Journal of Engineering Education Transformations ,
Volume 35 , No. 3 , January 2022 , ISSN 2349-2473, eISSN 2394-1707

Impact of Active Learning Methods on Students' Learning and Course Results

Sandeep R. Desai
Department of Automobile Engineering, K.E.S.'s Rajarambapu Institute of Technology,
Affiliated to Shivaji University, Kolhapur 415414, India

Abstract : Active involvement of the students during classroom sessions is becoming a tough task for those teaching to higher classes and upto some extent for those teaching in the schools. The reason is the change in learning styles of the students which ultimately call for the change in teaching styles too. In order, to satisfy the students in the world of competition today, the use of active and cooperative learning techniques is increased in the engineering institutes. This helps to increase the quality of technical education imparted by the institutes and help them to be distinguished due to the enhanced index of students' learning. The present study reports the application of some of the active learning techniques that include the Jigsaw technique, Muddiest point technique, Concept mapping, Case Study and Team-based learning. The different techniques are used for different segments of the 'Hydraulics and Pneumatics' course delivered to final year Automobile Engineering students studying in the final semester. The course contents, methodology of application of techniques, the students' responses and outcomes of application of the active learning techniques are discussed in the paper. It is concluded that proper planning, availability of resources and students' cooperation make it easier to apply modern-day teaching techniques. The positive change in students' learning level, their graduate attributes, passing percentage and average marks is noticed by doing the above-mentioned experiments during the classroom sessions.

Keywords : Active learning; Classroom sessions; Graduate attributes; Students' learning level; Students' responses.

1. Introduction

Engineering education has now shifted its focus from output-based education to outcome-based education. The achievement of graduate attributes matters a lot for passing out graduates as it speaks about the abilities of the graduates such as communication, teamwork, self-learning, problem-solving ability, subject knowledge etc. This necessitates that students learn every course curiously and achieve the expected outcomes. The essential elements of engineering education that involve curriculum design, delivery of instructions and assessment methods, are affecting the attainment of outcomes of a particular course and in turn attainment of outcomes of any program. The effectiveness of the

Sandeep R. Desai
Department of Automobile Engineering,
K.E.S.'s Rajarambapu Institute of Technology,
Affiliated to Shivaji University, Kolhapur 415414, India

delivery of instructions decides the success of the teaching-learning process that contributes to improve the student learning index. Activity- based learning is needed to attract the students to classes and make them experience joyful learning. This is the reason that active and cooperative learning techniques are widely used these days in engineering education to enhance students' attendance and participation during classroom sessions.

2. Literature Review

Though the implementation of active and cooperative learning techniques has become popular in recent times, the research outcomes can be found from research work carried out over the years. This section presents some of the research findings on active and cooperative learning methods. Nastasi and Clements (1991) carrying out research found the answers about the formation and implementation of cooperative learning groups. The factors affecting the efficacy of the approach are discussed in the work. Patrick and Anderson (2000) presented the results of the experiments to compare role-playing and collaborative exercises to the traditional style of teaching and found positive outcomes. Amburgh et al. (2007) developed an active learning inventory tool and found it valid and reliable to measure active learning in the classroom. Barroso (2010) used cooperative learning and problem and project-based learning for teaching an undergraduate course and found that the techniques help to expose the students to alternate solution strategies for solving the same problem. Stowe (2010) has presented the experiments with a writing activity; a one-minute paper and highlighted its importance due to its ability to enable the students to stop, focus their thoughts and address their questions before leaving a class. Jain and Dwivedi (2014) critically examined core elements of active, collaborative, cooperative and problem-based learning methods to find evidence for the effectiveness of active learning. The study helps to understand the assessment of active learning methods to see if they work. Sheng and Hu (2014) implemented an engineering application case-based teaching method for Hydraulics and Pneumatics course. The authors have used various engineering application cases of hydraulics and pneumatics to correlate theoretical knowledge with engineering practices. Meti and Giriyapur (2015) effectively planned theory sessions, laboratory sessions and course projects of hydraulics and pneumatics to enhance students' performance. During laboratory sessions, automation studio software and hands-on kits were used for designing and simulating hydraulics and pneumatics circuits. The experiments were conducted using a laboratory anatomy approach and finally, students completed a course project by selecting industrial application based problem definition. Renata Fortuna Ramos (2015) implemented amodified version of muddiest point technique for the project based bio-instrumentation course. Based on the muddiest points reported by the students, a written document covering students' questions and resource material to help them obtain additional information to address their queries was shared with the students. The impact of implementing the technique was assessed using the final project grades and was found to improve the same.

