Exploring Team-based Learning for Teaching Engineering Courses

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ABSTRACT

The aim of the study conducted in this paper was to study the impact and benefits of using active learning methods to teach Computer Science Engineering courses. The study was conducted using three active learning methods - Cooperative Learning, Collaborative Learning, Process Oriented Guided Inquiry Learning. Three courses were selected to conduct the study - Computer Organization, Computer Graphics, Information Retrieval Systems and selected topics were taught using team-based learning methods. After the completion of each activity, learners were prompted to attempt an online satisfaction survey. The statistical analysis of learner feedback on the three types of active learning methods implemented demonstrated positive impact on the learning levels, learner satisfaction, and performance in examinations. The feedback from final year learners was more positive towards Process Oriented Guided Inquiry Learning than Collaboration Learning. The feedback from second year learners was more positive towards Cooperative Learning than Process Oriented Guided Inquiry Learning. Overall, learners were satisfied and benefited by teaching courses with active learning strategies. Teaching complex engineering courses through team-based learning techniques encouraged learners towards self-reliance and team-work.

Keywords

Outcome Based Education; Computer Science Engineering Courses; Modern Pedagogy; Innovative Teaching; Active Learning; Learning Outcomes; Cooperative Learning; Collaborative Learning; Process Oriented Guided Inquiry Learning.

Article Received: 18 October 2020, Revised: 3 November 2020, Accepted: 24 December 2020

Introduction

The three major components of the outcome-based education are – outcome-based curriculum (OBC), outcome-based teaching-learning (OBTL) and outcome-based assessment (OBA). The objective of outcome-based education is to place emphasis on learner rather than on teacher. The activities of designing and implementing outcome-based curriculum, outcome-based teaching-learning and outcome-based assessment are performed by keeping in view the stakeholders - learners, instructor, industry, alumni, parents, society etc. To achieve outcome-based education, targets have to be set and are to be attained in terms of learning outcomes. Curriculum has to be designed in alignment with the learning outcomes (designing OBC), the curriculum has to be implemented (using OBTL), the learners performance has to be assessed (using OBA). Outcome-based teaching-learning plays an important role in implementing outcome-based education. Outcome-based teaching-learning serves as bridge between outcome-based curriculum and outcome-based assessment.

The outcome-based education is a learner-centric process which places emphasis on learning rather than on teaching. As such, the outcome-based teaching-learning is the process where instructor not only focuses on the content to be taught, but also on how to teach it. Outcome-based teaching-learning is specifically designed and implemented by instructor to achieve the learning outcomes as targeted by the outcome-based curriculum. Outcome-based teaching-learning also supports outcome-based assessment.

Instructor plans the suitable class-room activities (instructional design) through which the course content can be delivered for enhanced learner motivation, participation and learning. For the realization of the learner-centric teaching-learning process, learners have to actively participate in the

learning process. Engaging and motivating the learners for their active participation in classroom training is a challenging task for the instructor.

The seven C's of 21st century learning as discussed in [1] include Critical Thinking and Problem Solving, Creativity and Innovation, Collaboration, Communication etc. Innovative teaching strategies involving active participation on the part of the learners are hence gaining more popularity in 21st century teaching-learning [2, 3].

Literature Review

Active learning is "a method of learning in which students are actively or experientially involved in the learning process and where there are different levels of active learning, depending on student involvement" [4]. In [4], authors state that "students participate [in active learning] when they are doing something besides passively listening." Learners must actively participate in the classroom activity doing activities related to course content, involving in interactive deliberations with instructor as well as peers. In other words, learners must be engaged with tasks so as to provide them with opportunity to develop their higher-order thinking skills(HOTS) [5]. Active learning methods support a wide range of activities that are learner-centric. The activities involve active participation of learners in the teaching-learning process which improves communication skills, self-reliance, team-work, problem-solving skills, critical thinking skills in learners.

Group learning or team-based learning is one of the most popular approaches of active learning. The pedagogical practices like Cooperative Learning, Collaborative Learning, Process Oriented Guided Inquiry Learning (POGIL) are researched and implemented by many instructors in engineering education and have been observed to benefit learners through the process of their learning.

