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Impact of the flipped classroom approach in engineering education: A course analysis

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Abstract: The main purpose of the paper is to present a course analysis on the use of the flipped classroom. The objective is to explore the advantages and challenges for students and instructors. The impact of flipped classroom learning is analyzed with a set of students in the classroom. Student perceptions of lecture based learning and flipped classroom is compared to explore and promote active learning methodologies. The challenges of implementing a flipped classroom were identified and addressed using a variety of student-related activities. Mobile app learning methods, scale-up classroom and effective laboratory courses were implemented for a set of students. The significance of the flipped classroom model is noted. It was found that it promotes a deeper, broader perspective on learning, improves critical thinking capabilities and team work skills needed for a successful engineering career.

Keywords: flipped classroom, scale-up classroom, active learning, learning outcomes

1. Introduction

These days, many universities are transforming lecture-based learning (LBL) methods of teaching to flipped classroom (FC) teaching – a method of pedagogical aspect (Sohrabi & Iraj, 2016). The flipped classroom introduces a new solution to the challenges of traditional education. Hao (2016) have implemented this approach in higher education in different disciplines such as mathematics, social sciences, pharmacy and engineering. In lecture-based learning, interactivity is considered a tool for success. It is however, keenly noted that a lack of interactivity, a pedagogical approach, is missing in the traditional classroom. A brief study of Wang, Feng and Hsu (2017) revealed that only questioning and answering with the students is taking place in lecture-based learning.

The flipped classroom aims to address the many challenges of the traditional classroom approach. The present classroom scenario between instructor and student stops with question and answer. The objective of active learning is to enhance this using a smart education system. When using the flipped classroom, students are asked to perform group tasks, individual tasks and problem solving as a few of the best practices A day before the class starts, course content materials in the form of online videos, slide presentations and open education resources (OER) are given to students. Students learn and utilize the online course materials. This differs from traditional learning in that instructors not only transfer knowledge through lecture notes. The flipped classroom involves active learning through problem solving as

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individuals and in groups. This increases the potential for student learning. Figure 1 compares different aspects of the learning environment, inside and outside of the classroom, for a flipped classroom and conventional mode.

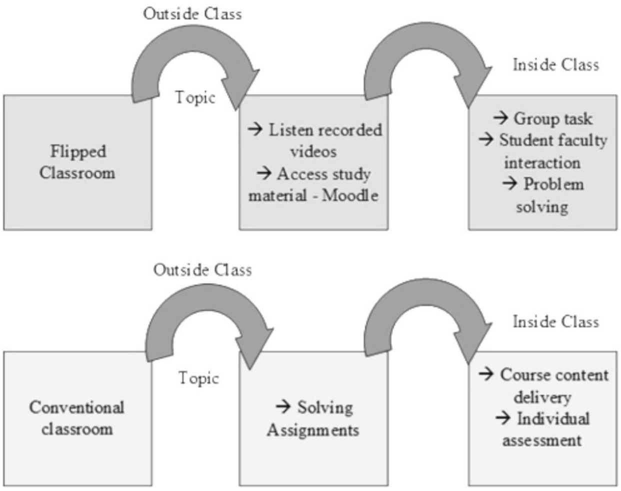

Fig. 1: Different aspects of the learning environment

A recent study focused on student perception and object learning outcomes and the impact created by the flipped classroom (Li et al., 2017). Maratou et al. (2016) and Jonassen (2000) also showed that the flipped classroom is a more flexible learning environment than lecture-based learning methods. There are however, a few limitations such as the design of course materials for better understanding of all students, not actively participating outside the classroom.

In recent years, research articles based on the flipped classroom approach have increased globally. Due to the increased use of the internet and information communication technology (ICT) the practice is followed in higher education, particularly in engineering education. There is a surge of new business models namely MOOCs (massive open online courses) – an emerging education system that does not require any tution fees but rather an individual course fee that is affordable to students. This system results in a rethink of the way education is delivered.

To evolve, software engineering courses should be designed with a learner-centered learning environment to increase learning performance. To highlight this, Munitr et al., (2018) and Lai et al., (2016) stated that the study instruction of theoretical methods and practical skills are required for software engineering courses and learner-centric and teacher-centric strategies should be characterized by participation, knowledge, interaction and thinking skills.