Gillies (2016) reviewed developments in the research on cooperative learning and studied the factors on which its effectiveness depends. Tharayil et al. (2018) discussed the strategies to reduce students' resistance to the use of active learning techniques for classroom teaching. Kalyana Chilukuri (2020) have used few online active learning tools to deliver an elective course 'Routing and Switching Concepts' and discussed impact assessment of the suggested framework with the help of students' responses.

The literature review shows that researchers have experimented with different active learning techniques and assessed their effectiveness. The pace of experimentation with the use of such techniques has been considerably increased in the recent past. With time, there has been continuous addition of several techniques to the list of active learning techniques. The literature review revealed that though active learning methods have been used for the course delivery in the past, the development of understanding about the implementation of such techniques need more experiments to gather data for different courses, under different conditions, and assess their effectiveness. An attempt has been made to apply different active learning methods to deliver the entire course over the semester long period. The research work presents the application of active learning methods including the muddiest point technique, case study, jigsaw technique, concept mapping and team-based learning to deliver the 'Hydraulics and Pneumatics' course to the final year B.Tech. Automobile engineering students. The active learning methods have been selected to serve multiple objectives such as exposing the students to real life applications, enabling them to interact and learn

during the classroom sessions, asking them to design, draw and connect different circuits, helping them to understand difficult concepts in a simple way, and establishing a mechanism so that students will highlight the muddiest points to address them subsequently. The objective is to study the effect of change in the learning environment on the students' participation, learning and the course results.

3. Research Question

In Outcome-Based Education (OBE) today, activity-based teaching-learning is the need of time to engage and involve the students and to ensure achievement of the course outcomes. Due to the higher difficulty level of the 'Hydraulics and Pneumatics' course, achieving higher values of average marks and the passing percentage is a challenge for a course teacher. The present work is an attempt to overcome these challenges by using active learning techniques for course delivery. The number of students enrolled for the course were 21 and the different activities were implemented throughout the semester.

4. Methodology

The 'Hydraulics and Pneumatics' course is offered as an elective course to final year B.Tech. (Automobile Engineering) students. The course delivery was planned to use different active learning techniques during the semester-long period. The different techniques used were Jigsaw technique, Concept mapping, Case study, Muddiest point technique and Team- based learning. The methodology of the application of different techniques and the outcomes are discussed in the subsequent sections.

The students were given a brief introduction about the active learning methods used and were clarified about its objectives. The evidence of implementation of the different methods was collected in the form of photographs. The report format was shared with the students to summarize their findings after visiting the workshops under the industrial application-based learning method.

The data for assessment of the impact of the active learning methods was collected in the form of performance of the students during In-Semester Evaluation (ISE), Unit Test (UT) and End Semester Examination (ESE). The data was also collected using the feedback survey expecting students' responses on the active learning methods implemented, and their effectiveness. The survey questionnaire is validated by referring it to a faculty member who taught the same course earlier. The course results were analysed to find the average marks and percentage of the students who passed the course. The attainment of course outcomes was also calculated by using the students' results in ISE, UT and ESE. The student's responses to the feedback survey were also analysed to get the qualitative data, to conclude on the students' perceptions and to summarize their views on the active learning methods implemented for the course under consideration.

5. Active Learning Techniques

A brief introduction to different active learning techniques is presented in this section.