Cooperative learning is a pedagogical method which practices interaction among learners to solve a given problem. Cooperative learning may be practiced in classroom activity or outside the classroom in activities such as assignment, project, case study etc. In this method, instructor will provide prerequisite knowledge to the learners if any required, forms teams, assigns roles and responsibilities to team members and proposes a problem to be solved. In cooperative learning, there is division of labor among team members to complete a synchronous activity. Each member has a specific role and responsibility, that is each member is accountable for completing a part of the given problem. The role of teacher in cooperative learning method is to facilitate environment for students to cooperatively solve a given problem. This method of pedagogy encourages empathy, teamwork with positive interdependence, collaboration with peers, accountability as member in a team, social skills, group skills, trust/rapport building, negotiation skills etc among learners [6, 7]. This kind of experience provides learners with more of a formal/informal but comfortable way of learning, under the guidance/assistance of the instructor and support from peers [8]. Cooperative learning has two-folded benefits: cooperation (learners within a team will cooperate with each other to win as a team) and competition (each member will compete with other members of the team to contribute more to the team as an individual, teams will compete with each other to win).

Collaborative learning is the pedagogical method that is an active learning strategy which is group-based. Collaborative learning involves "groups of learners working together to solve a problem, complete a task, or create a product"[9]. The benefits of collaborative learning approach are the same as that of cooperative learning, but collaborative learning is group-structured unlike the cooperative learning which is teacher-structured [10]. The differences between the approaches can be debated in terms of preparations by the instructor & learners, level of interaction required within the team members, philosophy and objectives [11]. In collaborative learning, there is no/minimal monitoring of the progress of learners by the instructor. Collaborative learning is the practice where learners team-up and work synchronously and co-ordinately with team members to accomplish a given task. Collaborative learning needs higher levels of preparation by learners [11].

In collaborative learning, learners make individual progress, and are self-accountable. But in cooperative learning team members are accountable for each other and for the team as a whole. That is knowledge sharing, peer learning, peer support and encouragement, rapport building and positive interdependence is the motto in cooperative learning. The motto of collaborative learning is working with other, share the work as per the strengths of the team members to complete a given task where team members need not necessarily demonstrate interdependence [12].

George M. Jacobs presents a debate on the terminology, similarities and dissimilarities of collaborative and cooperative learning approaches for group learning concluding that whatever might be the group learning approach used, the motive shall remain to keep teaching-learning process learner-centric [13]. Use of Collaborative learning approach to teach improves students' performance and their social relationship [14].

The goal of using Process Oriented Guided Inquiry Learning (POGIL) for Engineering subjects is to make students responsible for understanding the concepts on their own and the teachers serve as only facilitators for students learning. The authors illustrated different phases of POGIL considering the engineering course "Introduction to Materials" and focused on the qualitative assessment in order to understand the elements that helped students learning [15]. Use of POGIL a collaborative learning technique in classroom teaching improves the academic performance and confidence of students [16]. The CS-POGIL project and the IntroCS-POGIL project proposed in order to help faculty to implement POGIL in computer science and allied areas. The authors also discussed the future directions such as the use of learning management system and programming tools for POGIL activities in order to combine code and other related contents [17]. The authors presented the analysis of the Computer Science faculty perceptions considering benefits and obstacles in adopting POGIL. Participants expressed that using POGIL keeps students active and helps in improving teamwork skills, and achieve better learning outcomes. The obstacles in adopting POGIL were identifying relevant POGIL activities for the course, content coverage and lack of preparation time [18].

Method

In the academic year 2019-20, three undergraduate computer science engineering courses were selected and appropriate topics were taught using active learning techniques – Cooperative Learning, Collaborative Learning, Process Oriented Guided Inquiry Learning. This study was conducted to observe the impact of using active learning methods to teach computer science engineering courses. Details of the undergraduate Computer Science Engineering courses and innovative teaching methods used to teach the courses are presented in Table 1. The following sections present the case studies in detail along with the results of the study conducted.

Case Study 1: Cooperative Learning

Cooperative learning method was used to teach selected topics in two of the undergraduate Computer Science Engineering courses – Computer Organization, Computer Graphics. The details of implementation of cooperative learning method are presented in Table 2. The courses were taught using a combination of traditional classroom lectures and informal cooperative learning technique.