For this study, the LBL method and FC method is used infrequently in our college and there is limited analysis related to course methodology, best practices like mobile app learning and the remote laboratory. This FC approach was implemented during the Covid-19 pandemic situation for enhanced transfer of knowledge to the student community and the improvement of academic results.

2. Literature review

2.1 Implementation and procedure of the LBL method

Shi et al., (2018) have examined whiteboard-based instruction for college students. The LBL method is also known as the traditional class and in this case, it was used as the control group. The method was handled as follows. The instructor gives the lecture to the students in the class for 60 minutes using digital learning tools like slide presentation and keeps engaged. Students are idle to listen the class. Later, the handout materials are uploaded in moodle platform. Outside the class, they were asked to do the assignments. The results of the study have proved higher levels of academic self efficacy and student learning achievement is not affected. However, the main perspective of LBL is to transform knowledge to students in classroom with less interaction.

2.2 The Flipped classroom learning method

When using the FC method, the instructor is no longer a speaker, rather he facilitates individual and group tasks that promote active learning for the students. Opportunity is given to students to engage in new content through small group discussion to improve their skills. Different activities that can be used in the classroom are shown in Figure 2. Hwang (2014), mentioned that new learning modes will raise new pedagogic issues. Thus, new technologies and learning strategies are needed to support this method.

Shi et al., (2018) stated that as instructor and student contact in the classroom reviewed and reported that flipped model yields student learning outcomes in a positive manner. As an added advantage, Schlairet et al, (2014) defined a concept that is linked to three theories as behaviourist, cognitivist, and constructivist for a nursing course. This creates impact in students learning outcomes such as achievement and attitude. This interactivity approach transforms students in a rich learning environment.

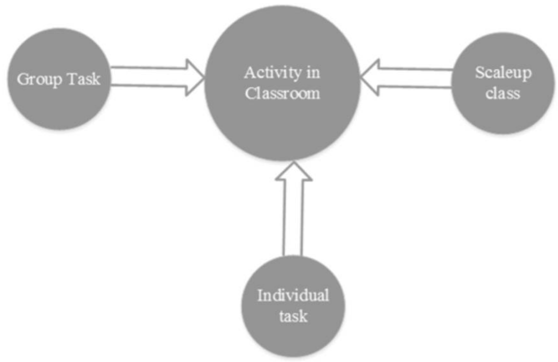

Fig. 2: Activities performed in the flipped classroom

Yelamarthi et al., 2016 and Kamerikar et al., 2020 have shown good results by applying this pedagogical approach in a first year course on digital circuits. The most significant contributions in pedagogy included a flexible learning environment. This allows the student to learn at their own pace if they miss the class. The strategy has been followed in pharmacy, medical and engineering with good results. Many institution had incorporated this pedagogical practice in the curriculum. Positive result of the individual student have made the class result much better than conventional method. In the flipped classroom method, the student can rewind, pause and learn at any time using present technology. Martinez – Rodrigo, (2017) report that students were prepared for class before class starts and project based learning (PBL) has improved the educational outcomes and student satisfaction in teaching the course. Individuals also reported that learning watching videos is easier than reading text books. They also discuss the four pillars of the flipped classroom method and its key components which is shown in Figure 3.

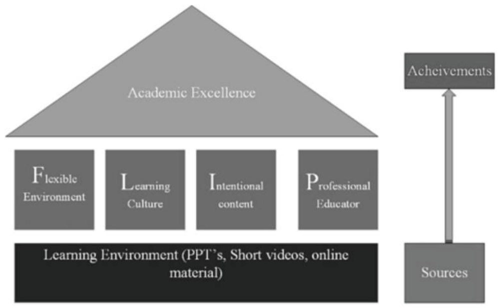

Fig. 3: Key components of the flipped classroom

2.4 Active learning methods

Many Indian universities have incorporated active learning methods into the curriculum. Programme outcome (PO), course outcome (CO) is a key role in engineering education. Outcome based education (OBE) is encouraged in engineering education and has proven success in helping institutions to measure learning outcomes. It also contributes in raising education standards to acquire accreditation such as the National Board of Accreditation (NBA). This significant initiative has increased the need to take necessary steps. Eichler, J. F., & Peeples, J. (2016) described how a student team of four engineering courses developed a video game approach for learning signal processing using project based learning. It also benefited students and gave an opportunity to upgrade the skills in the classroom. In the design part of course materials, the instructor has to pay more attention to create the high quality videos with rich content. Active learning methods have been shown to support students in creating new ideas and invoking knowledge. For the study purpose, Allais. S 2012, stated that learning outcomes are a major part of a curriculum and education policy reforms. The practice for different learning outcomes is shown in Table 1.

