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Redesign of Digital Circuits course for enhanced learning

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Abstract: The paper presents the restructuring of course design and delivery, to attain the enhanced learning in Digital Circuits course through pedagogic practices and hands on experience in laboratory. The objective of the paper is to enhance the understanding of the course beyond the class room teaching. The traditional approach of course design, course delivery and course assessment provide less scope for better learning of courses. To address the limitations of traditional approaches, an Outcome Based Education (OBE) proposes many pedagogical practices. The paper proposes a framework to restructure the Digital Circuits course w.r.t.. to content delivery in the class, course projects and the reframing the laboratory experiments. The contents delivery is supported by expert lecture through videos, course project is aided by concept/prototype development and the lab is formulated to exercise multiple problems on a single topic. The students' attainment is measured and analyzed through examination results and feedback. The technical and professional outcomes are achieved through the proposed framework.

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1. Introduction

The quality of education is a key performance indicator for any institution specifically in the areas of teaching and learning. The process of learning should not be passive and also it should not be limited to an individual. Learning can be meaningful when an individual starts developing a capability of using the ideas and information, tests the given information and generates new ideas [1]. At the same time as students begin to ask out of box questions rather than simply answering the questions is the point of opportunity where the strategies of the faculty can be enhanced. A teaching can be said as effective when the procedures followed are appropriate and its purpose benefits the student learning [2]. In this paper we seek to address this aspect.

For learning to be successful, student's involvement is essential and as a facilitator the teacher has to perform the tasks of guiding and promote student interaction. In this paper we address the teaching-learning based strategy development for the Digital Electronics subject, Laboratory and course project. A demonstration of a concept where relevant example is solved in the class or laboratory and students are asked to develop a design for the given problem is regarded as a basic method.

In this paper we see how a batch of around forty students are divided into smaller groups including two or a maximum of three students in a group and the strategies used to clarify the concept by making the students discuss or debate in the team to find the appropriate solution for the design and then tend to implement them further. This process also helps the students to interrogate with the fellow teams as to know what problem statement are the fellow teams working upon and analyse the design flow that these teams have used to arrive at the solution. This debate and interrogation with the co- groups along with the teacher's efforts to frame such relevant and brain storming question sets helps the students to find multiple solutions for a given problem. These solutions are cross verified by the help of simulation tools before implementing on the breadboard.

This methodology helps in making the student become active team-players. The same aspects are further enhanced where students are made to deploy their ideas as a part of course project, thus focusing on the ability of the student to divide the given task into different modules and share themamong themselves, thus understanding the role of individual in carrying out the process and identifying themselves as role-players. These explorations help students to regulate themselves to new concepts and principles and also allow them to maintain equilibrium by understanding each other mutually [3].

During the process of such joint activities, students may have to articulate their opinions, predictions and interpretations [4]. Sometimes these peer collaborations may result in conflicts when students disagree in approaches or interpretations of their team-mates while arriving at the solution to the task. This can also be taken as a part of learning as the students co- construct shared knowledge while solving a problem by understanding and complimenting on each other's ideas [5].

The paper demonstrates:

- In-depth learning in digital circuit course using pedagogical practices such as videos in the class.
- Paradigm shift in the course learning through course project to provide better exposure to simulation and prototype development.
- The redesign of laboratory plan to frame problem statements on the same topic in order to provide more exposure to varieties of problems.

The rest of the paper is organized as follows. Section 2 provides Literature survey, Section 3 provides the proposed methodology, Section 4 provides discussions the results and conclusions are provided in Section 5.

2. Literature Survey

In order to tackle with the real-life technical problems, students need to develop an art of critical thinking. Many researchers have highlighted the need and importance of the thinking ability [6]. Imposing the thinking ability within the students makes them extract the information by proper analysis which includes removal of biased or even false contents and hence sorting out only the subjective information [7]. According to the discussion done in [8] students need to be instructed on how to use the tools for enhancing their abilities and helps them to explore similar tools to perform the tasks in hand thus enabling them to acquire knowledge.