A. Jigsaw Technique

It is a cooperative learning technique in which students were divided into groups of 4 to 5, and each of the students in a group (first group) were given a topic to study independently. The students from each group with the same topic were then asked to form an expert group. The students discussed and shared their learnings on the same topic. In this way, a common understanding of the topic of interest was reached through cooperative learning in a group. The students were again asked to join their original group to finally share knowledge about their topic in the group, where every individual has a different topic to study. In this way, all the students shared expertise about their topics with each other and thus enabled a class to thoroughly understand different topics. Fig.1 shows the first groups (Phase I) while Fig. 2 shows students working in the expert groups (Phase II).

B. Case Study

The students visited an industry or a workshop to identify and study industrial and societal applications of hydraulics. They were expected to submit the report including the photograph of the application where the hydraulic system is used,specifications of the system, working of the system and learning outcomes. Every student could see different components of the hydraulic systems and connect his / her classroom learnings to real-life applications using fluid power.

The students after interaction with each other could list several applications and learn how hydraulic systems are used to meet the demands of different applications. They had shared the outcomes of their visit with each other and had known details of components used in various applications. Two-wheeler lifter, excavator, dumper etc. are some of the applications seen by the students. Fig. 3 shows the format of a case study report submitted by the students after the visit. Fig. 4 shows a student observing a hydraulic two-wheeler lift during his visit to a workshop.

Fig.1: Jigsaw technique (first group)

Fig. 2 : Jigsaw technique (Expert group)

C. Muddiest Point Technique

The technique was used after the course content was delivered in the class and the students were expected to write on a page about the concept that they felt most difficult to understand. It helped the teacher to know the learning of the concepts taught and thus helped to identify the gap, and further to take appropriate action to bridge the gap. Fig. 5 shows students independently writing the muddiest points while seating one on each bench.

B. Concept mapping

The technique involves listing different concepts/terms related to a given topic, categorizing them into different groups and then arranging different concepts from top to bottom based on their relationship with each other. This helped the students to list and define avrious concepts from the given topic of interest.

Case Study Report

Final Year B.Tech. (Automobile Engg.) **Hydraulics and Pneumatics**

Name of the Student:

Roll No. :

1.Title of the Problem:

Identification and study of the real life application in which hydraulic system is used to get the required work output.

2.Details of the Application:

2.1 Location (i.e. in the Industry / Society)

2.2 Purpose for which the Hydraulic System is used in the application:

2.3 Photograph (including the student) :

3.Block Diagram of the Hydraulic System

4.Hydraulic Circuit Diagram:

5.Details of the Components of the Hydraulic System:

Sr. No.	Name of the Component	Function / Description	Specifications

6. Description of the Working of the Hydraulic System :

Name and Signature of the Student **Name and Signature of the Course Teacher**

Fig. 3 : Format for submission of the Case Study Report (Template)

'Hydraulic Systems' was the topic given to the students to prepare a concept map using different terms related to it. Fig. 6 shows a group of students who are working together to develop a concept map.

E. Team-based learning

In this technique, the student groups with 5 to 7 members in a group were formed and were asked to develop different pneumatic circuits using a pneumatic trainer kit. Every group prepared different circuits including sequencing circuits, speed- control circuits, the circuit to control double acting cylinders etc. They were also asked to draw the same circuit on the paper. The students worked as a team to design, draw and connect a circuit to solve different problems involving a sequence of operations, speed control of the cylinders during extend or return stroke etc. Fig. 7 shows a team of students involved in the discussion to prepare a circuit for a given application. Fig. 8 shows a pneumatic circuit developed by the student teams.

Fig. 4 : Student observing hydraulic two-wheeler lift in a workshop

Fig. 5 : Students engaged during Muddiest Point Technique

The activity allowed the students to enjoy experiential learning. They have gone through every step to finally develop a pneumatic circuit by selecting appropriate elements and by logically connecting each element in a proper sequence. They have realized the importance of designing precise circuits to ensure output expected from the circuit i.e. desired motion, velocity and force.

