Enhancing Engagement and Learning Outcomes in Mathematics through Collaborative Gamification: A Case Study

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***Abstract*—Mathematics learning in Engineering has always been a strenuous task for the students as well as the teachers. Teaching mathematics especially for freshers is a tough job in terms of student engagement and academic performance. Though active and collaborative learning can be the solution for the same, modern teaching learning tools and techniques incorporating competitive learning are highly required. Gamification is a new approach that creates a competitive learning environment by incorporating gaming elements such as leaderboards, points and badges. Leaderboards are the readily implementable gamification elements that require the measurement of student performance but sometimes demotivating with drop in individual performance. Hence, collaborative learning with competitive environment shall be established with group leaderboards. The proposed approach recommends a computer assisted gamification with collaborative learning approach for mathematics learning. The approach proposes a series of group problem solving sessions followed by individual assessment tests and leading to a group leaderboard giving weightage to both group performance and individual performance. The approach is experimented with first semester students of Data science major (n=40) and the results are obtained for each of the course outcomes of the course. A software is developed to monitor the changes in the progress. The intermediate internal examination and terminal examination scores are observed and also feedback from the students is obtained. After statistical analysis of the examination scores and feedback, the findings of the work open a positive note to the proposed game-based approach to teaching mathematics.**

***Keywords*—Gamification, Leaderboards, Mathematics learning, Collaborative learning, Student engagement.**

***ICTIEE* Track—Innovative Pedagogies and Active Learning**

ICTIEE Sub-Track: Gamification and Student Engagement Strategies

I. INTRODUCTION

MATHEMATICS education plays an important role in equipping students with logical, analytical, and problem-solving skills needed in various aspects of life. Especially in the field of engineering, mathematics is a language that provides the analytical and problem-solving skills that are highly required for solving complex engineering problems. However, in practice, mathematics education in engineering has always posed significant challenges for both students and educators (Ausubel, 2019). The difficulty of engaging students in mathematical concepts, especially during their first year, often leads to lower academic performance and motivation. Traditional methods, while effective for some, may not fully address the diverse learning needs of students.

To address these challenges, various teaching methods have been explored to improve the way mathematics is taught in engineering programs. Active and collaborative learning methods have shown promising results in enhancing student engagement and comprehension. Active learning methods, such as flipped classrooms, problem-based learning (PBL), and case-based learning, encourage higher-order thinking and the application of theoretical knowledge (Merritt, 2017; Fung et al., 2021; Dewi, E. R., & Nurjanah, A., 2022). Collaborative learning, which involves group work to solve mathematical problems and share knowledge, promotes deeper learning, critical thinking, and better retention of mathematical concepts (Schwarz et al., 2021).

The introduction of gamification further strengthens these approaches by creating a competitive yet engaging learning environment (Ruipérez et al., 2017). Gamification utilizes game mechanics such as leader boards, points, and badges to stimulate motivation and participation. (Suresh Babu & Dhakshinamoorthy, 2024) claims that there are more than 20 gamification elements are currently included in different

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gamification approaches. Among these, leaderboards stand out as one of the most readily implementable gamification elements, as they provide a clear measure of student performance. Nevertheless, individual leaderboards may sometimes lead to demotivation. According to a study, students who do poorly and have low self-efficacy may suffer even though leader board leads to a sense of competence. They might experience peer pressure, which could reduce their self-esteem and challenge their enthusiasm and involvement (Andrade et al., 2016). Toda et al. (2017) also argue that leaderboards have a significant correlation with many of the negative impacts of gamification, and psychological research on ranking systems in educational contexts supports the same.

To mitigate the potential drawbacks of individual leaderboards and promote a more engaging learning environment, a collaborative approach to gamification is proposed. This method involves the use of group leaderboards instead of individual rankings, encouraging teamwork and collective progress. By shifting the focus from individual competition to group-based achievement, students are motivated to work collaboratively while still benefiting from the competitive aspect of gamification.

This study explores the integration of gamification into engineering mathematics to enhance the teaching and learning process. The proposed approach involves computer-assisted gamification integrated with collaborative learning strategies for mathematics education. The study is conducted with first-semester students majoring in Data Science, where the implementation of gamified learning is realized with leaderboards based on group performance points. This comparative analysis aims to evaluate the effectiveness of group-based gamification in enhancing student engagement and academic performance in mathematics.