Table 1: Learning outcome practice

Learning Outcomes	**A statement of what is to be achieved on successful completion of course.**
Learning experiences	The experienced candidates have to enable the knowledge and skills required for the learning outcomes to be addressed.
Assessment activities	Different task is given to candidate will engage with evidence they have achieved the learning outcomes.
Assessment criteria	A clear description of levels of achievement, and what performance is required at each level.

2.4 Smart learning techniques

This section discusses smart learning techniques and integrating learning materials like the internet and data projector to support the FC method. These activities transform the learning environment into smart education. In group discussions, inner talents of students is identified in generating more ideas of the subject. Lai et al., 2016 approach have created significant interactivity and it is a key component in engineering education. Lin and Yen–Ting (2019) created web browsers supported by any devices for instructors and students for many learning activities (in and out of class) showing good results. Cummins et al., (2016) used in-video quizzes as an approach which helped students to increase the interactivity of video content as formative assessment.

2.5 Mobile App learning methods

Recent developments in cloud technology have created new learning tools for material synthesis. This enhances the student skills in learning problem-based learning. Jou et al., (2016) created the Interactive Mobile Material Learning (IM2 Learn) app to facilitate student learning. Integration of mobile devices in present education environments focus on the classroom setting and its implementation. This creates an opportunity to guide students and help them effectively in acquiring knowledge. It serves as a complementary method to other forms of course delivery. Klimova, B. (2019) showed how their web app development had satisfied both student learning and study achievements. A need analysis evaluated SWOC (strength, weakness, opportunities, challenges) and was conducted at the beginning of the semester. Amongst the challenges of using mobile devices in the classroom, is that students face some distractions in the classroom. Asundi, S. (2019) described an alternate methodology of multi-tasking of the instructor in the role of facilitator. These learning methods had created innovative ideas for students and the teacher. The way of presenting the creative ideas in the mobile app to the student and the measurement of outcomes is a real challenge however. The objective would be technology enhanced learning methods for the students.

2.6 Activities using scale-up classroom

The scale-up classroom is designed to facilitate active learning environment in a team. Student-centred, active learning environments for undergraduate programs is a known acronym for the scale-up classroom. In the engineering discipline, it is used for collaborative problem solving in the undergraduate program. Students share their views and get stimulated with individual engagement. It involves students working on a group or individual task. The instructor interacts with students to create small discussion, questions, and debates keeps the class more interactive. Students are found to be active in these approaches. It can be identified by their communication skills, presentation skills and critical thinking in the form of projecting their views through cognitive thinking. The key activities performed in the scale-up classroom include brainstorming, problem-solving and decision-making, role-play, simulations, games and making comparisons. Collaborative, web-based methods have been created for engineering education. The physical setup arrangement of a scale-up classroom is shown in Figure 4 with several round tables. The classroom is further equipped with a microphone, laptop and white board with marker. A small group is setup at each table with the facilities created. Heitink et al., (2016) proposed the use of online tools with an internet cable or wi-fi facility to share views on the particular topic. The instructor interacts with the group and individuals. The instant stimulated thinking can be represented online through excel, power point and graphs with pictorial representation. Projector screens in larger rooms allow viewing from anywhere in the room. Innovative ideas can be shared within the group and represented in their own way. This is a part of learning methods that facilitates the student community in improving their knowledge transfer in a set of group. The student has the ability to showcase their thoughts in their own representation through the aid of technology.

