Journal of Engineering Education Transformations,
Volume No. 37, January 2024 Special Issue, eISSN 2394-1707

Using STAD as an Assessment for Learning (AfL) in Mathematics

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***Abstract*— This research paper delves into the innovative application of Student Teams-Achievement Divisions (STAD) as an Assessment for Learning (AfL) tool within the realm of mathematics education. Assessment for Learning (AfL) is a pedagogical approach designed to enrich student learning by incorporating ongoing assessment practices to inform instructional strategies. Within this study, we explore the seamless integration of STAD into AfL methodologies, emphasizing its capacity to facilitate active assessment, provide real-time feedback by peers, enhance mathematical comprehension and academic performance, and ultimately nurture self-esteem and intrinsic motivation in the pursuit of mathematics education. Drawing from established theoretical frameworks and empirical insights, this paper underscores the dynamic potential of STAD as an AfL instrument, offering educators a potent means to assess and bolster student learning within mathematics classrooms.**

Through an exhaustive review of existing literature, this paper seeks to furnish educators, researchers, and policymakers with a comprehensive grasp of STAD's pivotal role in promoting effective mathematics assessment and cultivating collaborative and engaging learning environments. The research findings were meticulously analyzed employing paired t-tests to glean valuable insights into the impact of STAD as an AfL strategy on student outcomes. The results are also supported by student's interview and teacher's observations.

***Keywords*— STAD; Assessment for Learning(AfL); Formative assessment; Cooperative Learning; Mathematics education**

***JEET Category*—Choose one: Practice**

I. INTRODUCTION

MATHEMATICS is the fundamental part of human thought and logic. It is an indispensable subject at all levels of education. It is essential not only for day to day activities but also to understand the concept of other subjects like science, technology, finance, social studies, music, art and so on. It provides an effective way of building mental discipline, problem solving skills, encourages logical reasoning and mental rigor. However, there is a common belief that majority of the students dislike mathematics or they feel it is hard, dry and boarding subject. Gafoor, K. A., & Kurukkan, A. (2015) claims that a large division of students use blind strategies in learning mathematics and possess less adaptive self-efficacy beliefs and epistemological beliefs.

In mathematics, one of the main challenges to teachers is to break the "*mental math block*". Due to lack of prerequisites knowledge & missing some fundamental concepts, many students have come to believe over time that they are "*just not good at mathematics*". Such attitude can result in fighting for self- esteem related issue. At this time, the main challenge to mathematics teacher is to make a positive attitude in students toward learning mathematics. Teachers should be aware of students' affective beliefs and inter relations of those in learning mathematics so as to employ more effective strategies in teaching and to improve students' mathematics learning by reducing their negative beliefs (Gafoor, K. A., & Kurukkan, A. (2015)). Lots of research is going on to make mathematics learning interesting, developing new pedagogy, integration of technology etc. (Simon, M. A. (1995), Viberg, O. et.al. (2023), Desai R. et.al. (2023)). Still assessment in mathematics is a big challenge to math teacher.

Assessments should not only evaluate learning outcomes but also helps students learn during assessments and gain their self-esteem. Kulm, G. (1994), Pegg, J. (2003), Desai R., et al. (2022), have discussed several techniques of assessments which can be worked out in math classroom. National Research Council (1993) talks about measuring what counts and gives a conceptual guide for mathematics assessment.

Currently in the world, there are three widely used approaches for assessment (Berry, R. (2008)): Assessment of Learning (AoL), Assessment for Learning (AfL) and Assessment as Learning (AaL). David Hargreaves (2004) described Assessment for Learning (AfL) as 'a teaching strategy of very high leverage'. The AfL is basically a formative assessment. As the name suggests, AfL is the assessment carried out not to just measure how much knowledge has been mastered by the student but also to check improvement of learning during assessments. AfL can be developed on the premise that students' ability to optimally increase, if they understand the purpose of learning, know their position in relation to the learning objectives, and understand how to achieve the learning objectives. (Kholid et. al (2014)).

According to Bloom (1969), the purpose of formative

This paper was submitted for review on September, 2023. It was accepted on November, 15, 2023.
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evaluation was '... to provide feedback and correctives at each stage in the teaching-learning process'. Popham. (2008) said, '...formative assessment is not a test but a process...'. Balan, A. (2012) proved that the change in assessment practices to a formative assessment (AfL) had a positive influence on students' mathematical learning. His study deepens the understanding of how the components of a formative-assessment practice may influence students and their learning in mathematics, but also how these components co-exist in an authentic classroom situation and influence each other.