II. Literature Review

The importance of mathematics to engineering is widely acknowledged, with organizations such as the Engineering Council emphasizing that an engineer's competence is largely determined by their mathematical training (Mustoe, 2002; Noskov et al., 2007). The "application of mathematics and sciences to the building and design of projects for the use of society" is a typical definition of engineering (M. Kirschenman, and B. Brenner, 2010). Engineers' critical and analytical thinking skills are greatly influenced by mathematics, which gives them the means to comprehend and model the systems (L. Mustoe and D. Walker, 1970).

However, mathematics education in engineering faces significant challenges, including student engagement and performance, particularly for first-year students (Rylands & Shearman, 2018; Croft & Ward, 2001). Numerous strategies are being employed to enhance student engagement and understanding. Research suggests that mathematics learning support can improve performance, with higher engagement associated with better outcomes (Rylands & Shearman, 2018). Innovative approaches combining traditional and modern technologies have shown promise in addressing the student needs (Croft & Ward, 2001). Active learning methods, supportive environments, and digital resources can enhance student involvement and understanding (Voon et al., 2024). Collaborative learning encourages students to work together, share knowledge, and solve problems collectively, fostering peer interaction and teamwork (Johnson & Johnson, 1994). The CDIO methodology has been used to develop engineering mathematics modules that promote deeper learning through active and interactive paradigms (McCartan et al., 2010). Strategies such as visualizing abstract concepts, connecting to practical applications, and integrating mathematics with other design-oriented modules have been effective in improving student engagement and performance (Voon et al., 2024; McCartan et al., 2010). Application of simple technology in collaborative learning eases the task of teachers and has impact on the academic performance, interest and joyful learning of learners (Anitha D & Kavitha D, 2022).

Gamification has become a remarkable instrument for transforming the educational process in recent years. This method makes teaching more engaging, entertaining, and motivating by appealing to people's passion for playing games (Chou, 2019). (Alt, D., 2023). According to Jagušt et al. (2018), gamification is the process of introducing elements of games, into non-gaming contexts. (Suresh Babu & Dhakshinamoorthy, 2024), claims that there are already over 20 gamification elements which is already used in various gamification approaches in education. Among these, leaderboards creates both positive and negative impact on students learning. A study found that introverts' position on the scoreboard lowers their motivation (Denden et al., 2017).

To address this, researchers propose the use of team-based leader boards that encourage cooperative competition (Koivisto & Hamari, 2019). The main objective of this study is to implement and evaluate a collaborative gamification approach in mathematics learning. This research contributes to existing literature by offering insights into how collaborative competition can enhance student learning outcomes. The findings align with previous studies that emphasize the importance of designing gamified learning environments that balance motivation, engagement, and teamwork (Toda et al., 2019).

III. Research Objective

The primary objective of this research is to investigate the effectiveness of a gamified collaborative environment for mathematics learning powered with technology. Leaderboards are introduced to give a competitive gamification environment. Based on the research objective, the following research questions are formulated.

RQ1. To what extent does the proposed gamified environment with leaderboards contribute to the improvement of academic performance?

RQ2. How do students perceive the use of leaderboards in enhancing their motivation and learning experience in mathematics?

IV. Experimental Methodology

This section discusses the proposed collaborative gamification framework and the implementation of the same in a mathematics course. For every major unit of the course or course outcome, there are problem-solving collaborative sessions in which the learners work in groups solving the problems posted by the instructor. The course content can be covered with multiple problems across multiple classes for a unit of the course. The solved problems are given to the students as a group activity to be completed during tutorial hours and extension hours. The instructor evaluates the worked-out solutions with scores based on the completeness and correctness of the notes of each student in each group. Following the problem-solving sessions, an individual test is conducted and the scores are observed. This individual assessment is an offline, descriptive problem-solving test conducted during regular class hours at the end of each unit. The duration of the test is 20 minutes with a maximum of 20 marks, ensuring consistency in evaluating the learners' understanding of that particular unit.

These are measured as performance components and tracked for improved performance.

Performance components include the following measures for every student i in every unit of the course:

Scores (S_i): Scores of Group Problem solving inside the classroom with minimum score of *0* and maximum score of *maxprob*.