As per the discussion in paper [9] it is said that making receive effective information and to practice deliberately can improve the skills and this is also associated with receiving appropriate feedback by the students. This practice is usually followed and without making the students to explore and inculcate the habit of thinking and analyze the related concepts would be a drawback of teaching. As per [10] students need to be scaffold by the teachers to bring out their thinking with respect to their learning from various perspectives and make them deploy the task with a structured presentation. Paper [11] highlights on the thinking levels given by revised Bloom's taxonomy that needs to be incorporated by the students. There are six such levels which are listed as follows:

- Knowledge
- Conceptual understanding
- Implementation
- Justification which is followed by analysis
- Regulating their analysis by self evaluation
- To create the given task in hand.

The authors in the paper [12] say that though the

aspects of critical thinking and making students think creatively are complementary to each other, but both these skills are in favor of the student and encourage the independent thinking ability of the student. The discussion in papers [13, 14] is about incorporating skills in the students in-order to enhance their thinking capabilities. Some of these skills are,

- Logical argument with proper evidence
- Analyzing the quality of the given sources
- Synthesizing the results from variety of sources
- Reasoning from general to specific (deduction)
- Reasoning from specific to general (induction)
- Solving the problems in hand by knowing the given specifications
- Evaluating their own decisions from different view points

Author in [15] suggests that a physical phenomenon can be made to understand conceptually by visualizations through demonstrations and experimenting in laboratories. But this paper does not specify regarding the student development in several aspects. As per the author's view given in the paper [16] scaffolding is the process where students are supported till they are able to apply new skills and develop the strategies without any further guidance by the teacher and this has been regarded as an excellent method in enhancing the thinking ability of the student. In [17] co- operative learning is emphasized which enables the knowledge of scaffolding by making the students discuss and interact in a systematic way. Paper [18] says that students can be asked to identify the logic or the origin of the conceptual idea by posing the questions in that regard.

As per the analysis made it says that scaffolding based activities help the students to develop the expertise in the following:

- Solving problems by capacity of cognitive thinking
- Ability to appreciate, value and care by developing the affective capacity
- Capability to perceive and apply physical skills
- Co-native ability which helps them to commit, decide and act.

3. The Proposed Framework

The proposed framework is practiced to teach the undergraduate courses of III semester for the School of Electronics and Communication Engineering and Department of Electrical and Electronics Engineering. The Digital Circuits course is restructured to enhance the practical exposure of the students towards the theoretical concepts. The digital circuits course is structured as classroom teaching for 4 credits and laboratory experience for 1 credit. The proposed framework was practiced for strength of 370 students. The proposed structured for the course is discussed as follows.

A. Classroom Teaching

The classroom teaching is categorized as content delivery and course project.

1) Content delivery:

The course contents are retained and mode of content delivery is restructured so as to enhance the teaching learning process. The traditional mode of content delivery of using chalk and talk was aided by expert lecture through videos. The content was delivered with real-time examples for formulating the problem and providing an engineering solution for the same. The real-time example was scenario based which helped the students' approach towards problem solving.

The Table I provides the traditional problem statements and the proposed statements.

1) Evaluation:

The students are evaluated for their understanding of the course thrice in a semester. The evaluation is twice through continuous internal examination (CIE) and once through semester end examination (SEE). The traditional evaluation was adhered to only PO-1 of ABET which was to apply basic engineering knowledge. The restructured course addresses PO-2, PO-3, and PO-5. PO-2 caters to demonstrate an ability to formulate a solution plan and methodology for an engineering problem. WhereasPO-3 provides an ability to generate a diverse set of alternative design solutions. Finally, PO-5 demonstrates an ability to

Table 1: The traditional problem statements and the proposed statements.