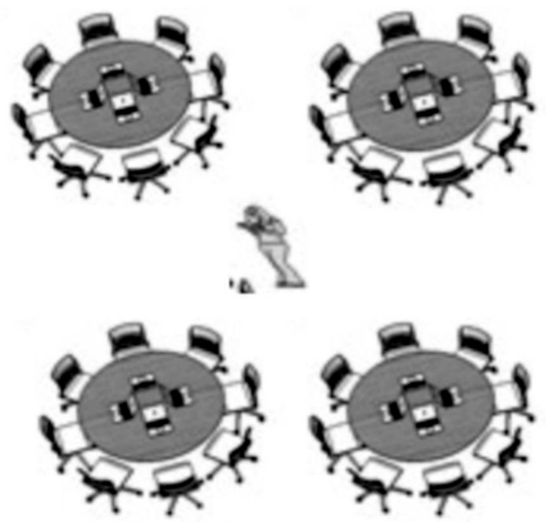

Fig. 4 : Scale-up room arrangement

2.7 Effective Laboratory Courses

Some theoretical courses need to include practical examples so that students appreciate and are involved in various hands-on activities. The main objectives of learning laboratory courses includes team work, motivation, object learning and networking. Other benefits include, inquiry-based learning. Borrego, M et al., (2009) often use conceptual knowledge transfer to students, integrating information text to experimentation quality. However, many courses remain unchanged with the exercise and the same data or reports used every year. Recently, laboratory courses have been reduced due to increased student numbers and teacher funding resource constraints. Sensor modelling and simulation lab, electrical machines lab, virtual electric drives lab can give exposure to students in laboratory courses. Kavitha, D., & Anitha, D (2018) discuss a laboratory using remote desktop and online workbench for electrical experiments for engineering students and certain virtual remote laboratories in a defined manner.

2.8 Strategy of student Evaluation

When using a flipped classroom method, the scope of student evaluation (or assessment) is wider and the scope of examination is narrow. Qualitative progress and behavioural changes are tested in evaluation. In examination, only qualitative progress is explored. Assessment and evaluation are an integral part of engineering curriculum. Different forms and their benefits are included in Table 2. In order to evaluate the technical skills of students, multiple choice question (MCQ) type is used to measure the higher level mental process and a wide variety of learning outcomes. A broad range of topics can effectively be test the breadth of a student's knowledge. Students rate the level of confidence they have in their answer and that is the score. Regular test of MCQ has the good working knowledge. Student mentality is assessed with alternate type quizzes.

Table 2: Different assessments and benefits

Assessment methods	Benefits
Formative assessment	Student modifying instructional objectives and correcting further learning in feedback loop
Summative assessment	It measures instructional objectives. It results in mark or grade awarding final cumulative grade point average (CGPA)
Criterion – referenced assessment	It measures student higher grade achievement learning outcome of course is achieved.
Norm referenced assessment	Individual student assessment is compared with his/her classmates on an assignment task.

3. Experimental Procedure

This section describes the methodology of the study and demographic data of participants.

3.1 Study methodology

This study focuses on evaluating two approaches- lecture based and flipped classroom mode in a four-year, engineering degree college at Madanapalle Institute of Technology & Science, Madanapalle, Andhra Pradesh. For the academic year (2018-19) learning methodologies like lecture-based and flipped classroom mode were used. For one semester, our college flipped three fundamental courses for three main engineering disciplines for electrical & electronics engineering, electronics and communication engineering and computer science engineering. All of these courses were at the second year level. Details of the engineering courses and student demographics is tabulated in Table 3.

Table 3: Engineering discipline, courses and student size

Number	Engineering discipline	Fundamental courses	Class size
1.	Electrical and Electronics Engineering	DC Machines & Transformer	53 (male:45, female:8)
2.	Electronics and Communication Engineering	Introduction to electronics	60 (male:50, female:10)
3.	Computer science engineering	Introduction to python programming	60 (male:45, female:15)

The framework of all learning methods in flipped classroom was used. Interactive group learning activities were used inside the classroom and direct computer-based individual instruction was used outside the classroom. A mobile app and scale-up classroom were also used to improve active learning. In this research, student performance is analysed both in flipped mode and LBL mode through student assessments and continuous internal assessments (CIA).

4. Results

Table 4 shows the average of continuous internal assessment (CIA) and standard deviation (SD) of two engineering discipline. For the electrical & electronics engineering, the success of quiz does not reflect the student gaining knowledge on topic area. The CIA-1 equals to quiz 1-4 and CIA-2 equals to Quiz 5-8. The scores show that the first CIA-1 of flipped model shows less result than LBL method of teaching. It depicts initially student felt difficult in flipped model later in CIA-2 the student performed well.