Fig. 6 : Team working for concept mapping

Fig. 7: Team of students working to prepare a pneumatic circuit

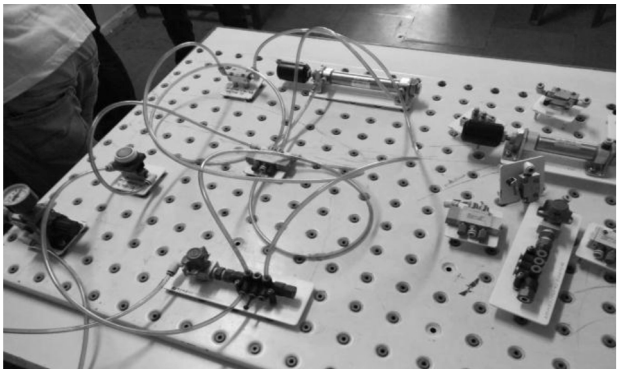


Fig. 8 : Pneumatic circuit prepared at the end of the activity

6. Results And Discussion

This section presents the course results, attainment of course outcomes and impact assessment of the active learning methods implemented for the course delivery. The impact assessment has been done using the following tools.

1. Comparison of the course results with the previous year results.

2. Comparison of attainment of Course Learning Outcomes with the previous year's attainment.

3. Analysis of students' responses to an active learning survey.

A. Improvement in course results

Table 1 shows the comparison of results for the 'Hydraulics and Pneumatics' course for the previous and current academic year.

Table 1 : Comparison of results for hydraulics and pneumatics course

Parameters	Academic Year	
	Previous Year	Current Year
Average marks in ISE (out of 20)	15.09	17
Average marks in UT 1 and UT 2 (out of 30)	18.57	16
Average marks in ESE (Out of 100)	48.54	59.8
Result of ESE (passing %)	78.79	95

The assessment of the course is done throughout the semester (continuous assessment) using assessment tools including In- Semester Evaluation (ISE), Unit Test-1 (UT 1), Unit Test-2 (UT-2) and End Semester Examination (ESE). The results show that there is a little improvement in the average ISE marks from 15.09 to 17. There is little fall in the average marks in UT 1 + UT 2 from 18.57 to 16. This is probably because Bloom's taxonomy level of questions was comparatively high and the impact of all the techniques together was yet to be seen at the mid of the semester. Despite questions with a higher level of Bloom's taxonomy and 100 marks question paper (50 marks

B. Comparison of attainment of Course Learning Outcomes with the previous year's attainment.

1) Course Learning Outcomes

Following are the abilities expected to be developed in the students after successful completion of the course.

1. Describe basic properties of fluid and important principles of hydraulics and pneumatics with their applications.

2. Identify various components of Pneumatic and Hydraulic control systems.

3. Design Hydraulic and Pneumatic Circuits for given engineering applications.

4. Diagnose probable causes of failure of components of hydraulic and pneumatic circuits.

2) Assessment Tools

The direct tools used for the assessment of the attainment of course learning outcomes and their weightage is given in Table 2 below (Desai and Patil, 2016).

Table 2 : Assessment Tools

	Assessment Tools			
	ISE	Unit Test-1	Unit Test-2	ESE
Weightage (%)	20	15	15	50

The questions in the question papers of Unit Tests and End Semester Examination are mapped to relevant course learning outcomes of the course. The analysis of question wise marks scored by each student and CO mapped to respective question helps to find attainment of each Course Outcome based on the performance of the students in various examinations of the course conducted during the semester.