The type of cooperative learning implemented is informal. Instructors have taken initiative in forming the ad-hoc teams. To achieve enhanced student participation in the active learning activities, care was ensured while dividing learners in to teams to involve all the members in the activity. Each team member was assigned a specific role and responsibilities in order to hold the individual responsibility and accountability towards the team as a whole [19]. Wherever required learners were provided with prerequisite knowledge through warm-up sessions, or lecture material or videos. Instructors have assigned problems to the teams where teams tried to solve the problem through cooperative learning. The duration of activity was a class hour of 60 minutes. Instructors have monitored the activity along with the help of two students who acted as Managers. After the activity is completed in a

given duration of time, teams presented their solutions for debate and discussion among the teams. The activity was ended by the instructors by providing valid conclusions on the undertaken problem and solutions. Figure 1 presents the details of an activity implemented in Computer Organization course to teach a lesson on "Sign-Magnitude Division" using cooperative learning. Figure 2 presents a sample template used to record the details of teams, roles/responsibilities of team members, starting time of activity, finishing time of activity by each team.

Table 1. Case Studies Conducted for Teaching Undergraduate Computer Science Engineering Courses

Name of the Course	Year of Study & Period of Study	Type of Innovative Learning Method Used to Teach the Course
Computer Organization	II Year & I Semester	Cooperative Learning
Computer Graphics	II Year & I Semester	Cooperative Learning, Process Oriented Guided Inquiry Learning
Information Retrieval Systems	IV Year & I Semester	Collaborative Learning, Process Oriented Guided Inquiry Learning

Table 2. Details of Implementation of Teaching Undergraduate Computer Science Engineering Courses using Cooperative Learning

Item	Description
Type of Cooperative Learning Method Used	Informal
Enrolled Batch Size	Students of a single section of size 60
Group/Team size	3 members in a team
Type of Learning Teams	short-term, with assigned roles and responsibilities holding all the team members equally responsible and accountable for completing the given task in the given time
Roles and Responsibilities	**Faculty** acts as facilitator along with two students who will act as **Managers** to monitor the activity **Process Monitor** will act as the leader of the team to guide the process and checks to be sure everyone understands the solutions and the strategies used to get them **Checker** checks whether the process, team work is going in the right direction **Reflector** speaks on behalf of the team in case of doubts, inter-team discussion etc
Activity Type	Classroom activity involving group problem-solving, and self-learning
Duration of Activity	An entire class hour to complete the task

Department of Computer Science and Engineering

Academic Year: 2019-2020
Course: Computer Organization
Class: II B. Tech I Sem (CSE)
Lesson: Sign-Magnitude Division
Innovative Teaching Method Used: Formal Cooperative Learning

Planned to use Cooperative Learning Activity

- To make students familiar with the process of sign-magnitude division of binary numbers.
- No lecture; Course instructor will act as facilitator; Prerequisite knowledge will be presented by the course instructor for a few minutes; Students will learn the lesson by team work and peer discussion.

Cooperative Learning Activity Goals:

- To encourage peer learning and student support system.
- To motivate self-learning and active participation of students in teaching-learning process.
- To support utilization of diversity of student skills in the teams to the best of their abilities.
- To promote peer discussion through team work.
- To develop and practice trust-building, leadership, decision-making, communication, and conflict management skills.

Lesson Learning Objectives: *At the end of the lesson, students will be able to:*

- Understand the use of binary subtraction operation to perform binary division.
- Demonstrate knowledge on sign-magnitude division of binary numbers.
- Identify the hardware required to implement sign-magnitude division of binary numbers.

Prerequisite Knowledge needed: *Students should demonstrate prerequisite knowledge on:*

- Decimal and Binary Number Systems.
- Sign-Magnitude Representation of Binary numbers.
- Logical Shifting Operations.
- Binary Subtraction Process.
- Flowchart for sign-magnitude division.

Roles and Responsibilities in the activity:

Role of Course Instructor: Facilitator

Team size: can be 3 – 4 and the **team roles** are:

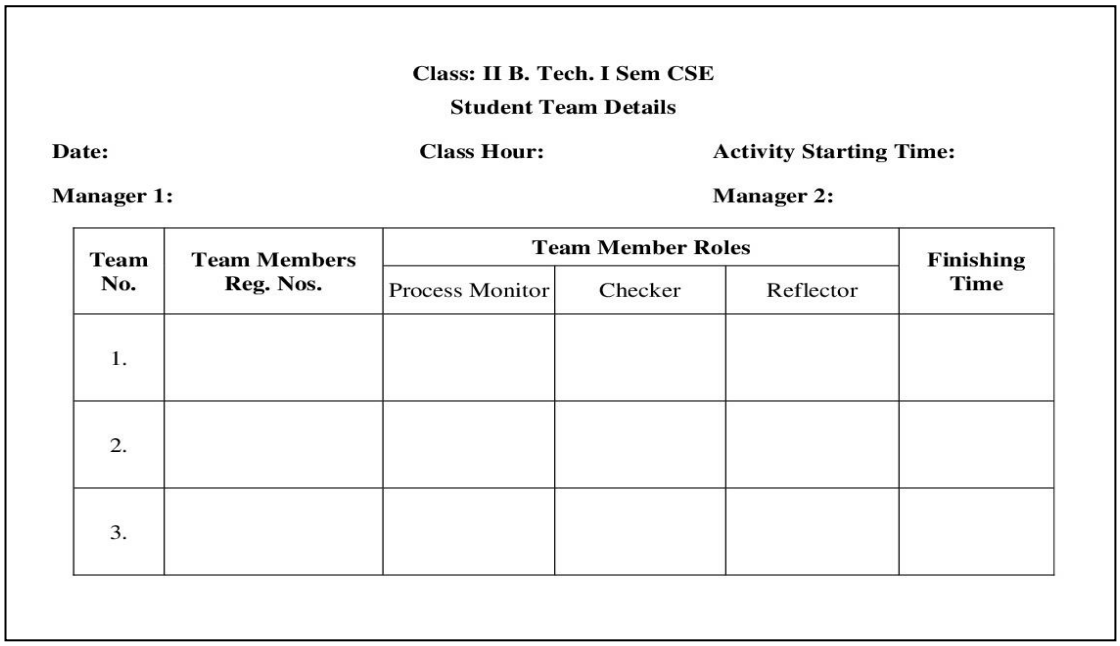
- ✓ **Process Monitor:** will act as the leader of the team to guide the process and checks to be sure everyone understands the solutions and the strategies used to get them.
- ✓ **Checker:** checks whether the process, team work is going in the right direction.
- ✓ **Reflector:** speaks on behalf of the team in case of doubts, inter-team discussion etc.

Type of Student Teams: Informal

Diversity in Student Teams: Heterogeneous

Individual accountability: To ensure active participation of all the team members in learning, among the team of three students, one student is asked to perform sign-magnitude division, the second student is asked to support the process by performing intermediate binary arithmetic as required for division, the third student is asked to monitor the correctness of the process time-to-time.

Figure 1. Details of a Topic in Computer Organization Course Implemented using Cooperative Learning



Class: II B. Tech. I Sem CSE

Student Team Details

Date: **Class Hour:** **Activity Starting Time:**

Manager 1: **Manager 2:**

Team No.	Team Members Reg. Nos.	Team Member Roles			Finishing Time
		Process Monitor	Checker	Reflector	
1.					
2.					
3.					

Figure 2. A Sample Template used to Record Details of Activity Implemented using Cooperative Learning

Case Study 2: Collaborative Learning

Collaborative learning method was used to teach selected topics in the undergraduate Computer Science Engineering course – Information Retrieval Systems. The details of implementation of collaborative learning method are presented in Table 3. The course was taught using a combination of traditional classroom lectures, innovative teaching methods.

The type of collaborative learning implemented is formal. Learners were given flexibility to form teams to compensate and complement their capabilities. Each team were given a problem by the instructor to solve. They were to collaborate with team members through deliberate discussions and were to solve a common problem. The duration of activity was 1 to 2 weeks. The LMS tool Instructure Canvas was used to create discussion forums. This was an approach to create online platform for learners to collaborate. Learners actively participated in the online discussion forums and shared their learning experiences. After the activity is completed in a given duration of time, teams presented reports on their findings.

Case Study 3: Process Oriented Guided Inquiry Learning (POGIL)

Process Oriented Guided Inquiry Learning method was used to teach selected topics in two undergraduate Computer Science Engineering course – Computer Graphics, Information Retrieval Systems. The details of implementation of POGIL method are presented in Table 4. The courses were taught using a combination of traditional classroom lectures, innovative teaching methods.

