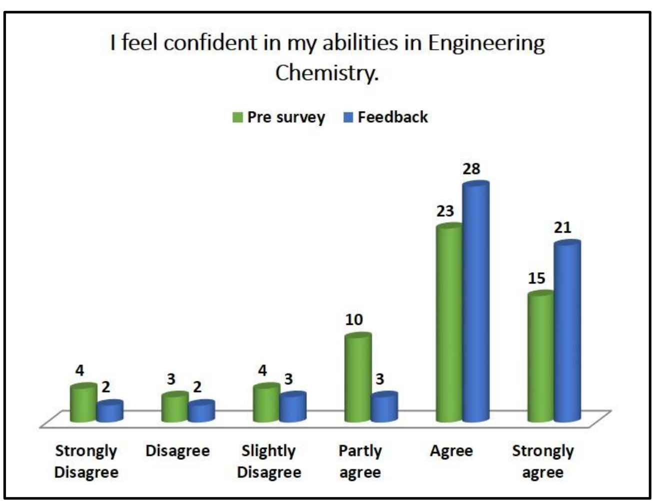

Figure 6b. Comparison of pre-survey and feedback for question 2 Engineering Chemistry

The comparison of pre- survey and feedback indicate that PjBL had a good effect on student's opinions about taking part in discussions and activities in Engineering Chemistry class. Every question had more positive comments than it did in the pre-survey. The study findings advise teachers to consider activity like the PjBL to boost learning by the students. In the beginning and end of the STAD activity, student involvement in class and confidence levels were measured in order to assess the impact of these teaching strategies. The Figure 7a, 7b and 7c compare the responses of students provided for the pre survey and feedback.

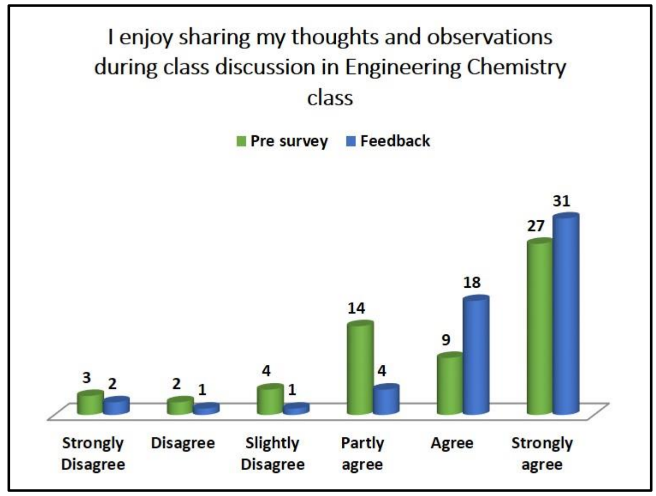

Figure 6c. Comparison of pre-survey and feedback for question 3 Engineering Chemistry

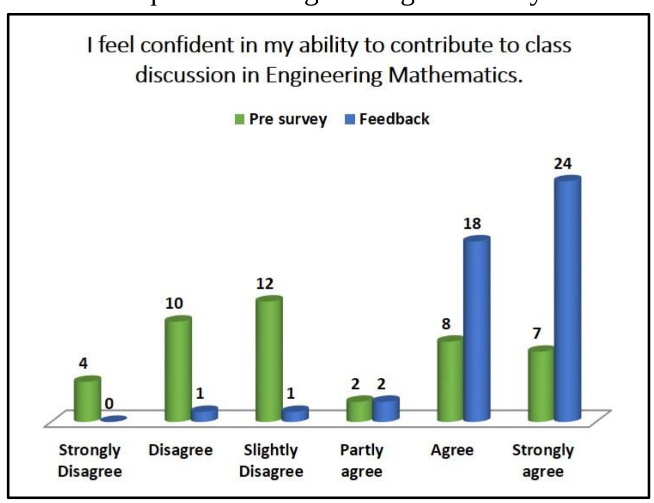

Figure 7a. Comparison of pre-survey and feedback for question 1 Engineering Mathematics

The results of a comparison between the pre-survey and the feedback show that STAD had a positive impact on students' opinions of participating in class discussions and activities in engineering mathematics. There were more encouraging responses to each question than there were in the pre-survey. According to the study's conclusions, teachers should take into account STAD-type activities to improve students' learning.