Post-test scores (T_i): Scores of post-test of i^{th} student at the end of each subunit with scores ranging from *0* to *maxtest*

The total points obtained by the student i in unit j is calculated as (1)

$$Points_{ij} = \frac{S_i}{maxprob} X\ w1 + \frac{T_i}{maxtest} X\ w2 \qquad (1)$$

where, w1 and w2 are customized weightage given to problem solving and test scores. The scores obtained by the individuals in every group are consolidated to give the group total. This process is depicted in Fig. 1.

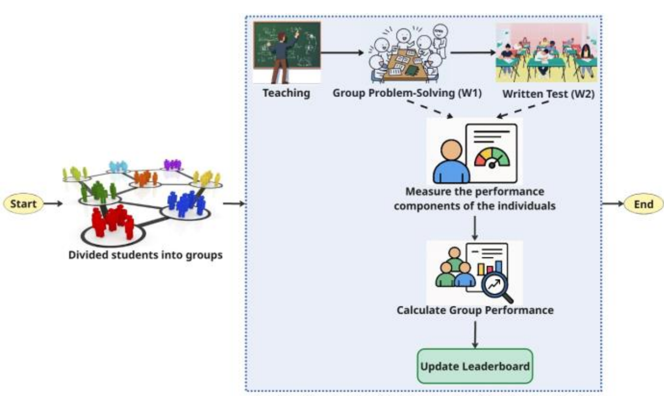

Fig. 1. Gamification process

The proposed framework is experimented with 40 first-year M.Sc. Data Science students studying *Calculus,* a mathematics course over the period of one semester. The course has 6 major units as listed in Table I with group problem solving sessions and follow up unit test. These units are linked to the Continuous Assessment Tests conducted twice in the semester. The first three units are linked to the Continuous Assessment 1 and the remaining units are linked to the Continuous Assessment 2. The students were divided into 8 groups with 5 students in each group based on the student preference. As the students belong to first year, a pre-test was conducted and based on the pre-test scores, the following grouping strategy is adopted so that every group comprise learners with higher to lower cognitive levels.

1. Let S= {S_1, S_2,…., S_N} be the sorted test scores of N students where N=40 in the implementation.
2. Divide S into subsets S_1, S_2,…., S_k of approximately equal size, where k =3 in this implementation representing three levels of cognitive ability
3. Assign $S_{i,j}$ (the j^{th} student in subset S_i) to Group (j mod g)+1 where g is the number of groups.

In the implementation of the proposed method, *maxprob* and *maxtest* are set with 25 as per the instructor's plan. The leader board points are calculated as per equation 1 with values of 0.3 and 0.7 for w1 and w2 respectively showing a 25% weightage to group problem solving scores and 75% weightage to the individual scores in the tests. This weightage can be customized by the instructor. As the instructor is keen on finding the influence of the group problem solving on individual performance, more weightage is given to individual performance.

TABLE I
Topics Covered in Major Subunits of "Calculus"

Topic No.	Unit name	CAT No.
1	Basic differentiation and integration	1
2	Partial derivatives	1
3	Ordinary differential equations	1
4	Double integration	2
5	Triple integration	2
6	Sequence and series	2

A software designed to display the group leaderboard with python and streamlit to automate this process which is available at https://groupleader.streamlit.app/. At the end of every unit, the scores obtained are updated in Microsoft excel and fed inside the software to update the positions on the digital leader board based on the previous data as shown in Fig. 2. In addition to the software, a class leader board is maintained physically in the classroom with the same scores obtained digitally, with the changing group positions for every unit to give a vibe of the competitive environment, as shown in Fig. 3.

Fig. 2. Sample Screenshot of Digital Leaderboard

Fig. 3. Sample picture of Leader board displayed in the classroom

This research study focuses its attention on academic performance and engagement and hence suitable data collections methods are determined.

The following scores are used to measure the improvement in academic performance

1. Pre-test score at the start of the semester
2. Test score (T_i) at the end of every unit (6 units)
3. Scores obtained at the internal examinations
    - CAT1 - Continuous Assessment Test 1
    - CAT2 - Continuous Assessment Test 2
4. Scores obtained at the terminal examination (TE)

Following quantitative analysis of the scores is performed to find the impact of the proposed gamification methodology.

5. Intervention index based on the positions of the group in the leader boards to understand the competitive progress among the students and to earmark the groups that are not performing well.
6. Average results of the groups in each test and the median improvement of the groups across the tests based on the complexity of the course units
7. T-test to compare the significance of score after each test

V. Result and Discussion

A. RQ1. To what extent does the proposed gamified environment with leaderboards contribute to the improvement of academic performance?