The type of learning implemented is formal. Learners worked in self-managed teams. Instructors provided teams with specially designed guided inquiry materials and guided set of questions. The objective of POGIL is to make teams learn a lesson through inquiries under the guidance of the instructors. The duration of activity was 1 to 2 weeks. The LMS tool Instructure Canvas was used to create discussion forums. This was an approach to create online platform for learners to collaborate. Learners actively participated in the online discussion forums and shared their learning experiences. After the activity is completed in a given duration of time, teams presented reports on their findings.

Table 3. Details of Implementation of Teaching Undergraduate Computer Science Engineering Course using Collaborative Learning

Item	Description
Type of Collaborative Learning Method Used	Formal
Enrolled Batch Size	Students of a single section of size 60
Group/Team size	3 members in a team
Type of Learning Teams	short-term, with assigned roles and responsibilities holding all the team members equally responsible and accountable for completing the given task in the given time
Roles and Responsibilities	**Faculty** acts as facilitator Each **member** is made equally responsible in the team, to complete the given task with proper and timely collaboration
Activity Type	Outside the classroom activity involving group problem-solving, and self-learning
Duration of Activity	1 to 2 weeks

Table 4. Details of Implementation of Teaching Undergraduate Computer Science Engineering Courses using Process Oriented Guided Inquiry Learning

Item	Description
Type of Process Oriented Guided Inquiry Learning Method Used	Formal
Enrolled Batch Size	Students of a single section of size 60
Group/Team size	4 members in a team
Type of Learning Teams	short-term, with assigned roles and responsibilities holding all the team members equally responsible and accountable for completing the given task in the given time
Roles and Responsibilities	**Faculty** acts as facilitator **Recorder** records all answers & questions, and provides copies to team & facilitator **Speaker** talks to facilitator and other teams **Manager** keeps track of time and makes sure that everyone contributes appropriately **Reflector** considers how the team could work and learn more effectively
Activity Type	Outside the classroom activity involving group problem-solving, and self-learning
Duration of Activity	1 to 2 weeks

Department of Computer Science and Engineering

Academic Year: 2019-2020
Course: Computer Organization
Class: II B. Tech I Sem (CSE)
Lesson: Sign-Magnitude Division
Innovative Teaching Method Used: Formal Cooperative Learning

Student Feedback Questionnaire

Cooperative Learning Approach has been used in the class room for teaching "Sign-Magnitude Division" in the subject "Computer Organization" on 30 July 2019 for II B. Tech. I Sem (Computer Science and Engineering). Students who were present in the class and have participated in this activity are requested to submit your opinion regarding the activity.

S. No.	Question	Express your opinion		
1.	Have you actively participated in the activity?	Yes	No	
2.	Have you interacted with your team members?	Yes	No	
3.	Did you understand the concept of sign-magnitude division?	Understood clearly	Still have doubts	
4.	Which type of teaching do you feel is a good approach for class room teaching?	Teacher teaches entire topic	Teacher introduces basic concepts; Students learn by interacting with friends and peers	
5.	Do you feel that this type of activity should be used in teaching the other topics in the subject?	Yes	sometimes	Not at all
6.	Were the debates and discussions between teams helpful to you to enhance your thinking/reasoning skills?	Yes	Up to some extent	Not at all
7.	What do you feel about this activity conducted using cooperative learning approach? Express your opinion.			

Figure 3. A Sample Questionnaire used to Record Learner Feedback of Activity Implemented using Cooperative Learning

Results

After the completion of each activity, an online survey was conducted to assess the impact of the innovative teaching methods and satisfaction/motivation among learners towards the learning process, understanding of the topic etc. Figure 3 presents the sample questionnaire used for learner survey on cooperative learning. Figure 4 presents a sample online feedback from the learners on an activity conducted using cooperative learning. A total of 35 out of 60 participants provided their feedback on the lesson on “Sign-Magnitude Division” taught using