In the current paper, Author tried to address above mentioned burning issues related to assessment in mathematics by implementing STAD as Assessment for Learning (AfL). Assessment should enhance mathematics learning and support good instructional practice. Students should not get scared of assessment, learns mathematical concepts during assessments, gets instant feedback on their understanding, improves their academic score and hence gradually develops self-esteem & gets self-motivated towards learning mathematics with interest.

II. METHODOLOGY

Student teams-achievement divisions (STAD) (Slavin, 1991) is considered as one of the most researched, simplest, and most straightforward cooperative learning strategy. The implementation of the Student Teams-Achievement Divisions (STAD) approach in the First year undergraduate engineering mathematics classroom represents a dynamic shift in pedagogical strategies. A class of 60 was divided in 3 batches of 20 students each. During dedicated 1 hour tutorial time the activity was conducted in all 3 batches. In each batch 5 teams were formed. In total 15 teams of 4 students per team were formed.

This innovative approach is tailored to the unique demands and complexities of engineering mathematics, fostering an environment of collaborative learning and active student engagement.

1) ***Team Formation:*** A class of 60 was divided into 15 teams having 4 students each in a team. Students were divided into heterogeneous teams based on their prior performance in mathematics assessments, ensuring that each team had a mix of high, medium, and low-performing students. The teams were formed by a teacher and students were not given chance to choose their team members.

2) ***Content Selection:*** The teacher selected specific topic of mathematics related to Double integration. STAD can be the one of the most appropriate techniques for teaching and clarifying the concepts of these topics, collaborative team learning and problem solving.

3) ***Collaborative Team Learning & Problem-Solving:*** Four open-ended problems from the topic "Double Integral" were posed to students that require critical thinking and application of mathematical principles. The team members pool their strengths & worked together to understand, analyze, dissect, and solve assigned problems related to the given topics. Within their teams, students embark on a journey of exploration and discovery. They collectively grapple with engineering mathematics challenges, encouraging discussions, knowledge sharing, and brainstorming sessions. This cooperative learning environment mirrors the collaborative nature of engineering projects and research.

4) ***Quizzes:*** After a designated learning period of 40 minutes, each team took a quiz individually to assess their understanding of the topics. Quizzes contents conceptual questions, MCQs and descriptive problems related Double Integration.

5) ***Assessment:*** Following the individual quiz, team members discussed the problems faced during implementation of STAD and collectively assessed their individual and team performance, reflecting the importance of teamwork.

6) ***Peer Feedback:*** The STAD approach places a premium on peer feedback. Team members constructively critique each other's work, reinforcing the importance of peer review and quality control in engineering mathematics problems. Peers give immediate feedback to student making conceptual mistakes and correct them.

7) ***Teacher Facilitation:*** The role of the teacher evolves into that of a facilitator and mentor. They guide discussions, encourage interactions, clarify doubts, break the deadlocks and provide valuable insights on quiz results and collaborative efforts.

8) ***Reflection and Improvement:*** After each collaborative session, teams engage in reflective discussions. They assess their performance, identify areas for improvement, and strategize for future challenges—reflecting the continuous improvement ethos inherent in engineering practice. As the team gets joint rewards, high scoring students took responsibility of low scoring student and helped them understand topics.

III. DATA COLLECTION

Data was collected through three various means:

1) ***Quiz Scores****: Pre-STAD and post-STAD quiz scores were recorded and compared to measure improvement. Each Quiz was for 25 marks. It also helped* students *& teachers* to find out what level they are at *and where they need improvements*.

2) ***Student Interview:*** Students were interviewed to know their feedback about self-assessment of their mathematical understanding, their experiences with STAD, and their perceptions of the learning process.

3) ***Observations:*** Classroom observations were conducted during STAD activities to assess student engagement, teamwork, and participation levels. Team scores were also

analyzed to understand the team participation in discussions and improving results of their peers.

IV. RESULTS

Students' Pre-STAD and Post-STAD quiz scores are analyzed using paired t-test with the null hypothesis: there is no difference between the Pre-STAD and Post-STAD quiz scores. Student's individual score are represented by Fig.1.