As discussed earlier in the methodology section, the leader board positions of all the groups in the unit tests and other tests are listed in Table II. It is evident from the table, that the positioning on the leader board indicates active competition among all groups, highlighting a notable increase in their engagement levels. Three groups have not made their entry in the top 3 positions. Other than those groups, all the other 5 groups have managed to secure positions in top 2. There is a clear trend of support and motivation towards slower learners by their peers.

TABLE II
FREQUENCY TABLE OF LEADER POSITIONS OF EACH GROUP

Group Name	Leaderboard Position Numbers							
	1	2	3	4	5	6	7	8
Aryabhatta	2	-	3	2	1	1	-	-
Bhaskara	-	-	-	1	1	5	1	1
Brahmagupta	1	2	3	2	1	-	-	-
Euler	1	6	-	1	-	-	-	1
Newton	-	-	-	-	2	-	2	5
Pythagoras	-	1	2	1	2	2	1	-
Ramanujan	-	-	-	2	-	1	4	2
Taylor	5	-	2	-	1	-	1	-

To further evaluate the rankings, key metrics are identified to process the ranks obtained by different groups (Astleitner. 2020, Esserman et al., 2013).

8. Average Rank (2)
9. Standard deviation of rank (3)
10. Weighted score (4)
11. Z-score for position (5) and Intervention index (6)

The formulas for all these metrics are given as below.

$$\text{Average Rank} = \frac{\sum(\text{Position}\times\text{Count})}{\text{Total number of entries}} \tag{2}$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \tag{3}$$

Where,

x_i are the positions and $\bar{x}$ is the average rank.

$$Weighted\ Score\ = \sum(Weight_i\ X\ Count_i) \tag{4}$$

Where,

$Weight_1 = 8$ and further reduces as $weight_8 = 1$.

$Count_i$ is the number of times that the group appears in the i^{th} rank.

$$Z = \frac{\bar{x} - \mu}{\sigma} \quad (5)$$

Z-score for each group's average rank.

$$Intervention\ Index = \alpha\ X\ Average\ Rank + \beta\ X\ \sigma \quad (6)$$

Where,

α, β are weights emphasizing the importance of performance and consistency.

Table III shows the results of the metrics and sorted in descending order by intervention index. Following are the observations based on the metrics:

- Groups Newton and Ramanujan have the highest Intervention Index values, indicating they need the most instructor intervention due to poor average rank and variability. These groups are reserved for closer interaction with the instructor and closely monitored for their progress.
- Bhaskara also requires moderate intervention.
- Pythagoras and Euler are mid-performers; some support recommended.
- Aryabhatta, Taylor, and Brahmagupta have low Intervention Indices, confirming they are strong groups needing less intervention.

In addition to this, the Z-score values further strengthen the interpretation. Groups with positive Z-scores (Newton, Ramanujan, Bhaskara, and Pythagoras) lie above the class mean of ranks, indicating consistently weaker relative performance. These groups correspondingly show higher Intervention Index values, confirming the need for structured instructor support. Conversely, groups with negative Z-scores (Euler, Aryabhatta, Taylor, and Brahmagupta) perform significantly better than the mean, and their Intervention Index is low, aligning well with their stronger rankings. This statistical alignment across metrics confirms that the groups identified as weaker or stronger by the system are mathematically consistent, supporting the earlier qualitative recommendations on who needs support and who can mentor others. The software is designed to reflect these recommendations.

TABLE III
METRICS FOR EACH GROUP BASED ON POSITIONS

Group name	Average rank	Std Deviation	Weighted score	Z-score	Intervention index
Newton	6.176	1.73	49	2.08	5.31
Ramanujan	6.08	1.48	57	1.91	4.87
Bhaskara	5.09	1.25	70	1.21	3.74
Pythagoras	3.69	1.51	88	-0.22	3.32
Euler	3.06	2.15	87	-0.62	3.11
Aryabhatta	2.54	1.55	92	-1.25	1.96
Taylor	2.4	2.36	92	-1.39	1.92
Brahmagupta	2.17	1.0s	102	-1.61	1.5

To assess the effectiveness of the proposed gamification approach in improving the academic performance of the students, the average test scores of each group are recorded and presented as in Table IV. The average scores in the tests would differ and may go up and down based on the complexity of the topic. Hence, the complexity levels of the units are obtained from the domain expert and given as below. The scale of complexity level is from 0 to 1 where 0 is closer to lesser complex unit and 1 tends to show the higher complexity level.

