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Virtual Lab Integrated Flipped Class for Effective Implementation of CDIO Framework in a Theory Course – A Case Study

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Abstract: **CDIO (Conceiving — Designing — Implementing — Operating) Initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome-based assessment which demands more active learning strategies. A flipped classroom is a student centric instructional strategy and a type of blended learning, which aims to increase student engagement and learning by having complete readings at home and work on live problem-solving during class time. Virtual labs are interactive, digital simulations of activities to learn/explain certain concept that improves the content delivery of all types of courses and is helpful for students understanding and applying the concepts in a better way. How can a virtual lab help in flipped mode especially in what type of course? The experiment is conducted for the course 18EE340 -Digital Systems with two sets of students: experimental group with virtual lab integrated Flipped model and controlled group with flipped model without virtual lab. The outcome of the activity is measured using focus group discussions and it is understood that students have involved in the activity with attentiveness and the positive outcome is also seen in the results of CAT performance. It is found that 14.5% improvement is obtained in the experimental group when compared to the controlled group. Also the research study shows that the CDIO skills get improved by adopting the proposed method. On the other hand, this paper also discusses the common errors made in Flipped Class during planning and how to overcome them based on experiential learning using 5 different case studies.**

***Keywords*: CDIO, Flipped Class, Virtual lab, learning outcome**
JEET Category—

I. INTRODUCTION

The CDIO framework provides students with an education emphasizing engineering essential knowledge/skill in the context of Conceiving — Designing — Implementing — Operating (CDIO) real-world systems and products with a good attitude. [Berggren, K. F et al, 2003].

Throughout the world, CDIO Initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome-based assessment. Hence, each and every course is required to be delivered with the connection to real world [Crawley, E. F et al, 2011]. Active strategies are required to make students participative and to enhance the learning. It is proven that student centric learning improves the learning outcome attainment.

The whole world witnesses the use of online teaching practices during the pandemic. The debates continue about the various merits and demerits of online education. Now as normal life is resuming, the engineering education is returning to its original offline mode. The good essence of online practices should be poured into face to face interaction classes to make the learning strong in blended mode. In the existing syllabus, most of the theory courses are dealt with lectures and demonstrations. Lower cognitive skills are inculcated in class room and higher cognitive skills are tried to be imparted through assignments.

A flipped classroom is a student centric instructional strategy and a type of blended learning, which aims to increase student engagement and learning by having complete readings at home and work on live problem-solving during class time. As, most of the information is available in internet, the role of teacher needs to be changed to facilitator and mentor rather than mere lecturer. Virtual labs are interactive, digital simulations of activities to learn/explain certain concepts. Virtual lab improves the content delivery of sll types of courses and is helpful for students understanding and applying the concepts in a better way. [Budai, T., & Kuczmann, M. 2018, Koretsky, M. D et al, 2008]. The impact of a flipped classroom approach on student learning experience is well defined in literatures [Awidi, I. T., & Paynter, M. 2019, Shi, Y et al ,2020]. Enhancement of student learning in experimental design using a virtual laboratory is also well explored [Koretsky, M. D et al, 2008]. Active learning including these methods play important roles in attaining the learning outcomes [Kavitha, D et al, 2016]. It is also reported that flipped class technology may be failed if not properly planned and implemented. [Murillo-Zamorano et al, 2019]. The use of ICT tools in flipped class seems to increase the success rate of flipped class [Kavitha, D et al, 2018]. Many studies are going on to improve the outcomes through flipped class. This paper attempts finding solution for the following research questions and further discusses the initial plan and objective of the session, challenges faced while implementation, observations, outcomes and future directions.

II. RESEARCH QUESTIONS

With the above literature study, the following research questions have been formulated for the research.

1. What will be the improvement in learning outcome attainment if virtual lab is integrated with flipped class?
2. Will virtual lab included flipped class learning improves the CDIO skills of the student?
3. What are the common mistakes done by a facilitator while implementing the flipped class technique and how to overcome them?