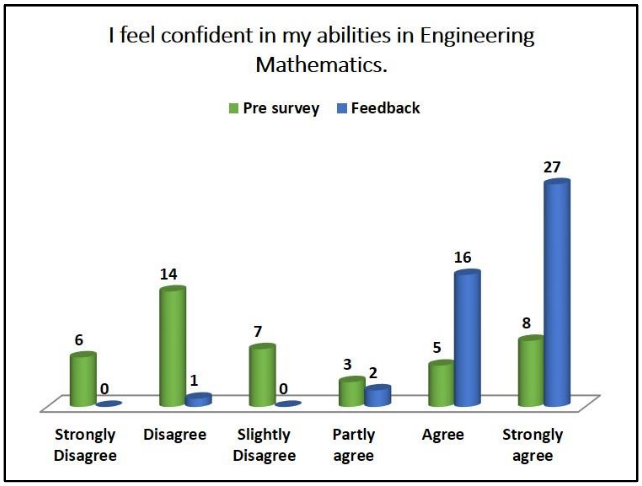

Figure 7b. Comparison of pre-survey and feedback for question 2 Engineering Mathematics

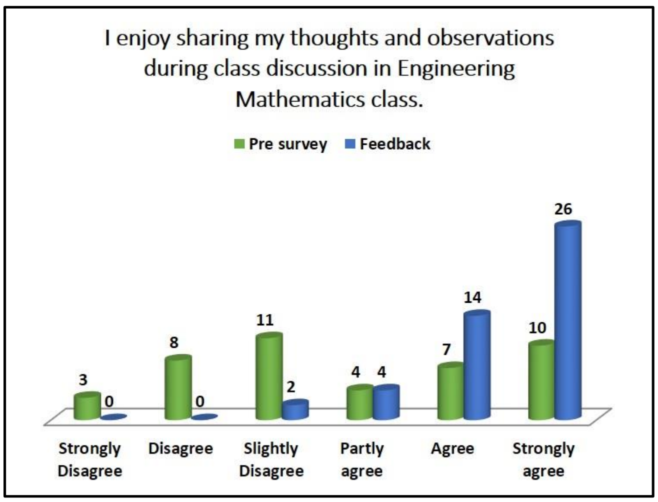

Figure 7c. Comparison of pre-survey and feedback for question 3 Engineering Mathematics

E. Overall Feedback

Overall feedback for conduction of PjBL and STAD conducted. The questionnaire and detailed analysis of feedback is as given below in Figure 8a to 8e.