Traditional Statements	Proposed Statements
Find The minimal sums for the following Boolean Expression using K-Map reduction technique. P=f(w,x,y,z) = ? m(1,5,6,7) +dc(0,4)	Two motors, M_2 and M_1, are controlled by three sensors, S_3, S_2, and S_1. One motor, M_2, is to run any time when all three sensors are ON (true). The other motor is to run whenever sensors S_2 or S_1, but not both, are ON and S_3 is OFF. For all other sensor combinations where M_1 is ON, M_2 is to be OFF, except when all three sensors are OFF, both motors must remain OFF. Identify a technique that cannot be programmed and that is used for less number of variables, to provide minimal sums.
Design a Synchronous Mod-6 Counter using clocked JK Flip-Flops	Design a system to provide status of the number of people present in a seminar hall. The maximum occupancy of seminar hall is 7 members. The status is checked six times in an hour at equal intervals. It is observed that, initially it was empty. After these four members entered the hall, then one member left, and then two more entered. Again three members left, then five entered at the end. Store this status and demonstrate the occupancy of the hall continuously at all intervals. Use Flip flops with two inputs.

identify/ create modern engineering tools, techniques and resources. The results obtained in traditional mode of course delivery did not highlight the student's attainment in formulating and analysing the engineering problem. The proposed course design emphasizes the student's performance in PO-1 as well as PO-2.

2) Course Project:

Project is a universally used word in engineering, defined as a unit of work carried out based on the provided specifications. The projects will have various structures w.r.t. size of project, timeline of project, complexity of projects etc. Projects relate to the fundamental concepts and techniques of an engineer's discipline. Mini projects involve one area of engineering specialization, but major projects will be multidisciplinary, not only involving engineers from different specializations, but other professional and non- professional personnel also. Successful completion of projects in practice requires the integration of all areas of an Engineer's undergraduate training.

Course project is a component associated with the teaching of a course. Course projects are defined to occupy few weeks for implementation and is directed towards the application of knowledge. Project-based learning is usually accompanied by subject courses to enhance skills such as time management, resource management, group learning and discussions, self directed documentation, budget requirements, optimization of design, oral and written presentations. Hence the chalk and talk mode of content delivery limits the students understanding and imagination and enhances the above discussed skill set. The digital circuit course is framed so as to address many more aspects of circuit design and simulation. A proactive treatment is initiated for improved level of understanding of course content with better exposure to practical issues.

The Table II provide the problem statements for the course project. The statements are framed such that the students are able to apply the knowledge gained the course and get better exposed to the formulation of objectives for the stated problem and implementation of the same.

Table 2. Problem statements for course project

Sl. No.	Few of the proposed statements
1	Design and implement an IC tester for testing the basic gates.
2	Design and implement 4 bit binary divider using Vedic mathematics.
3	Design and implement a 4 digit lottery number generator.

4) Competency addressed in the Course and corresponding Performance Indicators

The Table III provides the information about the competency addressed in the course through the listed performance indicators. The students are focused towards the attainment of problem formulation, identifying multiple solutions, optimizing the designw.r.t. cost, components and space, simulation of the optimized circuit, developing the prototype on printed circuit board.

Table 3. Competency addressed in course project

Competency	Performance Indicators
PO 2.2 - Formulate a solution plan and methodology for an engineering problem	PO 2.2.2 - Identify, assemble and evaluate Information and resources.
	PO 2.2.3 - Identify Existing processes/solution methods for solving the problem, including forming justified approximations and assumptions
PO 3.2 - Generate a diverse set of alternative design solutions	PO 3.2.1 - Apply formal idea generation tools to develop multiple engineering design Solutions
PO 5.1 - Identify/ create modern engineering tools, techniques and resources	PO 5.1.1 - Identify modern engineering tools, techniques and resources for engineering Activities
PO 10.1 - Comprehend technical literature and document project work.	PO 10.1.2 - Produce clear, well-constructed, and well-supported written engineering documents

5) Sample project snap shots and evaluation:

The course project is evaluated for the above performance parameters. Figure 1 shows the simulated circuit for the lottery number generator for 4 digits. The same circuit is implemented on printed circuit board as shown in Fig. 2

