Development of Problem Solving Skills Amongst Undergraduate Engineering Students through a Team-Game-Tournament Collaborative Learning Method

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***Abstract*— Problem-solving ability through critical thinking is an important skill required by an engineering student. Through these skills, students are expected to solve a real-world problem and provide an optimized solution. Working as an individual and as a team member can help a student to achieve this. Small-sized group activities will give opportunities to every student for interactions, reflect upon and reply to the diverse responses from their peers and hence contributing to the individual as well as group learning. One such activity is a Team-Game-Tournament (TGT) which builds a cooperative learning environment to develop a competitive activity that can help students to engage in critical reasoning. The quasi experimentation is done with 23 students of T.Y.B. Tech in wireless communication course by the implementation of TGT activity in the classroom. The class is first divided into heterogeneous (home) teams where students of different ability to learn together (team game) through collaboration, discussion and help each other in learning. New homogenous teams are formed later where students of same ability compete with each other (tournament) by applying the knowledge they have learned through collaboration in home team. Students then return to their home groups and report their earned scores. Feedback survey reveals that 82% of students strongly agree that collaborative activity was engaging and motivating for critical thinking. Semi-structured student's interview reveals that classroom collaboration is superior to web collaboration. Points earned in the game and tournament phase measures the learning of every student. On comparing the median score of each team with the class median score it has been found that four teams have scored more than the median score of class indicating improved learning. There was 30% improvement in a number of students attempting numerical example in unit –II test after TGT activity.**

Keywords—cooperative learning, collaboration, problem-solving, critical reasoning

I. INTRODUCTION

Engineering students are expected to have problem solving ability with critical thinking after graduation. Also working as an individual and as a member or leader in diverse team is one of the characteristics of engineer. In the traditional classroom, teacher delivers lecture and gives assignment/task to the students which is to be completed out of class. The assignment having numerical problems requires critical thinking for changes in parameters to come up with optimized solution. When such assignment is given as out of class activity, student tends to indulge in plagiarism from peers, internet resources and therefore lack in problem solving ability. The purpose of this study is to develop problem solving ability through critical thinking in collaborative learning environment.

The above problem can be addressed through collaborative learning in classroom. A student is more likely to recall something; discovered through active contribution and peer work than through passive receipt of information presented by teacher. In collaborative environment, soft skills, development of critical thinking, self-management and communication with others can be learned. [1].

There is persuasive evidence that cooperative teams achieve higher levels of thought and retain information longer than students who work quietly as individuals [2]. The shared learning gives students an opportunity to engage in discussion, take responsibility for their own learning, and thus become critical thinkers [3]. Also critical thinking skills can be enhanced by using collaborative learning activity that actively engage students in the learning process rather than relying on lecture and rote memorization [4].

Several web based platforms like Virtual-U (VU), EVA [5, 6], MOODLE, Google classroom, etc. supports innovative pedagogies based on active learning, collaboration, multiple views and knowledge building but these platforms are web based and do not fully engage the students, since there is lack of face to face interaction, students cannot discover the activities of peers until they sit in front of the computer and connect to the internet. Also network errors and glitches in the working of internet sometimes disturb the student's collaboration.

If in class collaborative learning environment is built where students do not require internet connection, then environment will be more engaging since there is face to face interaction among students. Author have implemented one such activity, Team-Game-Tournament (TGT) where students will be divided in heterogeneous teams collaborative learning and discussion and then teams are restructured in to homogenous teams to compete with peers of similar ability and to earn points for home team through tournament.

Feedback from students revealed that 82% of students strongly agree that TGT collaborative activity was engaging, motivating for critical thinking and has positive effect on

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learning. Subjective semi-structured interview with students reveled that classroom collaboration gives them opportunity for face to face interactions, as compared to web collaboration. Such interactions are important to clear misunderstanding of concepts and build social relationship and rapport with peers. Four teams out of six have scored more than the median score of the class in the activity. Thus collaborative learning activity will improve problem solving ability of student and classroom collaboration will be more efficient than web collaboration.

Section II of the paper describes related work for TGT implementation. Section III describes step by step implementation of activity. Section IV describes the research methodology; section V describes results and discussion.

II. Related Work

Collaborative learning is a student-centered, instructor-facilitated instructional strategy in which a small group of students is responsible for its own learning and the learning of all group members. Students interact with each other in the same group to acquire and practice the elements of a subject matter in order to solve a problem, complete a task or achieve a goal [7]. The collaborative learning should equip the instructional understanding including elements of (i) Positive interdependence (ii) Face to face interaction (iii) Individual accountability (iv) Interpersonal and small group skills (v) Group processing [8].