Q. 1 This active learning strategies was associated with curriculum (Syllabus) of your course?

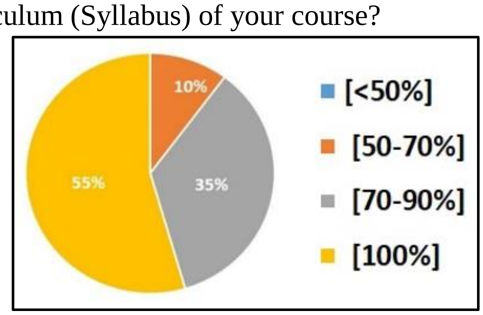

Figure 8a. Graphical distribution of correlation with curriculum

Q. 2 Whether the activity content is informative?

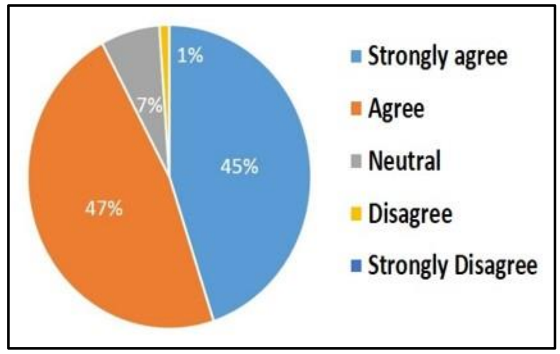

Figure 8b. Content of activity was informative

Q. 3 The content covered during the activity are helpful for better understating of topic and learning of concepts.

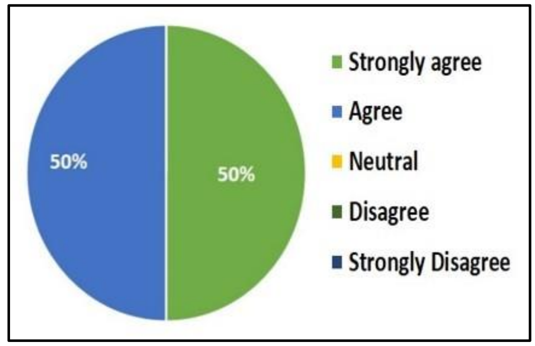

Figure 8c. Understating of topic and learning of concepts

Q. 4 Your overall rating for this active learning strategy

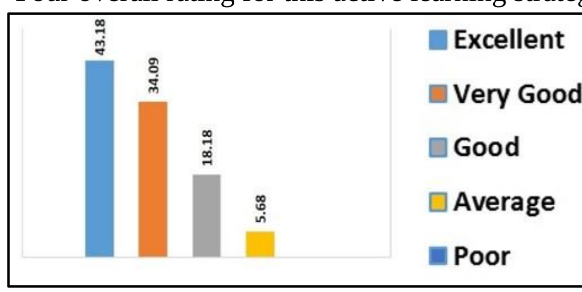

Figure 8d. Overall rating for this active learning strategies

Q. 5 How you rate this implemented active learning strategies with utilization of only theory sessions for teaching.

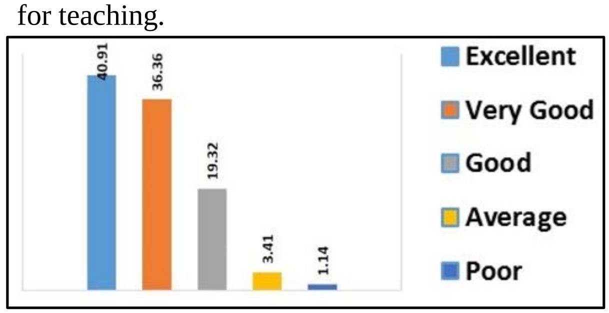

Figure 8e Compared activity with theory sessions

Q. 6 Do u like to participate in such active learning strategy for better learning in future?

a) Yes b) No c) May be

The graphical distribution shown in Figure 8.1 specifies almost all students feel these both activities are strongly associated curriculum. Further, majority of the students agree that the used strategies are informative. Figure 8.3 demonstrates that 100% of students believe PjBL and STAD will improve topic understanding and concept learning. No single students appeared for PjBL and STAD marked overall rating for this active learning strategies as poor. Almost 96.5 % students attended both PjBL and STAD gives good or more than that rating. In the future, 95% of students will be ready to participate in such activities. Moreover as last question students have been asked to put their valuable suggestion for further improvement in implementation of active learning strategies. Variety of reposes are achieved some of them are tabulated in Table 1.

Table 1 Suggestions by the students about implementation of active learning strategies

Roll No	Name of Student	Valuable suggestions
2208025	Shravani Jaywant Patil	The activities work on the practical skillset more than the theoretical part, Good.
2203061	Prachi Pradip Mohite	Learning strategies are good though so I don't think there are any suggestions from me.
2208046	Om Mayuresh Ghorpade	There should be given a bit more time to complete activities.
2217066	Shreya Sagar Rumale	Practical basis knowledge is given.
2208066	Pallavi Sunil Raut	To conduct such activities on each chapter.

Conclusions

The use of STAD and PjBL in a targeted class has been found to be helpful for increasing the proportion of students who participate in class discussion, enabling students to provide detailed clarifications, and strengthening students' ability to articulate their ideas. Further, following important outcomes were discovered that impacts significantly on methodology utilized for carrying out both PjBL and STAD as activity.

i. STAD promotes a more inclusive and participative learning environment for Engineering Mathematics by placing an emphasis on cooperative learning and offering scheduled opportunities for students to interact with one another.

ii. Communication and knowledge exchange were accomplished effectively after successful completion of the STAD. Students were understanding theoretical information in better way with help of active learning strategy. The active learning strategy STAD serves as a visual aid to learn the complex concepts.

iii. PjBL, on the other hand, promotes deeper comprehension and the application of knowledge by encouraging students to work on projects that are meaningful and relevant to Engineering Chemistry.

iv. A Problem solving by doing experiments and comparing their analysis results increases an interactive learning. Enhances learning ability of students by providing more emphasize on practical session. The PjBL strategy inspires students to create, develop their problem-solving skills.

The creation and analysis of strategies through rubrics allows teachers for successful evaluation of participated students. The impact analysis carried out through pre-survey and feedback reinforced that utilizing like these strategies for basic science course is trustworthy. Moreover, the overall feedback analysis provides thorough interrogation of the employed strategies. The impact analysis also confirms that these strategies significantly improved students' learning.

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