Unit 1 : 0.1
Unit 2 : 0.4
Unit 3 : 0.5
Unit 4 : 0.6
Unit 5 : 0.8
Unit 6 : 0.6

Difficulty weighted average formula is used to calculate the complexity weighted scores based on the complexity of the units as mentioned in (7) (Nassar et al. 2023, Romera et al., 2019).

$$NewAvg(\alpha, \delta) = \frac{\sum_{i=1}^{6}(c_i + \delta)^{\alpha} s_i}{\sum_{i=1}^{6}(c_i + \delta)^{\alpha}} \quad (7)$$

Where,

s_i = student's average score in unit i (0–100)

$c_i \in [0,1]$ = complexity of unit i(0 = easy, 1 = hard)

δ = small floor to avoid zero weight (we have it 0.2 as the max complexity is 0.8)

α (emphasis) = 1 for linear weighting so that easy and complex topics are equally handled.

The complexity weighted scores clearly show the upward progress of the learners and thus supporting the proposed method. Also, the average score increases from CAT1 to CAT2 and further increases in terminal examination showing the effectiveness of the proposed methodology in improving the academic performance of the students.

TABLE IV
AVERAGE MARKS SECURED BY THE GROUPS

Group name	Average mark of groups								
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	CAT 1	CAT 2	Terminal
Aryabhatta	71.4	85.4	69.4	70	74.0	78.0	70.0	78.0	73.6
Bhaskara	65.4	58.6	61.8	61.2	67.4	72.8	65.8	65.5	67.8
Brahmagupta	82.4	74.4	69.4	68.8	74.0	82.2	81.8	77.7	70.4
Euler	64.2	83.6	70.6	70.6	78.6	83.8	70.7	71.7	77.4
Newton	73	65.4	58.4	60.2	60.4	65.0	54.3	61.5	58.8
Pythagoras	78.8	63.2	66.7	66.7	76.0	82.0	55.8	65.4	75.5
Ramanujan	78.6	70	55.4	57.2	65.8	71.0	57.5	61.7	66.2
Taylor	90.6	62.6	82.2	81.6	82.4	90.8	65.2	72.8	74.0
Average	75.6	70.4	66.8	67.1	72.3	78.2	65.14	69.3	70.5
Complexity level	0.3	0.4	0.5	0.6	0.8	0.7	-	-	-
Complexity weighted scores	50.4	56.3	62.3	71.5	96.4	93.3	-	-	-

In addition to this inference, it is essential to show that learners progress with the support of the peers. Hence a boxplot of the individual scores in each of the tests is visualized in Fig 4. It is observable that with the process of intervention, the median scores are getting higher than the average scores in all the assessments including unit tests, CAT exams and terminal exams. This shows the continuous improvement in the student performance and the impact of the proposed gamification methodology.

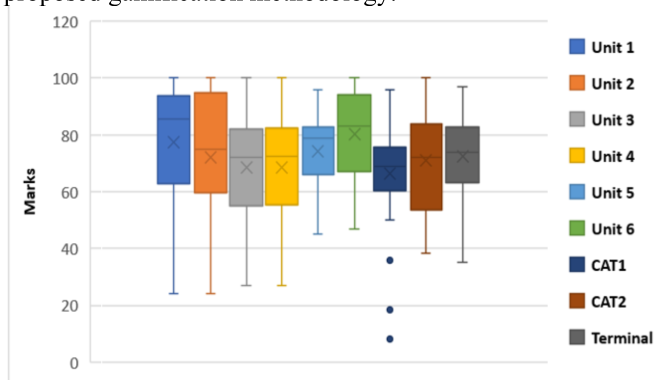

Fig. 4. Box plot for the student scores

Units in CAT 2 (4, 5, 6) generally show higher performance and lesser variability than CAT 1 units (1, 2, 3). The presence of outliers (very low scores) in CAT1 indicates some students struggled, possibly those with lower unit test scores and thereby representing a need for targeted support. Greater spread in CAT2 shows variability, reflecting complexity or student engagement with later units. The Terminal exam results are more consistent across units, indicating that by the end of the course, students' knowledge levels tend to grow and level up.