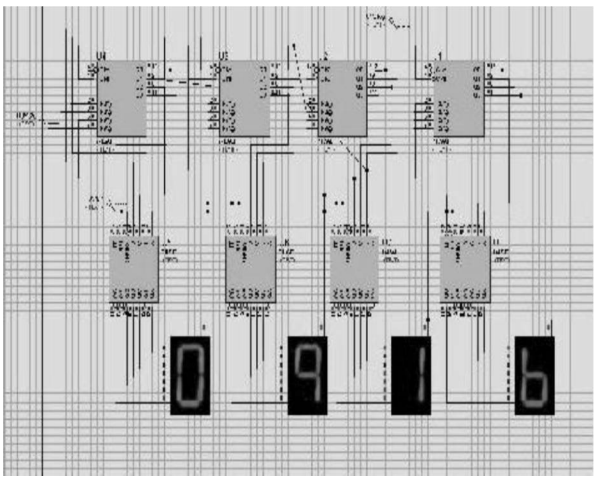

Fig.1: Simulated circuit for the sample course project

B. Laboratory experience

The objective is to enhance the learning of the course beyond the traditional mode of conduction of experiments. Where, lab design, conduct and lab assessment provide less scope for in depth learning of courses. Outcome Based Education (OBE) is an effort to overcome limitations of traditional education by using progressive pedagogical models, ideas, to meet student outcomes of ABET.

1) Laboratory categorization:

To meet the expectations of present engineering education, the designs of Digital Circuits lab experiments are categorized as demonstration, exercise, structured experiments.

Demo Experiments: The demonstration experiments are designed basically to get exposure regarding the major components used in the laboratory and to apply few basic concepts.

Exercise Experiments: The exercise experiments are given to provide experiential learning to the students in basic working of modules, components and small systems.

Structured enquiry experiments: The structured enquiry experiments are given to provide an exposure to identify solution to given problem, existence of alternate solutions and to choose optimal.

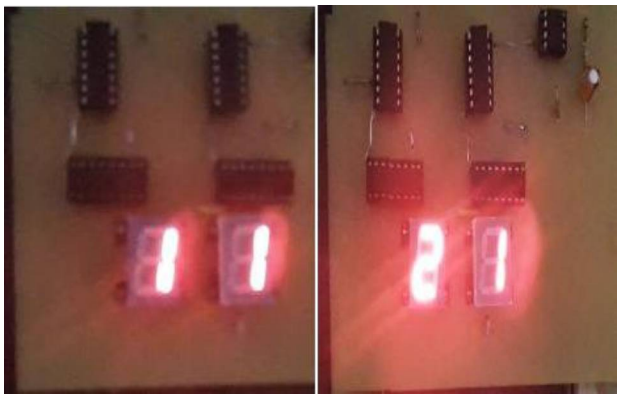

Fig. 2: Implementation of designed course project on PCB.

The Digital Circuits laboratory comprises of total 10 experiments out of which 2 are demonstration type, 6 are exercise type and two are structured type experiments. The paper concentrates on restructuring exercise and structured enquiry experiments. Each of the exercise and structured enquiry titles are framed with 6-10 problem statements as shown in Table IV. A batch of 40 students is formed for laboratory exercise at a time supervised by faculty members. Different statements will be given to a sub batch of 2 students

Table 4: List of problem statements for a single title.

Few of the proposed problem statements	
Title :	Design and implement n bit magnitude Comparator
Statements:	• Design 6 bit binary comparator using only one 4 bit comparator i.e. 7485. • Design 5 bit binary comparator using only one 4 bit comparator i.e. 7485. • Design 6 bit binary comparator using only two 4 bit comparators i.e. 7485. • Design 5 bit binary comparator using only two 4 bit comparators i.e. 7485. • Design 1.2.3.4 bit binary comparators using only one 4 bit comparator i.e. 7485. • Design 1 bit and 2 bit binary comparators using only basic gates. • Design 1 bit and 2 bit binary comparators using only NAND gates.