The study [9] identifies the effectiveness of TGT learning strategy incorporated with web based games in mathematics learning on grade eight students. Authors have reported that TGT experimental group students had achieved a significant learning outcome than the lecture based control group students. Whereas in [10] authors have implemented web-based TGT activity where the system sends SMS messages to each team member to notify them of progress of collaboration activity when a student performs a team study action on the internet. Since students cannot be immediately aware of the activity, and cannot provide timely response to their teammates, it is a drawback of web-based collaborative learning environment. Such activity awareness delays may interfere with the efficient and promotive interaction between teammates. Each student logged on 11.44 times on average with SMS alert as compared to 9.79 times without alert.

Collaborative learning is implemented [11] and results are compared with individual learning for the subject matter of series and parallel dc circuits. They found that posttest scores for the participants in the group that studied collaboratively (12.21) was higher than the group that studied individually (8.63) on a test comprised of "critical-thinking" items. Whereas in [12] Team Games Tournament cooperative learning model is applied on students' creativity learning mathematics. Data collection techniques are conducted by observation to observe student activities and test them to measure skills, knowledge of intelligence, abilities or talents possessed by individuals or groups. The results showed that cooperative learning model type teams games tournament has an influence on students' creativity in learning mathematics is 63.71% while the remainder 36.29% influenced by other factors.

In the literature the TGT activity is implemented in web based learning environments or implemented in analytical course like mathematics. However, web-based collaboration does not fully engage the students, because there is lack of face to face interaction and eye contact. There is time lag between the student who issues learning activity and response from their peers. This time lag may lead to doubt and insufficient interaction among students. Lack of complete engagement may prevent interaction; hence web-based collaborative learning environment is unlikely to have the same quality of service as classroom learning environment. Also such activities can be used for developing critical thinking in theoretical courses too.

The author of this paper has implemented TGT activity in theory course of wireless communication in classroom over a period of 2 weeks with one lecture per week. The wireless communication course has more concepts and application of it on numerical examples. It was found that student had positive perception and engagement towards implementing collaborative activity in class room as compared to web platform.

III. Implementation

Team-Game-Tournament (TGT) activity is implemented in classroom, where learning phase continues for two weeks with one lecture per week and tournament phase continues for two lectures in subsequent week. Following Fig. 1 shows TGT implementation in four phases: (i) Team formation (ii) Teams game (learning phase) (iii) tournament (competition phase) (iv) Final Team score and reward.

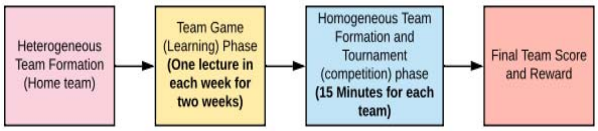

Fig. 1. Implementation Stages of TGT activity

A. Team Formation

Heterogeneous (home) team formation is essential aspect of TGT activity for the collaboration and learning to happen. The teams are formed by arranging unit Test-I mark of all students in descending order and then pick one student from top and one student from bottom and assign them same team ID. Each team formed with this method will have high, medium and low scorer of unit Test-I marks. Following Fig. 2 shows home team formation. Each team has to select a "team leader" who will be guiding the team further. Maximum number of student in each team is four. There will be five teams containing four students each and one team containing three students.

B. Team Game (Learning) Phase

In this phase one student from each team will be called and asked to draw two chits from the bowl. Each chit will have one number in between 1and 15. Once chits are drawn teacher will display 15 topics/parameters/sub concepts with serial number on data projector. Each team has two topics corresponding to the numbers which they have got in chit. The teams have to now combine the two topics and build a theme that will connect the topics with real life examples or study effect of changing one parameter on other and provide some application examples. To develop critical thinking among students each team have to build a theme by defining following criteria's [13]: (i) Identification and information

(ii) Organizing information (iii) Using prior knowledge (iv) Using opinion (v) Making decision.