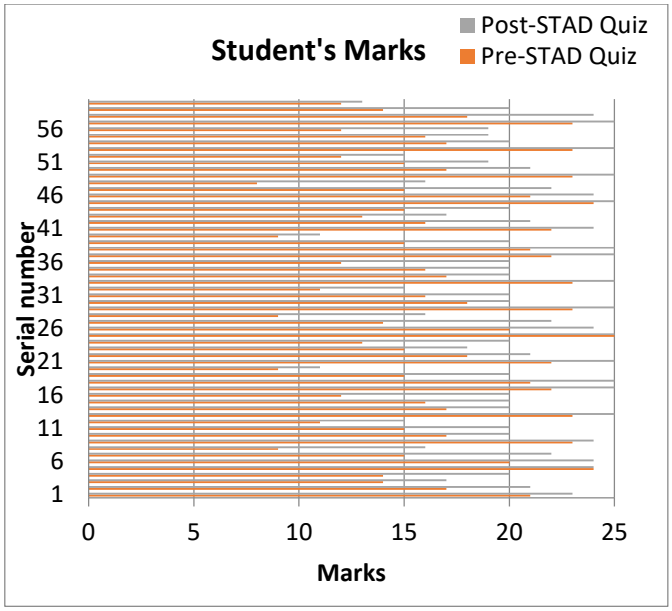

Fig. 1. Students Pre-STAD & Post-STAD quiz Marks.

For Pre-STAD quiz, students' individual score ranges between 6-25 marks with mean 16.833 and median 16 while for Post-STAD quiz, the score ranges between 11-25 marks with mean 20.716 and median 20. In post-STAD quiz, students have improved their score in the range between 0-8 marks. Based on Students individual score of Pre-STAD and Post-STAD quiz the following interpretations are made.

1. The test statistic is -8.54 and the p-value is less than .0001. This means that there is a significant difference between the pre-STAD and post-STAD quiz scores.
2. The negative sign of the test statistic indicates that the post-STAD quiz scores are higher than the pre-STAD quiz scores on average.
3. The p-value is much smaller than the common significance level of .05. This means that we can reject the null hypothesis that there is no difference between the pre-STAD and post-STAD quiz scores.

We can conclude that STAD has a positive effect on students' individual academic achievement.

Results were also analyzed based on their team score to understand the participation of student and effect of STAD during AfL. Before implementation of STAD, out of 100, initial team score were ranging between 66-68 with mean 67.33 and median 68. After the group discussion and interactions, the team scores were improved and now ranging between 79 to 87 with mean 82.86 and median 82. Significant increase of 12 to 19 marks was reported in team score. The results of paired t-tests are as follows.

1. The test statistic is -17.64 and the p-value is less than .0001. This means that there is a significant difference between the pre-STAD and post-STAD team average score.
2. The negative sign of the test statistic indicates that the post-STAD team average scores are higher than the pre-STAD team average scores on average.
3. The p-value is much smaller than the common significance level of .05. This means that we can reject the null hypothesis that there is no difference between the pre-STAD and post-STAD team average scores.

We can conclude that STAD has a positive effect on students' team performance.

Student's feedback through interview and Teacher's observations supports the statistics presented here. Team 8 was having less interaction & hence got increase of only 12 marks in team score with 2-4 marks improvement in their individual score. While team 7 having maximum interactions got increase of 19 marks in team score with 0-8 marks improvement in their individual score. For better discussion, data of only main three groups are represented in Table 1.

TABLE I
TEAM SCORE FOR GROUP 7, GROUP 8 & GROUP 10

Group No.	Sr. No. of Student	Pre-STAD marks	Post STAD marks	Increase in marks
Group 7	25	25	25	0
	26	20	24	4
	27	14	22	8
	28	9	16	7
Group 8	29	23	25	2
	30	18	20	2
	31	16	20	4
	32	11	15	4
Group 10	37	22	25	3
	38	21	25	4
	39	15	20	5
	40	9	11	2

After the implementation of STAD as an AfL tool, all Students' with interviewed. Some answers were remarkable. Especially students showed least/most improvement in individual score. Results of the interview of students having least marks in pre-STAD were really useful to understand effect of group discussion and brain storming session. Students reported that the approach of student having 20-25 marks in Pre-STAD played leading role in motivating other.

For eg. Group 7 had student (Sr. No. 28) having 9 marks & also had a student (Sr. No. 25) with 25 in pre-STAD quiz. This group showed maximum increase in group marks due to efforts of team work, healthy discussions, self-motivation and openness of release "*mental math block*". Teacher also observed this group as one of the most vibrant groups during the discussions with lots of interactions and everyone involved in the activity. When student with Sr. No. 28 was interviewed, he reported, "*It was a team, who helped him score well otherwise I had a fear of math. When asking silly questions to them, I was not hesitant and team solved his all doubts sportingly. Even though my fundamentals in math are not good, I tried to listen to them and tried to understand the concepts that helped me score well in next test.*" When Sr. No. 25, having 25 marks in both Pre-STAD & Post-STAD was interviewed, he answered, "*I am happy that my team performed very well. While explaining the concepts to them and while interacted with them, I got idea of different possible solutions, different thinking process and different approaches to solve them. Also, I got insight of where I can make mistake and where I should be careful while solving problems so that I don't make same mistakes which they were making.*"