2) Comparison between CO attainment levels for the two consecutive years

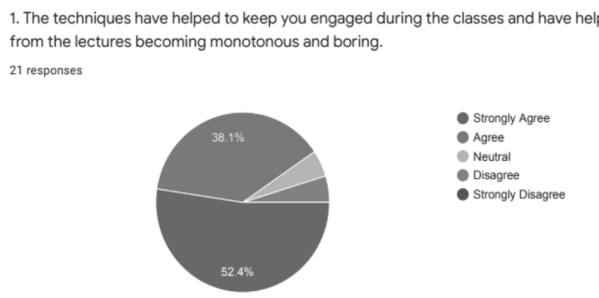
Table 3 shows the comparison between the level of attainment of COs for the previous and current academic years.

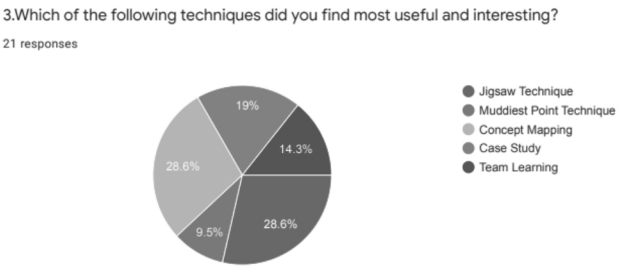
Table 3: Comparison Between Level of Attainment of Cos for the Previous and Current Academic Year

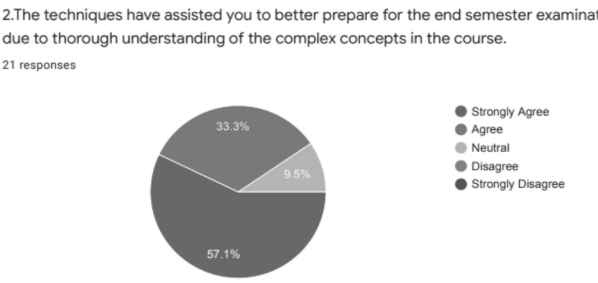
Course Outcomes	Level of Attainment (%)	
	Previous Year	Current Year
CO 1	91	95
CO 2	86	74
CO 3	69	63
CO 4	79	77

Table 4 : Active Learning Survey (template)

Sr. No.	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	The techniques have helped to keep you engaged during the classes and have helped from the lectures becoming monotonous and boring.					
2	The techniques have assisted you to better prepare for the end semester examination due to a thorough understanding of the complex concepts in the course.					
3	The technique such as 'Case Study' has given you an opportunity of exposure to real-life problems where Hydraulics and Pneumatics systems are used to get the necessary power to exert the load in the application of interest.					
4	Activity-based teaching gave you chances to interact with your peers and learn from them.					
5	The learning environment during classroom sessions has allowed you to work in teams and improve your communication.					
6	The motivation to and promotion of interactive learning in the classrooms has improved your problem-solving ability.					
7	Overall, you feel that ability has been developed in you to design a hydraulic and pneumatic circuit for any industrial application.					
8	Which of the following techniques did you find most useful and interesting? (i) Jigsaw Technique (ii) Muddiest Point Technique (iii) Concept Mapping (iv) Case Study (v) Team Learning (vi) All of These					
9	Please express your experience of attending the 'Hydraulics and Pneumatics' lectures during the semester-long period. .... ……					