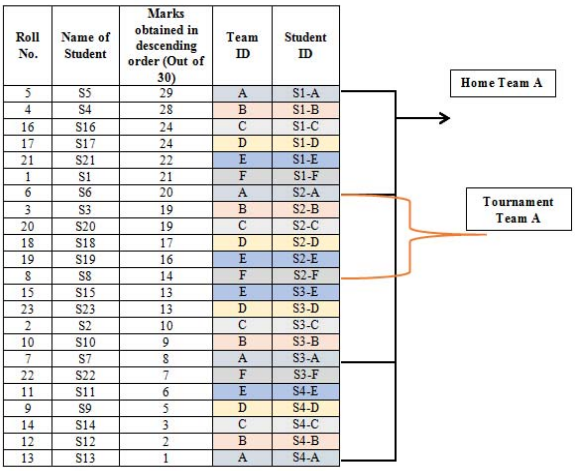

Fig. 2. Heterogeneous (home) and Homogenous (tournament) team formation

Each team will be getting 30 minutes to prepare theme and then five minutes for presentation which will be evaluated by teacher out of 10 on pre-defined rubrics. Each team member will get same score in this phase because it is group evaluation. Teacher can ask question to any team member and team members can help in answering.

Some of the topics given to students are: (i) Co-channel interference and system capacity (ii) Cell splitting and base station power requirement (iii) Cell sectoring and trunking efficiency (iv) Hand off and cell sectoring (v) Cluster size and system capacity (vi) Trunking and grade off service etc.

Team leader has responsibility to encourage every teammate for the discussion, by taking their opinion, and encouraging silent member (may be low scorer) of the group to collaborate. Team leader also have to ensure that each team member get equal opportunity to speak in the discussion and all members have learned the concept, or effect of changing parameters etc. through collaboration which will improve their performance in tournament phase.

Teacher will act as facilitator by monitoring the discussion among team members and can ask question to individual of any group. If there is a dead lock in the discussion where none of the team members can connect the topics, then teacher can help them by giving clue/hints/theories/examples and ask team members to connect and open a dead lock. Teacher can also ask each teammate to list down whatever they know about topics and then build idea and help team to arrive at appropriate concept.

C. Tournament(Competition) Phase

In this phase students will be placed in new teams made up of all student 1 (high achievers) tournament team 1, all student 2 (medium achievers) tournament team 2 and all student 3 and 4 (low and extremely low achievers) forms tournament team 3 and 4 respectively as shown in Fig.2. Students of similar ability will compete with one another. The questions in this phase will have variety of numerical problems, concept explanation based on given condition, logical reasoning, MCQ, analysis, comparison etc. which requires critical thinking and apply the knowledge of learning from team game phase.

Questions with variable marks and time depending on complexity will be displayed on data projector. Maximum marks for activity is 20 (will be converted later out of 10) and maximum time is 15 minutes. When question is displayed student knowing answer from team can raise hand (like buzzer) and give the correct answer/explanation/reason depending on question type Student will earn corresponding points assigned to that question and will be recorded by teacher acting as score keeper for each team. At the end of the activity teacher announces points earned by individuals in a team. Similar process will be repeated for other tournament teams. Following Table, I show types of question given in this phase.

TABLE I. TYPES OF QUESTION IN TOURNAMENT PHASE WITH MAXIMUM MARKS AND TIME ALLOTTED

Sr. No.	Question	Max. Marks	Time allotted
1.	For a system supporting 1000 voice channels, if the service area is divided in to 20 cells with a frequency reuse factor of 4, computer the system capacity **Options: (i) 5000 users (ii) 25000 users (iii) 100000 users (iv) 500 users**	1 Mark	1 Min.
2.	While, handoff the termination of call may be avoided by **Options: (i) Providing guard channel (ii) Queuing of handoff request (iii) Both (i) and (iii) (iv) By using umbrella cell (v) Option (i), (ii) and (iv)**	1 Mark	1 Min.
3	Find signal to interference ratio for cellular system having S/I of 18 dB with cluster size 7. If S/I is increased to 20 dB, same cluster size will work? If not why and what is new cluster size?	3 Marks	2 Min.
4	Give one practical example with illustration where you have observed handoff and shadowing effect	3 Marks	2 Min.
5	What is the effect of co channel interference on system capacity? Justify	2 Marks	2 Min.
6	What will be optimum value of cluster size to maintain signal to interference ratio of 15 dB? Illustrate with one example	4 Marks	2 Min.
7	Which type of cell sectoring 60 degree of 120 degrees will be better to maintain S/I of 18 dB in cellular system. Defend your answer with example.	4 Marks	3 Min
8	As a system design engineer suggest methods to improve capacity in cellular system other than frequency reuse.	2 Marks	2 Min.