III. MATERIALS AND METHODS

This research is proposed as a quantitative analysis with performance assessment scores of the students and qualitative analysis with Focus Group Discussion (FGD). The research is conducted with second year Electrical and Electronics Engineering students of Thiagarajar College of Engineering, Madurai, India. This research study has been implemented in an undergrate engineering course "18EE340- Digital Systems " with 67 students as experimental group. The outcome of this research is compared with other 65 students in the other section (controlled group).

One of the important concepts in the course is to design synchronous counters. The procedure of designing will be in 'understand' level which is normally covered in one lecture hour. For designing, it is required to start the procedure from the state table. But, generating the state table for the given case will be in 'apply' level. Hence, it is planned to provide material for design procedure as out of class activity and generating the state table will be handled as in-class activity. This enables dealing higher order thinking skills inside the class. The realization of the design can be done using virtually using software which provides stronger learning and confident to the students towards the topic. [Kavitha. D., & Anitha. D ,2021]

At the end of this activity, students will be able to

Design synchronous counters by generating suitable state tables for the given task/application.

This counter design is one of the important topics in CO5 which is in Apply level. Alarm Clock, Set AC Timer, Set time in camera to take the picture, flashing light indicator in automobiles, car parking control are some of the real time applications of synchronous counter. They are used for measuring frequency of occurrence and time period of different parameters in industries. This topic is especially chosen for flipped class since some students understand the procedure easily and some asks repeated doubts. Hence, if this is given as out of the class material, they can learn in their own pace.

This study used the academic data of students such as test performance, performance in the activity conducted and also the qualitative analysis using focus group discussion. To understand the learning outcome attainment improvement, the performance of the experimental group students are compared with the performance of controlled group students in other section who received the same question paper.

IV. EXPERIMENT CONDUCTED

To address the learning objective, some concrete material is required which should not be exhaustive. It is essential that students should learn the procedure for designing the circuit as well as to simulate the designed circuit. Though there are wonderful learning materials from online resources, a personal touch with the students is required from faculty side (Anitha & Kavitha, 2021). The learning material has been prepared by the course conducting teacher for students to learn in the self-learning mode. It is a 14 minutes video file with the following link
https://www.youtube.com/watch?v=1nGbWC7A86o
Content of the video includes design of 3-bit up-counter using J-K flip-flops with the detailed description of design procedure. After the procedure explanation, the video describes how to simulate the designed circuit and verify the results.

A. Initial out-of-class activity:

The students should follow the video in their own pace and have to work out the same problem in their course journal (notes). Then they need to simulate the circuit using the online simulation software. To assess their out of class learning before they come for in- class activity, it is planned to conduct a quiz based on the out of class material and activity. If they failed doing out of class activity, they can't understand the follow-up activities inside class. The quiz results can be easily analyzed and students who don't participate can be noted easily for further action.

The following message is informed in the class and also recorded and disseminated to the students via whatsapp group along with a support word file that details the step by step process to be done by students. The flow of the out of class activity is given in fig 1.

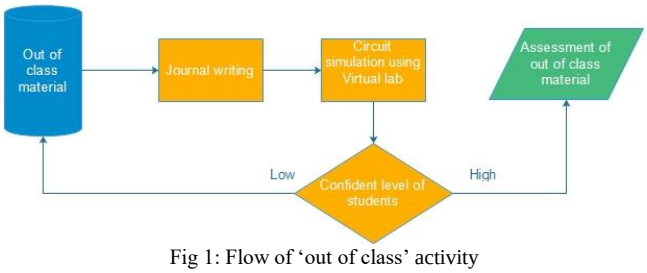

Fig 1: Flow of 'out of class' activity

The information provided to students are as follows:

"*Dear students, we are going to participate in a flipped class activity. The attached file provides you detailed information. You are given with a youtube link which deals with the design of synchronous up counter. It is one of the most important concepts in our course. You will definitely*

get these types of questions in both internal and terminal exams. You have to view the video and start doing the procedure as stated in video in your course journal. Very essential data is provided in the video. So, watch with patience until end. Subtitles will be available if the cc-icon found below the video screen is clicked. After that, simulate the circuit in https://logic.ly/demo. Once you grasped the concept after viewing that 14 minutes video, you need to attend a quiz in the link https://docs.google.com/forms/d/e/1FAIpQLSdP0OI2xpJ_hab7mnIanonJyqgb91-jM5gAp7a8lDm7eTGzEA/viewform?usp=sf_link available in the support word file. You should complete these activities in the week end holidays before you come for the next face to face interaction class. We are going to have 'learning by doing' activities in class time. You will be working with teams. The main objective of in-class activity is to generate state table for the given task. 5 different tasks will be given. You should discuss along with your team members and generate state table. After completing this, you select one among them and design the complete circuit. At the end of the activity, one test task will be given to all. Students need to solve it individually without their group help. Formal feedback will then be collected regarding your experience and learning from this Flipped class activity.

For a flipped class in-class activity, it is normally proposed to have a group to improve understanding through peer learning. Different strategies are reported for the formation of Collaborative groups. [Gratton, L., & Erickson, T. J. 2007] As entire activity is in-class, heterogeneous group is preferred. The plan is to form 14 groups with 4 to 5 students (There may be absentees in total strength of 70). Based on test marks, top 14 students will be called to the stage and appreciated. Then the remaining students are asked to form a team according to their month of birth. January born students will form a group. Similarly 12 groups are formed. If any group has members>4, students are again separated based on criteria like, students born upto 15 dates are picked to form a new group. These excess students form 2 more batches and added to groups having members<3. The top 14 students are assigned to the 14 teams according to their willingness. If two toppers opt same batch, priority goes to younger. This strategy will result in heterogeneous group where top performers are available to avoid deadlock.

Plan:

1. Create video, create quiz, In-class tasks, test task, feedback form
2. Guide preparation regarding the sequence of activities to be done by students
3. Circulation of guide to the students using whatsapp and LMS(Learning Management System).
4. Providing suitable deadlines for each and every activity.
5. Assess google quizzes and get the data of non participating students.
6. Non participants are motivated by suitable strategy such as involving in mandatory discussion and should made to participate.

The in-class activity plan and implementation is given in Table I.

TABLE I: THE IN-CLASS ACTIVITY PLAN AND IMPLEMENTATION

Activity No.	Activity	Planned Time (Minutes)	Actual time (Approximately in minutes)
I	Students are grouped with 4 to 5 members per team. Thus 14 teams are formed. Each team generates team name.	5	10
II	Think – Share – Task 1		
	Think : Students should individually think of the state table for task 1	5	7
	Share : Students share their thought process with their team mates and write state table	5	8
III	Think – Share – Task 2	10	15
IV	Think – Share – Task 3	10	15
V	Think – Share – Task 4	10	Not conducted
VI	Think – Share – Task 5	10	Not conducted
VII	Students as a group, develop complete solution for any one task with assistance of faculty	20	20
VIII	Test problem / Individual activity	15	20
IX	Peer assessment using rubrics	15	20
X	Students are instructed to provide reflections on flipped classroom activity in online survey form.	10	5
	Total	115	120

The rubric for the last assessment problem (Activity VIII) is provided to the students. Out of 15 marks, the problem is evaluated by their peers. Solution is provided on the board. Rubrics used for assessment by peers is given in table II.

TABLE II: RUBRICS USED FOR ASSESSMENT BY PEERS

Criteria No	Criteria	Ratings			
1	Conversion of problem statement to state table	4 – All entries in the state table are correct	-0.25 for each wrong entry in the table		
2	State diagram	3 – If state diagram is perfect	-0.25 for each wrong arrow or state or missing data		
3	Drawing K-Map and obtain expressions	5 – Expressions are correct.	3 to 4 – K- maps are drawn correctly but expressions are longer	2-Mistakes in K-map and entry	0-1 – Lot of Mistakes in K-map and entry or k-map

					not drawn
4	Logic circuit implementation in virtual lab	3 Perfect circuit as per the expressions	-0.25 for each missing component		

V. RESULTS AND DISCUSSIONS

Student Participation in (%)

- Out of class activity : 78%
- In class activity: 95%

To check whether the set objective is reached, the result of in-class activity (Individual test problem) is assessed in class room and is given in Fig 2.