The (Avg: 85, SD: 5.5) t (20) = -3.56, P= .03. For computer science engineering in the CIA-1 flipped model student performance is quite higher than the LBL method. The SD is 4.7 in flipped and 4.4 in LBL method. Self-efficacy and the motivation for self-learning are necessary in engineering careers. Based on the above flipped classroom practice, students & faculty have shared their experiences and views and it is tabulated in the Table 5. This data was collected during training and placement activity from each student and by conducting various assessments like social, psychological and academic.

Table 4: Quiz averages and standard deviation of Flipped and LBL method

Continuous Internal Assessments (CIA)	Electrical & Electronics Engineering (Flipped)		Electrical & Electronics Engineering (LBL)		Computer science engineering (Flipped)		Computer science engineering (LBL)	
	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD
CIA -1: Quiz:1-4	76	4.3	81	4.8	80	4.7	79	4.4
CIA -2 : Quiz:5-8	85	5.5	80	4.4	82	5.3	76	4.5

Sample undergraduate courses is taken for the study that includes DC machines & Transformer, Introduction to electronics and Introduction to Python Programming The core and programming courses have taken for consideration. Class size of 60 have taken different courses. According to student choice they have shown interest in LBL and FC model in learning. The end result analysis says many students of below average students have shown interest and participated in flipped classroom. The average students have shown partial interest. In Figure 5 the trend analysis shows that learning activities in classroom is classified into traditional learning and flipped learning methods. Most significant courses have been taken to measure the practices of students and their participant in the classroom. In deep analysis, below average, and above average students have been classified in a class.

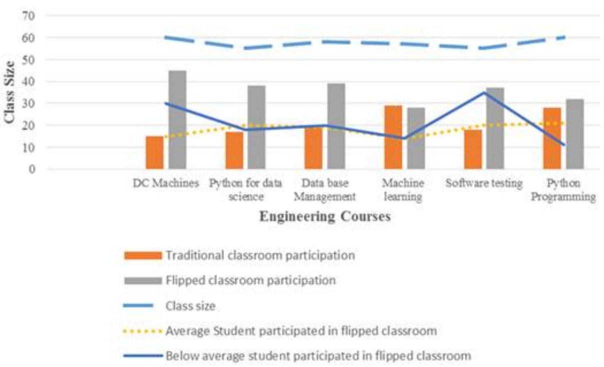

Fig. 5: Analysis of traditional classroom learning and flipped classroom learning

Table 5: Listed benefits of Flipped classroom environment

S.No.	Social benefits	Psychological benefits	Academic benefits
1.	Establishes a positive environment for modelling and practising cooperation.	Self-esteem through student centric.	Academic results are improved
2.	Builds positive heterogeneous relationships and promotes diverse understanding amongst students and staff.	Creates positive attitudes among students towards instructor	Active participant of student in learning process
3.	Develops learning communities		Inter personal skill development

In many courses, students show interest in flipped classroom method rather than traditional method. The most traditional electrical engineering courses like DC machines have been student's most interest in flipped classroom learning. However, in few programming courses it shows student participants is equal. Below average students shows more variations in the learning methods. However, programming courses would be the choice for students in flipped classroom method. The student uses mobile application to contact colleagues through facebook, twitter, and SMS learning materials for their convenient.

4. Conclusion

The main objective of this research were to determine student involvement through class and exam attendance and to measure (quantitative) student involved in flipped classroom experience. Although, there are many surveys, student performance and course instructor perceptions were compared to the same course offered in LBL method, with promising results. The learning practice is taken through information and communication technology (ICT) to the students. Overall outcome of the research is to provide literature by filling existing gaps in engineering education by providing FC approach. Implication shows that learners change the method of learning based on the selection of courses. The findings pertaining to student satisfaction have been influenced by design aspects of learning materials used in flipped classroom. This study investigated that although flipped classroom has given opportunity to save time for the instructors and to deliver the course content to the students. In addition to that, use of mobile app create enjoyment in learning and commented that size of the phone and text bigger is more convenient for reading.

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