D. Team (Home) Score and Reward

After tournament activity students return to their home team and report the earned score. Points given by teacher during team game phase which is out of 10 (same for all team members) and points earned by each team member in tournament phase is added and winning team is declared. Efforts taken by winning team is appreciated giving "outstanding" remark to the team members.

IV. RESEARCH METHOD

A. Research Questions

Through this study author tries to find answer of the following research questions:

1. What is the perception of learners towards the implementation of Team-Game-Tournament activity in the course of wireless communication ?
2. What are the benefits of classroom collaboration over web collaboration?
3. Whether student can develop problem solving ability through critical thinking by working in collaborative learning environment?

B. Sample

All students (N=23) registered for the course were part of this research study. No sampling technique is applied to select the sample size. Effective collaboration requires team of three to four students [9] hence smaller sample size is effective for measurement of learning.

C. Instruments

The aim of this study was to examine whether student develop problem solving ability through critical thinking by working in collaborative environment as compared with individual learning. For this purpose, a quasi-experimental design was carried out. The methods of semi-structured interview (first stage), questionnaire survey (second stage) and score improvement in unit test and TGT activity (third stage) were employed in this investigation.

The data on the students' subjective learning experiences were collected in the interviews conducted after the completion of the course. All students were asked to take part in the interview, but 11 students did not attend. The total number of interviewed students was thus 12 only. In the interview students were asked to answer the following question: (i) "How do TGT activity helped you to collaborate with your peers and hence learning?" (ii) "Do you think that heterogeneous team formation is best option for everyone to learn" (iii) "What are the benefits of classroom collaboration over web collaboration"? (iv) "Are you able to think critically for the given problem and find multiple solutions and take decision for optimized solution?" (v) What do you feel that you have learned during this activity? Answer given by all students are not presented in paper, some of the responses were common for many students hence summarized responses are presented.

All the students were given four-point Likert's scale online questionnaire survey after the activity. The survey questions were about students' perception for TGT activity (6 questions), face to face interactions (5 questions) and problem solving ability (4 questions). All students have taken the online survey.

Sum of the team score in team game phase and tournament phase is used as another instrument to measure the students learning. Each phase is evaluated out of 10 marks and each team will score out of 20 marks. Median score of all students is calculated and score of each team is compared with median score of the class. Number of students attempting problem in unit test-II is counted as compared to unit Test-I to show development of problem solving ability.

V. Results And Discussion

The results from the questionnaire data examine student's perception for TGT activity, face to face interaction and critical thinking. Throughout this section, analysis is also made from interview data to offer deeper insight into questionnaire data. The TGT activity was implemented in classroom and it was found useful for student to collaborate as compared to web based platform. Qualitative analysis of the implementation is done by conducting semi-structured interview of students. Quantitative analysis is done through questionnaire survey, team performance and unit test marks.

RQ1: What is the perception of learners towards the implementation of Team-Game-Tournament activity in the course of wireless communication ?

A. Student's perception towards implementation of TGT (RQ 1)

Table II indicates that 82.61 % of students strongly agree that TGT activity has positive effect on learning and activity was engaging and has individual accountability. 91.30% students strongly agree that such activities prepare them for future learning, tests and give them confidence to attempt challenging questions. Each team had team leader in team game phase; 78.26% of students strongly agree that because of team leader they got equal opportunity to participate in discussion. Also 91.30% students agree that through this activity their role is defined to work as individual and in team. In responding to the interview question "How does TGT activity helped you to collaborate with your peers and hence learning?" the students described their learning qualitatively as follow:

i. Student 4: "I was the leader of my team and this collaboration activity taught me how to handle my teammates. On the given topic first I took opinion of every student one by one, noted in paper and then we all started discussion. In my team student 12 was not speaking anything and was not confident. My self and other 2 members encouraged him to speak for whatever he knows about the topic. Because of this learning student 2 earned good marks in tournament phase for our team".

Student 12: "I got 1 mark in unit Test-I and when topics were given in team game phase it was new for me. But because of help from my teammates I am able to know about the given topic, my concepts were clear and I could perform better in tournament phase. The activity was engaging".

ii Student 7: "I was having 8 marks in unit Test-I and when team formed I was having lowest score in my team. But learning from my teammates and discussion prepared me for the future test and for the tournament phase. I found the activity engaging and motivating".

In response to the interview question "Do you think that heterogeneous team formation is best option for everyone to learn". All the students agreed that the team formation method adopted was appropriate for everyone to learn. Responses from some students are summarized as follow

i. Student 23, 10, 14: "We got very less marks in unit test and in heterogeneous we could work with our friends scoring high marks and learn from them. Such team formation gave us chance to learn concepts in class and then revising at home".