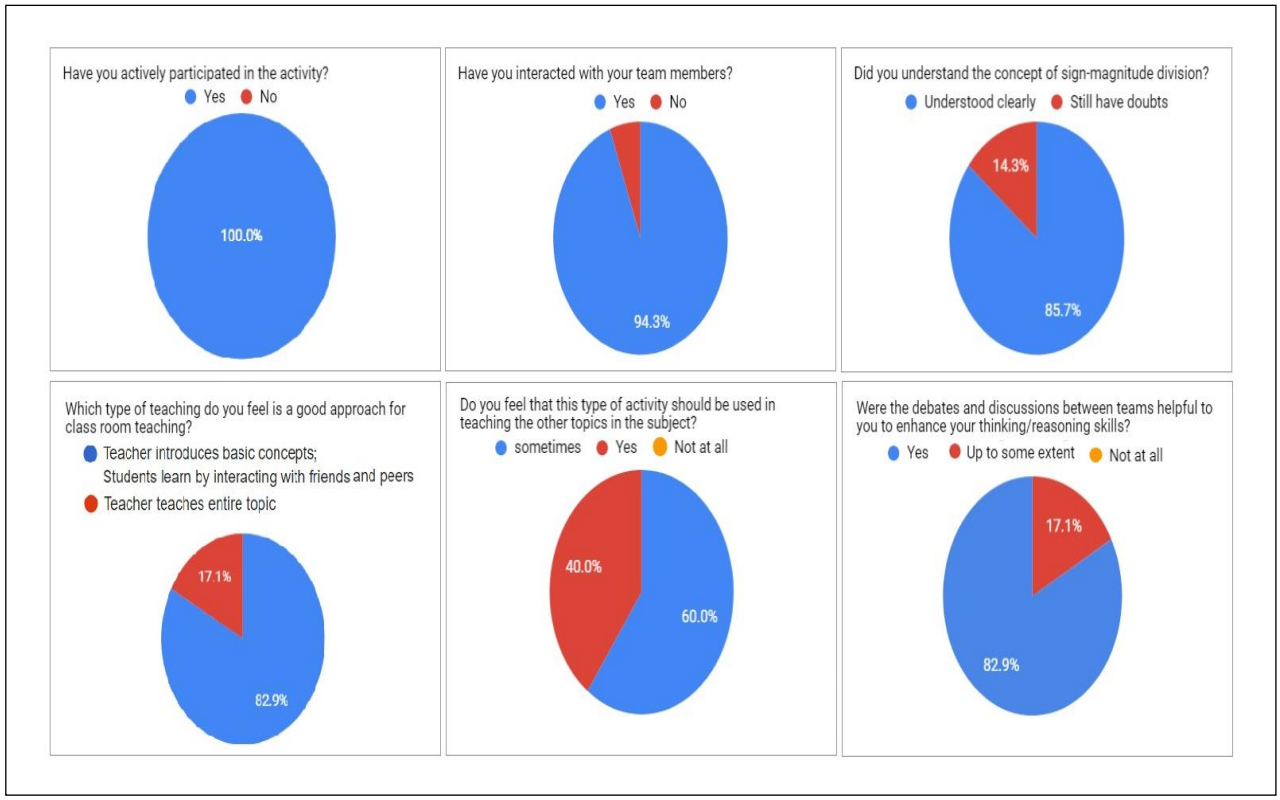


Figure 4. Statistical Analysis of Sample Online Feedback from the Learners on an Activity Conducted Using Cooperative Learning

cooperative learning. The statistical analysis of learner feedback on the three types of active learning methods implemented demonstrated positive impact on the learning levels, learner satisfaction, and performance in examinations. The feedback from final year learners was more positive towards Process Oriented Guided Inquiry Learning than Collaboration Learning. The feedback from second year learners was more positive towards Cooperative Learning than Process Oriented Guided Inquiry Learning. Overall, learners were satisfied and benefited by teaching courses with active learning strategies. But, a few learners from second year were unable to adapt to active learning quickly. After, verbal conversation with such learners, the reasons were found to be lack of language proficiency, lack of social skills, habituated to traditional teaching etc. Those learners were further counselled to create awareness on the benefits of active learning methods.

Conclusion

The aim of the study conducted in this paper was to study the impact and benefits of using active learning methods to teach Computer Science Engineering courses. The study was conducted using three active learning methods - Cooperative Learning, Collaborative Learning, Process Oriented Guided Inquiry Learning. The participation of learners in the online discussion forums to shared their learning experiences with peers was encouraging to the instructors. The statistical analysis of learner feedback collected through online satisfaction survey on the active learning methods implemented demonstrated positive impact on the learning levels, learner satisfaction, and performance in examinations. Overall, learners were satisfied and benefited by teaching courses with active learning strategies. Teaching complex engineering courses through team-based learning techniques encouraged learners towards learning process thus improving their interpersonal skills, communication skills, and individual accountability.

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