Table V shows a comparison of min, max and median scores according to the boxplot. The minimum score is comparatively higher in CAT2 than CAT1. It is interesting to note that students from the team Newton and Ramanujam have scored lesser marks as inferred earlier from the rankings of the group in Table III. From the observations as given in Table V, targeted corrective actions can be devised to improve the performance which shall be direction towards this research work should align with.

TABLE V
MEDIAN SCORE COMPARISON IN THE INDIVIDUAL SCORES

Test	Min score	Max score	Mean Score	Median Score	Observations
Test 1	24	100	77.53	85.5	High performance and less variability
Test 2	24	100	71.98	75	High performance yet more low scorers
Test 3	27	100	68.4	72	Lower performance with little variance
Test 4	27	100	68.7	72.5	Lower performance and moderate variability
Test 5	45	96	74.23	79	high performance and less variability.
Test 6	47	100	80.25	83	High performance more varied performance.
CAT1	8	100	66.63	68.5	Moderate variability
CAT2	38	100	70.98	72.5	High performance and varied performance
Terminal	35	97	72.35	74	Consistent high performance with less variability

To add on to the analysis, a statistical analysis is to be performed. A t-test is performed between the intermediate test scores and the subsequent Continuous Assessment Test (CAT) performance scores. The impact of Test 1,2 and 3 are matched with CAT1 and Test 4,5, and 6 are matched with CAT2 as the corresponding units are tested in the respective assessment tests. Similarly, CAT performance scores are compared against terminal exam scores. The results of these analyses are tabulated in Table VI.

TABLE VI
STATISTICAL COMPARISON BETWEEN THE STUDENT SCORES

T- Test comparison	p-value	Observation
Test 1 Vs CAT1	0.008	Significant difference
Test 2 Vs CAT 1	0.13	No significant difference
Test 3 Vs CAT1	0.3	No significant difference
Test 4 Vs CAT2	0.3	No significant difference
Test 5 Vs CAT2	0.13	No significant difference
Test 6 Vs CAT2	0.006	Significant difference
CAT1 Vs Terminal	0.07	No significant difference
CAT2 Vs Terminal	0.3	No significant difference

From Table VI, it is obvious that there are no significant differences in scores between the class tests and subsequent CAT exams except Test 1 and Test 6. This validates the experimental methodology. Further exploring this analysis, a paired t-test is performed with the test scores to the marks obtained for the questions pertaining to the unit in CAT exams. This helps to understand the impact of the proposed approach and the same is tabulated in Table VII. The observations from Table VII confirms with the results of Table VI. However, unit 6 scores in CAT2 questions are lesser than the unit 6 scores and made a significant difference. A closer analysis needs to be performed for Test to understand the difference in scores and the same unit has to be given full consideration for better conduct in the next offering of the same course.

TABLE VII
STATISTICAL COMPARISON COMPARING INDIVIDUAL STUDENT PERFORMANCE

T- Test comparison	Average Unit test scores	Average scores in CAT for the unit questions	p-value	Observation
Test 1 Vs Unit 1 scores in CAT1	77.53	55.5	0.0001	Significant difference
Test 2 Vs Unit 2 scores in CAT1	71.98	83.77	0.038	Mild significance
Test 3 Vs Unit 3 scores in CAT1	68.4	72.45	0.3	No significant difference
Test 4 Vs Unit 4 scores in CAT2	68.7	68.8	0.87	No significant difference
Test 5 Vs Unit 5 scores in CAT2	74.23	75	0.83	No significant difference

Test 6 Vs Unit 6 scores in CAT2	80.25	64.13	0.006	Significant difference
CAT1 Vs Terminal	66.54	72.35	0.5	No significant difference
CAT2 Vs Terminal	70.91	72.35	0.6	No significant difference

After implementing the novel educational approach in mathematics education for freshmen, the results revealed a significant improvement in student academic performance and answered research question 1.

This shows that everyone's performance directly influenced the group's overall standing. Consequently, group leaders and members took proactive measures to assist and motivate slower learners, resulting in a higher passing percentage among students for the subject over the course of the semester.

B. RQ2. How do students perceive the use of leaderboards in enhancing their motivation and learning experience in mathematics?

To answer research question 2, it is important to get the views from the instructors on the advantages and challenges of using the proposed approach and to get the feedback from the students.