TABLE II. Students Perception towards TGT implementation

Students Perception towards TGT implementation (N=23)				
Questions	Strongly Agree (%)	Agree (%)	Partially Agree (%)	Disagree (%)
TGT collaborative activity has positive effect on my learning and activity was engaging	82.61	13.04	4.35	0.00
The activity prepares me for future learning activities, tests and also gave me confidence to attempt question	91.30	8.70	0.00	0.00
There is positive interdependence and individual accountability in this activity	82.61	8.70	4.35	4.35
I am able to learn from my peers in team game phase	78.26	17.39	4.35	0.00
Team leader gave me equal opportunity to speak in discussion	69.57	17.39	8.70	4.35
I am able to work as an individual and in team after this collaborative learning activity	91.30	4.35	4.35	0.00

RQ2: What are the benefits of classroom collaboration over web collaboration?

B. Student's feedback on face to face interaction(to promote classroom collaboration)(RQ2)

Table III indicates that 95.65% students strongly agreed that classroom collaboration has more face to face interactions as compared to virtual collaboration on web platforms. 82.61% students strongly agree that in face to face collaboration they are able to listen and value other people's response which improves their thinking. 87% students strongly agree that such collaborative environment gave them opportunity to build social relationship and work in team for different projects. However, number "strongly agree" responses were comparatively less for the question-face to face interaction helped to clear misconception about some theories and concepts. In response to interview question "what are the benefits of classroom collaboration over web collaboration"? Student's replied as follow:

i. Student 16: "I have used web collaboration platform of MOODLE in my previous semester for online discussion. When my peers respond to particular question I am able to see that only when we log in to the system (computer), and therefore I feel disconnected from the discussion. To actively participate in discussion I have to remain "always on" on internet which is not feasible all the time. But for classroom collaboration peers are in our front so discussions are fruitful."

ii. Student 7: "Classroom collaboration gave me opportunities for face to face interaction and eye contact in the group discussion which is important to learn from others. Peers are there in front of me to clarify any doubt and ask question".

iii. Student 23: "The classroom collaborative activity was fun and learning become very easy for me since we can discuss various possibilities for particular concept in group, I was eager to learn more through this collaboration".

iv. Student 17: "Most of the time in web collaboration we try to find answer for any question through Google and copy and paste in discussion forum which will not force our mind to think, but in classroom collaboration we have to depend on our teammates for learning and only by brainstorming we can come to correct solution".

TABLE III. FEEDBACK ABOUT FACE TO FACE INTERACTION

Feedback about face to face interaction (N=23)				
Questions	Strongly Agree (%)	Agree (%)	Partially Agree (%)	Disagree (%)
Collaboration in classroom has more face to face interaction as compared to virtual collaboration	95.65	4.35	0.00	0.00
I am able to get live feedback translated through body language during face to face interactions	95.65	4.35	0.00	0.00
During face to face interaction I was able to listen and value other persons response	82.61	8.70	4.35	4.35
Face to face interaction helped me to build social relationship and rapport with my peers	86.96	8.70	4.35	0.00
Face to face interaction helped to clear misconception about some theories and concepts	78.26	13.04	4.35	4.35

RQ3: Whether student can develop problem solving ability through critical thinking by working in collaborative learning environment?

C. Student's feedback about development of critical thinking (RQ 3)

Table IV indicates that 86.96% students strongly agree that the task given was challenging and through collaborative discussion we are able to gather information from each member, organize it and make decisions. 82.61% students strongly agree that through peer discussion they are able to investigate the topic and critically think on all aspects related to topic and helped them to develop analysis and logical reasoning skills. However, number "strongly agree" responses were comparatively less for the Question-I am able to relate and understand theory concepts with real world example. Student response to interview question "Are you able to think critically for the given problem and find multiple solution and take decision for optimized solution?"

i. Student 5: "Our team has got topic of "Handoff and cell sectoring for which our team have first listed concept of hand off, concept of cell sectoring and tried to connect them. After brainstorming we are able to relate them and make various conclusions like "hand off is more in sectoring", "hand off in sectoring reduces trunking efficiency", "it also burdens MSC", "sectoring is not a good option for high mobility users since it requires more handoff" etc. Because of opinion from team members we could think critically and come up with multiple solutions".

ii. Student 23: "I was able to solve numerical example in unit test-II; it was based on concept we discussed in the learning phase. I was able to see the different dimensions of problem statement and then apply the formula to get correct answer".

iii. Student 4: "The step by step implementation of the TGT activity helped me in critical thinking by identification and organizing information, using prior knowledge, taking opinion of all members and then making decision".