Group 10 also had a student with least individual score (9 marks) in Pre-STAD quiz. When he was interviewed, he reported a "*Math phobia*" and "*lack of prerequisite knowledge*". He said, "*I feel math is difficult for me and I am unable to understand, so I was not in a position to interact with others. They tried to explain me, I learnt few things which helped me score few more marks*." Teacher also observed this student not interacting much with others. He being irregular in theory class missed some important concepts. Teacher & his teammates tried to encourage as much as possible, but due to many basic calculation mistakes, he couldn't improve much in the Post-STAD quiz. However, he understood what was wrong with him and later on improved gradually in every single assessment. Students' self-assessments showed a deeper understanding of their strengths and areas requiring improvement in mathematics. Many students acknowledged their own learning progress and identified specific topics where they had improved.

Group 8 showed minimum increase of 12 marks in team score. Here it was observed that students were not interacting at all in the beginning. After teachers' encouragement they initiated the discussion but not much. There was a conflict of opinions while discussing and students were not ready to come to one conclusion. However, there is increase of marks in individual score as well as team score.

Some common comments from students were: "*I feel that I work better in groups*", "*I think I learned a lot more than just sitting there by myself"*, "*I viewed myself as a better math student*", "*First time I enjoyed the assessment, I felt it is not assessment but its learning through interactions*", "*Happy to get more grades, alone I may not be able to score so good!*", "*Keep all assessments just like this one. I was only interacting with my friends & learning; least worried about my mark but enjoyed learning*".

The teacher observed a noticeable shift in student behavior while implementing STAD in the classroom. Students demonstrated a heightened sense of responsibility, ensuring that all team members grasped the concepts and were adequately prepared for assessments. Additionally, sharing individual quiz and test scores empowered group members to identify specific areas where their peers might require assistance & helped solve their problems. Positive Peer Influence was also observed. Student feedback and observations revealed that working in teams allowed them to learn from their peers. Many students cited that discussing problem-solving strategies with their team members helped them grasp complex mathematical concepts more effectively.

STAD's utilization aligns with the principles of formative assessment, a process involving ongoing feedback to enhance teaching and learning and achieve desired instructional outcomes. As a result, a majority of team members successfully mastered the concepts of Double integration covered during AfL. Through the assessment, teacher not only assessed the students but made provisions of peer learning & ensured the necessary learning of concepts required for further topic.

Following their STAD experience, students exhibited increased engagement in the classroom. They actively participated by raising their hands, asking more questions during teacher instruction, interact more with peers and developing a newfound confidence in their ability to comprehend mathematics when paying attention. This transformation in behavior contributed to enhanced self-esteem as learners.

Furthermore, students became more vocal about their thought processes, articulating their answers to group members and engaging in constructive debates to support their viewpoints. They not only uplifted their peers but also demonstrated heightened engagement during class, further fostering social interactions with their peers.

The benefits of employing STAD in the classroom extend beyond academic achievement. They encompass the development of self-esteem as learners and the cultivation of meaningful social interactions among peers, collectively contributing to a more enriching and collaborative learning environment.

V. CONCLUSION

The implementation of Student Teams-Achievement Divisions (STAD) as an Assessment for Learning (AfL) approach represents a pedagogical strategy designed to facilitate continuous improvement in students' performance. Within this framework, students collaborate in groups to enhance their understanding of academic content. This research shows that

this collaborative learning experience fosters their academic score, increased engagement and confidence in their ability to meet learning objectives. It also helps to release mental block related to mathematics. The success of each team hinges on the individual learning progress of all team members, effectively bridging the gap between their current knowledge and their desired level of achievement.

STAD promotes students' independence in learning, encouraging active participation in peer and self-assessment processes. When executed according to a well-planned strategy, it can emerge as a highly effective assessment tool, particularly beneficial for students facing challenges in their academic journey.

Furthermore, data presented in this paper shows that, utilizing STAD as AfL creates a dynamic, interactive, and collaborative learning environment. Beyond deepening their mathematical comprehension, students also cultivate essential skills such as teamwork, problem-solving, and effective communication, qualities crucial for success in the field of engineering. STAD can be considered as an effective and flexible AfL strategy that can be adapted to different courses and contexts. As such, STAD's integration into education not only improves academic performance but also prepares students for the practical demands they will encounter in their future careers & life.

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