1) Interview excerpts from the instructors:

Benefits

> "As we are keeping tests focusing on application-level questions in all course outcomes, it gives good time to learn those topics periodically. By writing intermediate tests, they are learning those topics well and can understand those concepts then and there. So that it will be easy to understand the concepts of upcoming topics too. It creates an interest in learning and to feel easy while preparing for final semester exams too. Periodic learning and practicing tests regularly will help the students to get more marks and improve their grades."

Challenges

> "As it is a 4-credit course, only 4 class hours will be allotted weekly in the timetable schedule. Time management is tough to incorporate the proposed approach. Also, unplanned incidents make us postpone any of the test. So, the students feel it is hard to study more topics and write in the next one-hour class."

2) Student feedback:

The students have been asked to submit their feedback on the proposed approach. A simple questionnaire is circulated among the students to get the feedback. The feedback is designed as 4-point Liker Scale (Strongly Agree: SA, Agree: A, Disagree: D, Strongly Disagree: SD). 30 out of 40 students responded to the survey. Table VIII gives the questionnaire and the student responses for the same.

TABLE VIII

FEEDBACK QUESTIONNAIRE AND STUDENT RESPONSE COUNT

Questionnaire	SA	A	D	SD	% of positive responses
I prefer group leaderboards than individual leaderboards	19	9	2	0	95
Group leaderboard makes me to contribute more effort to the improvement of my group	14	8	5	3	73
Group leaderboard helps me to get more help from my peers	10	7	8	5	57
I prefer working in groups for mathematics learning	18	8	3	1	87
Leaderboard in mathematics motivates me to learn	17	10	2	1	90

From the survey responses, the following observations are made:

a) Most students prefer group leaderboards and group work, highlighting the social and competitive benefits in learning environments.
b) Leaderboards strongly motivate students and encourage increased effort to aid group success.
c) Peer help is moderately impacted, suggesting the need of more supportive and collaborative peer learning system beyond just competition.
d) The high positive responses for motivation and preference suggest leaderboards are an effective tool in math learning settings for this cohort.

Suggestions to improve the proposed work are as follows:

a) Continue using group leaderboards as they promote collaboration and motivation.
b) Create structured peer support mechanisms to enhance help-seeking behavior among students.
c) Monitor students who are less influenced by leaderboards to provide differentiated encouragement.
d) Combine leaderboards with other motivational strategies to reach all learner segments.
e) The feedback can be analyzed in depth to understand the needs of the students in terms of motivation and learning experience.

CONCLUSION

The paper discusses the challenges of teaching mathematics to engineering freshmen, highlighting the difficulty in engaging students and enhancing their academic performance. It proposes a gamification approach that combines competitive and collaborative learning to improve mathematics education. Specifically, the study focuses on using leaderboards as gamification elements, noting that individual leaderboards can sometimes demotivate students when their performance drops. To address this, the paper suggests using group leaderboards to foster collaboration within a competitive environment. An experiment was conducted with 40 first-semester Data Science major students, with a focus of finding the effectiveness of the proposed method in students' academic performance and engagement. Statistical analysis of the results indicates that the game-based, collaborative learning approach has a positive effect on teaching mathematics. The findings support the effectiveness of incorporating gamification into mathematics education to enhance student engagement and learning outcomes. The proposed approach enables the first-year students to create interest in mathematics learning with game-based collaborative learning. This implementation shall be customized to any mathematics classes that shall result positively. Additionally, based on the classroom observations, it is evident that the proposed method is not limited to calculus or mathematics alone. Since the core structure of the approach involves forming student groups, conducting descriptive assessments, and evaluating the completeness of their notes at the end of each unit. The method is fundamentally pedagogical rather than content-specific, which makes it flexible for wider academic applications.

From the observations, there are few shortcomings or challenges. For example, though with systematic implementation, the improvement is not reflected in one of the units. The root cause of such limitation needs to be deeply analyzed. Along with leaderboards, there shall be a structured peer support mechanism that permits the dynamic formation of groups. Also, we understand that there might be few students who are not interested in any kind of leader boards. For such students, a differentiated instruction methodology shall be explored. The automated system should be strengthened to inform the instructors of the interventions that are highly required at the end of every unit. Also, the student strength associated with this research work is minimal giving a direction to increase the scale of this work. The future work is related with achieving such an automated intervention and making the system available for general usage.

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