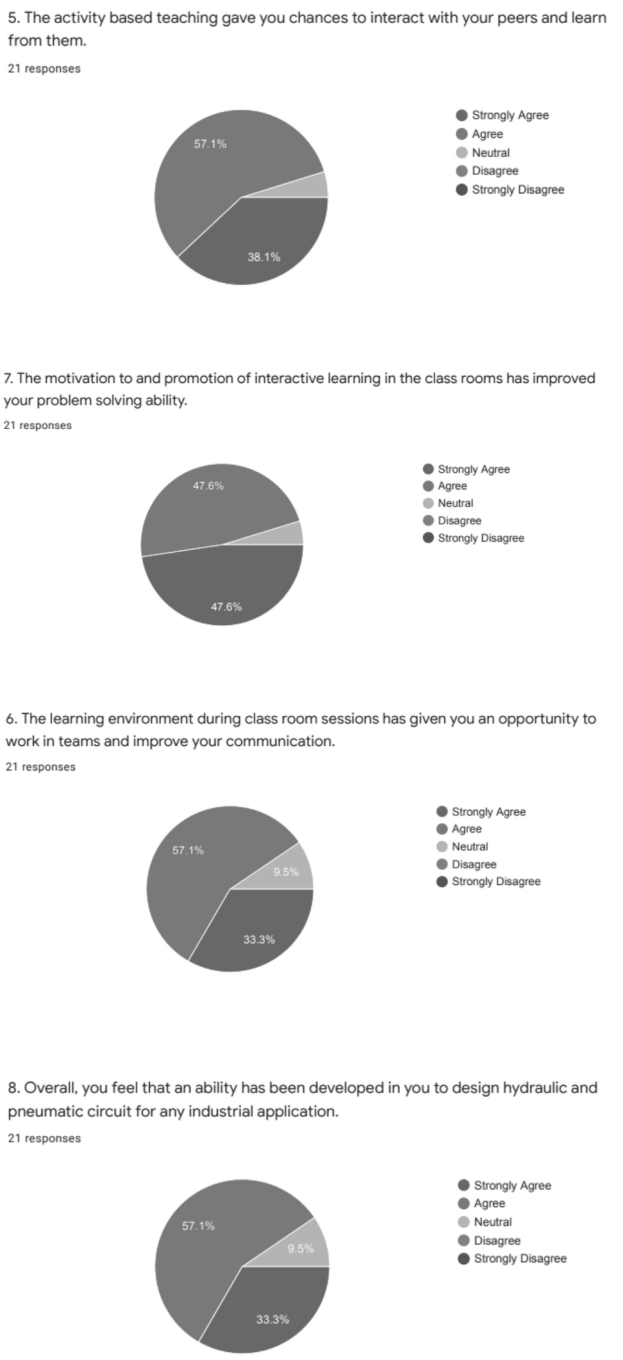


Fig. 9 : Summary of Responses of the Active and Cooperative Learning Survey

The attainment calculated is threshold-based with ISE threshold 60 % and ESE threshold also 60 %. The attainment is increased for CO1, decreased up to a certain extent for CO2 and CO3, and is almost the same for CO4.

A. Analysis of students' responses to active learning survey

To measure the effectiveness of the active learning methods used during the delivery of course contents, an active learning survey was conducted using Google forms (Fig. 9). The survey template is shown in Table 4. The summary of findings of the students' responses to the statements/questions is discussed below.

- 90.5 % of the students believe that the techniques have helped them to be involved during the classes.
- 90.4 % of the students feel that they could better prepare for the end semester examination because of the clarity about complex concepts in the course.
- Among different techniques, the concept mapping and Jigsaw technique were most liked by the students (28.6 % for each technique)
- 95.2 % of the students expressed that the use of active learning techniques have given them exposure to real-life problems where Hydraulic and Pneumatic systems are used.
- 95.2 % of the students feel that it allowed interacting with their peers and learn from them.
- 90.4 % of the students feel that the classroom environment allowed working in teams and improving their communication.
- 95.2 % of the students believe that active involvement during classes has helped them to improve their problem- solving ability.
- 90.4 % of the students agreed that they can design hydraulic and pneumatic circuits for any industrial application.
- Finally, the students while expressing their experience have said that they have understood basic concepts and understood the industrial applications of hydraulic and pneumatic systems. They said that the activities helped them to develop an interest in the course and they are now able to prepare and draw the circuits.
- Few students have given suggestions and expected additional efforts to implement the suggestions received through the muddiest point technique.

The analysis of both the course results and students' responses to the survey questionnaire indicates that the use of several techniques has made available a platform for learning where students are actively involved during the classroom sessions. The implementation of active learning techniques has helped to create an environment and support system for self- learning by the students. It has helped to create confidence among the students that active learning makes the understanding and application of difficult concepts easier.