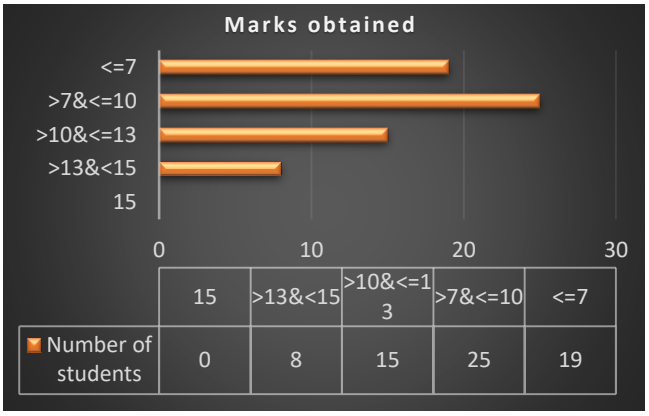

Fig 2: In-class activity marks obtained by students

67 students participated in this assessment. The set target is, 60 % of the students will score more than 10 marks, but only 34.3% of students were able to achieve. At the nutshell, Students found flipped class as a new experience and enjoyed it. Focus group discussion is conducted and open feedback of students are collected. The feedback is that students enjoyed the group activities inside the class and felt refreshed. The out of the material is helpful for them to learn in their own pace.

Some feedback in the voice of students are as follows:

Problems worked out in class fetched me confident to solve test problem myself
Virtual lab make me to understand fast
It is fun to simulate in Logic.ly and I learnt the concept clearly
I love the class time in which I learnt many from my friends and mam.

From the feedback, it seems that students enjoy the experience and wished for the same in near future also. These activities may be conducted during the beginning and mid of the semesters and not at the end.

A. Research Question 1- Results and Discussions

What will be the improvement in learning outcome attainment if virtual lab is integrated with flipped class?

The experiment conducted is the portion for the second internal continuous assessment test - 2. The assessment pattern of this test is provided in table III.

TABLE III: ASSESSMENT PATTERN OF TEST -2

S.No	Bloom's level	Number of questions	Mark of each question	Total marks
1	Remember	5	2	10
2	Understand	4	5	20
3	Apply (Either – or)	1	20	20

Most of the students in the experimental group did the apply level question in this model correctly and got 16.5 marks as an average. Two questions are directly related to the taken learning outcome. (One is compulsory and other one is Either – or choice of same outcome)The results of Maximum marks and Average marks obtained by both groups for questions in different Bloom's level are provided in the table IV. 14.5% improvement in marks is observed. ((19.5-16.5)/24)

TABLE IV: MAXIMUM MARKS AND AVERAGE MARKS OBTAINED BY BOTH GROUPS FOR QUESTIONS IN DIFFERENT BLOOM'S LEVEL

Question No as per question paper	Bloom's level of question	Maximum Marks of the corresponding question	Experimental group Average	Controlled group Average
A3 , A4	Remember	4	3.5	3.5
C1/C2	Apply	20	16.5	13