TABLE IV. FEEDBACK ABOUT DEVELOPMENT OF CRITICAL THINKING

Feedback about critical thinking (N=23)				
Questions	Strongly Agree (%)	Agree (%)	Partially Agree (%)	Disagree (%)
The given task was challenging and through collaborative discussion I was able to organize information and make decision	86.96	8.70	4.35	0.00
I am able to investigate the information on given topic through peer discussion and critical thinking	82.61	8.70	4.35	4.35
The activity helped me in developing analysis and logical reasoning skills	82.61	8.70	4.35	4.35
I am able to relate and understand theory concepts with real world example	73.91	13.04	8.70	4.35

Common responses for interview question "what do you feel that you have learned during this activity"? are as follow: "I am able to describe my role as an individual and as a team member", "I have individual accountability for my own learning during tournament phase", "I learned that in team every member have equal right to speak", "I got to know that for single problem there can be multiple solutions", "I learned the effect of varying cluster size on co channel interference", "I learned how to motivate and increase confidence of non-participating member" etc.

D. Improvement in Team Performance

Team game phase was evaluated by teacher and marks were added to the score earned in tournament phase by each member. Median score of entire class was 12.5. Team B, C, E and F scored 17, 13, 13, 13.5 marks respectively. Four teams out of six scored more marks than median score of class. Following table V shows score of team B and F.

TABLE V. TEAM B AND F SCORE AFTER TGT ACTIVITY

Team B					
Sr. No.	Team ID	Students ID	Instructor Evaluation in Team Game (same score for all students) (G1)	Individual Students Score after TOURNAMENT Phase (I 2) (Out of 10)	Total Score (Q)= G1+I 2
1.	B	S1-B	8	9	17
2.	B	S2-B	8	6	14
3.	B	S3-B	8	9	17
4.	B	S4-B	8	9	17
Team Median Score					17

Team F					
Sr. No.	Team ID	Students ID	Instructor Evaluation in Team Game (same score for all students) (G1)	Individual Students Score after TOURNAMENT Phase (I 2) (Out of 10)	Total Score (Q)= G1+I 2
1.	F	S1-F	8.5	8	16.5
2.	F	S2-F	8.5	2	10.5
3.	F	S3-F	8.5	5	13.5
Team Median Score					13.5

E. Improvement in Unit test-II score compared with Unit test-I

After implementing this activity there was improvement in the number of student making attempt to solve numerical problem. In unit Test-I, two problems of five marks each was asked, and only 3 students out of 23 could solve them correctly, and 11 students had attempted the problem. In test-II one problem of ten marks was asked and it was found that 18 students have made attempt to solve it and could get average five marks and 9 students could solve correctly.

VI. CONCLUSION

The purpose of this study was to measure effectiveness of the Team-Game-Tournament collaborative learning activity to develop problem solving ability though critical thinking in the course of wireless communication. Students were surveyed on their perception and semi-structured interviewed about their experiences of learning. 82.61% of students strongly agree that TGT collaborative learning environment was engaging and has positive effect on their learning. 87% of students strongly agree that given task were challenging and through collaborative discussion they are able to organize the information, think critically on parameters and take decisions. When compared with web collaboration of literature review it was found that 95.6% students strongly agree that classroom collaboration has more face to face interactions compare to virtual collaboration. Through semi-structured interview it was found that students have deep understanding of concepts and critical thinking through collaboration and heterogeneous team formation helped weak student to learn and compete in tournament phase. In TGT activity four teams out of six scored more than median score of class which is 12.5. Team B scored 17 marks on 20 and declared as "outstanding" team. Also number of students attempting numerical example in unit test-II increased to 18 as compared to 11 in unit Test-I. Thus there is significant improvement in the problem solving ability of students through TGT collaborative environment; students found activity engaging, motivating and face to face collaboration has opportunity to learn and discuss in classroom as compared to web environment. Further TGT activity can be implemented by conducting team game (learning) phase for longer duration of 4 to 6 weeks with larger sample size of more than 30 students and giving open ended questions to students in tournament phase. The TGT activity can also be combined with project based learning to measure effectiveness of individual learning through project.

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