7. Conclusions

The experiments were conducted in the classroom to use several active learning methods and study the effect on students' learning and achievement of graduate attributes. The course considered was 'Hydraulics and Pneumatics' which was delivered to the students of final year B.Tech. Automobile Engineering. The activities were conducted after regular intervals of time during the semester. Following are the conclusions derived.

- The comparison of the course results with previous year results has shown that the passing percentage in ESE is increased by 21 % while the average marks in ESE are increased by 23 %.
- The comparison of the level of attainment of COs indicates that there is an increase in % attainment for some of the COs while there is a slight decrease for some other Cos.
- It was experienced that the students' participation in the classroom was increased which resulted in the development of abilities such as communication, working in teams and problem-solving ability.
- It thus concludes that active participation of the students avoids the lectures from becoming monotonous and helps to develop an interest in the course under consideration.

Acknowledgement

The authors acknowledge the cooperation and support of the Final Year Automobile Engineering students who played a key role in the implementation of the active learning techniques in the classroom. The authors also express their sincere thanks to the Director and management of the institute for creating a conducive atmosphere for the implementation of such techniques and for providing necessary support and facilities.

References

[1] Bonnie Nastasi and Douglas H. Clements (1991) Research on Cooperative Learning: Implications for Practice, Scholl Psychology Review,20(1), 130-131

[2] J. Patrick McCarthy and Liam Anderson (2000) Active Learning Techniques Versus Traditional Teaching Styles: Two Experiments from History and Political Science,Innovative Higher Education, 24(4),279-294

[3] Jenny A. Van Amburgh, John W. Devlin, Jennifer L. Kirwin and Donna M. Qualters. (2007) A tool for measuring active learning in the class room, American Journal of Pharmaceutical Education, 71(5), 1-8

[4] Luciana Barroso (2010) Active Learning Strategies to Enhance Learning in a Civil Engineering Graduate Vibrations Course, American Society for Engineering Education, 15.120.1- 15.120.10

[5] Kristin Stowe (2010) A Quick Argument for Active Learning: The Effectiveness of One-Minute Papers, Journal for Economic Educators, 10(1), 33-39

[6] Anurag Jain and Pravesh Kumar Dwivedi (2014) The Evidence for the Effectiveness of Active Learning, OrientalJournal of Computer Science and Technology,7(3), 401-405

[7] Xiaoming Sheng and Xuewu Hu, (2014) Teaching method reform of the hydraulic and pneumatic course based on engineering application cases, IEEE Workshop on Advanced Research and Technology in Industry Applications (WARTIA), 528-531

[8] Vinod Kumar V Meti and Arun C Giriyapur (2015) A Structured Approach To Teaching And Learning Hydraulics & Pneumatics Journal of Engineering Education Transformations, 28, 56-61

[9] Renata Fortuna Ramos (2015) Addressing Muddy Points Early in the Semester Increases Student Learning in a Bioinstrumentation Laboratory Course 122nd ASEE Annual

Conference and Exposition, June 14 -17, 2015, Seattle, WA

[10] Robin M. Gillies. (2016) Cooperative Learning: Review of Research and Practice, Australian Journal of Teacher Education, 41(3), 39-54

[11] Sneha Tharayil , Maura Borrego, Michael Prince , Kevin A. Nguyen , Prateek Shekhar , Cynthia J. Finelli and Cynthia Waters (2018) Strategies to mitigate student resistance to active learning, International Journal of STEM Education,1-16

[12] Kalyana Chakravarthy Chilukuri (2020) A Novel Framework for Active Learning in Engineering Education Mapped to Course Outcomes, Procedia Computer Science, 172, 28-33

[13] Sandeep R. Desai and Satyajit R.Patil (2016) Design and execution of strategies for effective implementation of Outcomes Based Education (OBE) in Engineering, Journal of Engineering Education Transformations, 30(1), 111-117