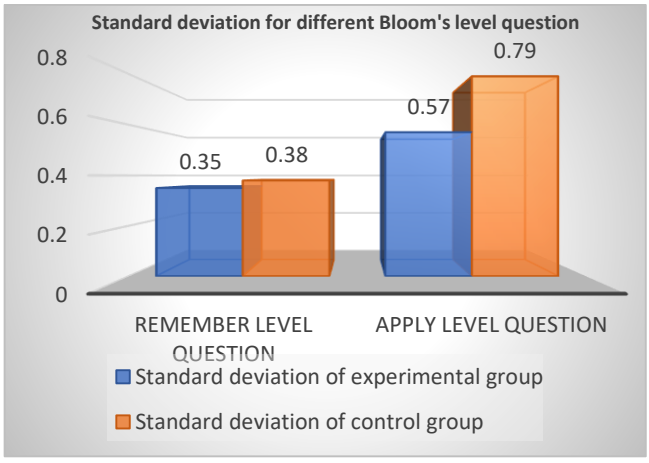

Fig 3: Standard deviation of both groups for different Bloom's level question

Standard deviation of both groups for different Bloom's level question is shown in figure 3. It is inferred that higher cognitive skills are improved with the conducted experimentation. The standard deviation is same for remember level question for both groups. It is noted that standard deviation is high for controlled group implying the

presence of very low mark as well as very high mark. For experimental group, the deviation is low indicating the learning of all students is good.

B. Research Question 2 - Results and Discussions

Will virtual lab included flipped class learning improves the CDIO skills of the student?

To measure the CDIO skills of the student for the mentioned course outcome, the split-up of the marks obtained by the students in the question C1/C2 is taken. The marks are analysed in C(Conceive)- D(Design) – I(Implement) skill as O- (Operate) skill is not applicable in assessment exam.

The The broad classification of marks related to CDIO skills are shown in table V.

TABLE V CLASSIFICATION OF MARKS WITH RESPECT TO CDIO SKILLS

S.NO	Mark split-up parameter	Maximum Marks	Average marks of experimental group	Average marks of control group
1	Correct formulation of real world problem (CDIO Skill: Conceive)	5	4.25	3.13
2	Design is clear and error-free (CDIO Skill: Design)	10	7.75	6.5
3	Implementation using logic gates and flip-flops (CDIO Skill: Implement)	5	4.5	3.37

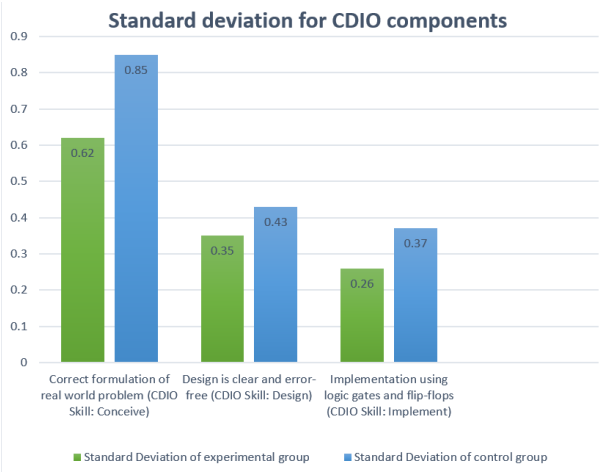

Fig 4: Standard deviation of marks for different CDIO parameters

Standard deviation of marks for different CDIO parameters for both groups are shown in figure 4. From the analysis of SD, it is evident that students feed difficulty in conceiving the problem than designing and implementing it (Both groups). This is primarily due to the fact that they have given training for design and implementation but no much prior training on formulating a real world problem. Still SD is less in experimental group in all the parameters indicating the FC activity along with virtual lab integration improved students learning in the topic and leads to the increase in attainment.

C. Research Question 3- Results and Discussions

What are the common mistakes done by a facilitator while implementing the flipped class technique and how to overcome them?

Initially the teachers are given training for conducting flipped classes. Various recommendations to faculty for improving the TLP methods are already provided in the literatures. [Anitha, D et al, 2020, 2021].

To obtain the common mistakes, case study in different courses are done. Thus, Then after the implementation of flipped class, some observations are taken. The different implementation is done in different departments with varying students as shown in Table 6.

Flipped class integrated with virtual lab is done for different students in five different classes. Based on feedback of teachers in different five experiments conducted as in table VI, the general observations is provided in this section.

TABLE VI : DEPARTMENT AND COURSES IN WHICH EXPERIMENTS ARE CONDUCTED

Case Study No.	Department	Course Name	Number of Students
CS1	EEE	Digital Systems	70
CS2	Data Science	Predictive Analytics	40
CS3	MCA	Data Structures	58
CS4	EEE	Soft Computing	68
CS5	EEE	Computer Architecture	24

The success of flipped class activity is measured through the students pass percentage in the last individual activity.

From table VII, it is noted that the planning was around 74.9% success (Mean value). Most of the planned activities are conducted.

TABLE VII: PASS PERCENTAGE REPORTED IN CASE STUDIES

Case Study No.	Number of Students	Number of students passed	Pass Percentage (%)
CS1	70	48	68.57
CS2	40	33	82.5
CS3	58	42	72.41
CS4	68	46	67.65
CS5	24	20	83.33
		Average Pass %	74.89

Initial plan of the teachers reflected their minimal previous experiences. Also, some pitfalls are expected and alternate plan B and C are made ready. Even, plan collapsed at some instants due to disinterest showed by students at some point of time. Teachers reported that they might have chosen some wrong problems for the activity and these accounts to 25% failure. Also it is interestingly noted that increase in the number of students results in lower pass percentage compared to other case studies with minimum number of students. This may be explored as separate research study that if there is any empirical relationship between these strategies and the number of students participating in it.

Main challenges are listed in table VIII and probable way of addressing them is also provided.

TABLE VIII: MAIN CHALLENGES AND ADDRESSING OF CHALLENGES

S.No	Challenges	Addressing of Challenges
1	Some students who were not regular for the classes made an excuse for not doing out class activity, even they knew about the activity through whatsapp group. But, they are present for the in-class activity	The importance of the activity is highlighted to them. Warning is given that attendance will not be given for in-class activity if they don't do home works.
2	Some students report various reasons for not viewing the video and submitting the google forms	The students are asked to take the responsibility and peer instructions are motivated to complete the task.
3	Some students show disinterest towards the activity & Non participation in group activities	Non participating students name is written on the board and erased if participated.
4	Too much noise inside the class	Green/Red cards used
5	Responding to students as a single person	Hand raise and queuing technique to respond to batches. Waiting time is used to do next activity
6	Time management	The speed of the activity shall be improvised using suitable ICT tools and technological devices.

Most of the above listed challenges were anticipated in the beginning itself and hence, teachers had some ideas to address them. There might be some unexpected problems too. For example, Internet speed is the major challenge faced by students during out class activity while simulating the circuit in the given online virtual lab. In one case, this result in the formation of intermediate states in the simulation and some students were really confused with the working of the simulation. Then, problem is addressed and the students are informed to simulate the circuit only if internet speed is >25Mbps.

VI. FUTURE IMPLEMENTATION

In the next run, the last assessment part of the FC will be included in the session internal marks and will be announced earlier to the students. This will be informed to the students in well advance so that students will seriously participate in the activity. The experience gained by the trained faculty shall be taken in the planning sessions. These FC activities may be conducted in the beginning and mid of the semester and avoid this during the end of the semester. Problems or in-class activities should be prepared with much more care so that the students should enjoy and not exhaust with the activities. The support of projector to highlight the problems/ noise levels may be also taken.

VII. CONCLUSION

In this research study, experimental group is taught the concept with FC integrated with virtual lab. The research study focused on comparing control group with experimental group for their performance in a common test. The research question is formulated for the study of impact of such activity on the attainment of learning outcomes. From the research analysis, it is found that properly planned and implemented virtual lab integrated flipped class has much impact on the development of CDIO skills of students and improved the learning outcome. It is also seen that CDIO skills are correlated to this active strategy. Standard deviation is computed for all the cases to confirm the participating score of all students. Hence, the required skills of a graduate engineer shall be fostered through these activities. Different five case studies on FC integrated with virtual lab are taken and the success rate is computed. The faculty involved in these case studies are priorly trained with pedagogy methods and hence, their experience shall be used for the strategy improvement along the peers. This paper also discusses the common mistakes done during planning and how to overcome them based on experiential learning.

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