Table 5. Competency addressed in laboratory

Competency	Performance Indicators
PO 4.1- Conduct investigations of technical issues consistent with their level of knowledge and understanding.	PO 4.1.2- Relate modern engineering experimentation including experiment design, system calibration, data acquisition, analysis and presentation
	PO 4.2.3- Identify multiple solutions, and choose an appropriate design for the problem.
	PO 4.1.4- Establishes or validates a relationship between measured data and underlying physical principles
PO 5.2- Select and apply discipline specific tools, techniques and resources	PO 5.2.2- Demonstrate proficiency in using discipline specific tools

for design and implementation. The students will collect the statement one week prior to the scheduled dates. On The scheduled date the students will design the circuit on the paper, simulate and implement the same for functional verification

1) Evaluation in laboratory

The students are evaluated for the competencies in table V through the predefined rubrics. The outcome of this mode of laboratory experimentation:

· Avoids copying the design from friends.

· Prevents mass design and simulation

· Avoids the last moment preparation for laboratory.

4. Discussions and Results

This section provides the discussions on the results and feedback for the proposed framework and its implementation.

A) Feedback of students

Q1. To what extent expert lecture has enhanced the overall learning of Digital Circuit Course?

a. 80-100 % b. 60-80 % c.40-60 % d. less than 40 %
Q2. The activity has helped in gaining proficiency in using the simulation tool.

a. Strongly Agree b. Agree

c. Neutral d. Disagree

Q3. To what extent project-based learning helped in overall understanding of the course?

a. 80-100 % b. 60-80 % c.40-60 % d. less than 40 %

Q4. Has multiple design statements for a single experiment helped in enriching the design concept?

a. Yes b. No

Q5. Time allocated to carry out the entire course was enough?

a. Yes b. No

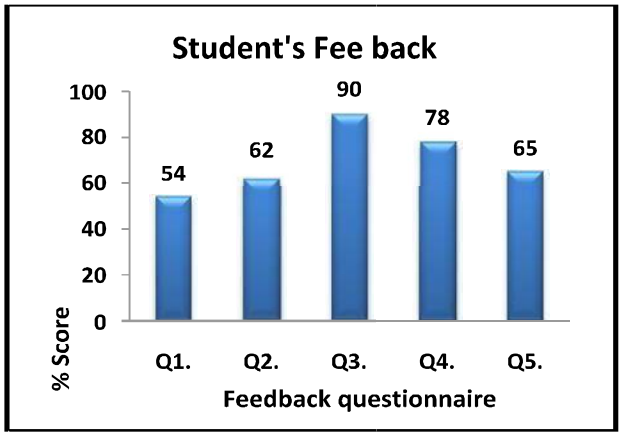

Fig. 3: Feedback Score for overall course design and delivery

A common feedback was taken at the end of the theory and laboratory course. Out of 370 students, 325 students have given the feedback. In the Fig.3 the percentage score of feedback given by students is depicted for the highlighted option in the questionnaire. The feedback was collected through goggle forms. More than 50% of the students said that expert lectures have enhanced their overall learning. 62% students strongly agree that they have gained proficiency in using the simulation tool after undergoing this process. 90% of students expressed that project-based learning has improved the overall learning. Only 18% students said that they are less confident in designing the complete system. Around 35% students have raised a concern about the time allotted to carry out the complete course. The feedback questionnaires are presented below.

B) Attainment of performance indicators

The proposed framework addressing the identified performance indicators are measured through In Semester Assessment Continuously End Semester Assessment. The individual performance indicator is set with a threshold value based on the previous experience. The overall attainment of the performance indicators is depicted by the graph in Fig. 4. The performance is satisfactory but, provides ample scope for further improvement. Few PI's are attained to the satisfaction level, but few are not up to expectations. The proposed framework provided the course instructor to evaluate the skill set of students such as problem formulation, identifying multiple solutions, optimizing the design w.r.t. cost, components and space, simulation of the optimized circuit, developing the prototype on printed circuit board individually. The course instructor could identify the strengths and weaknesses of students and reframe the course for further improvement.

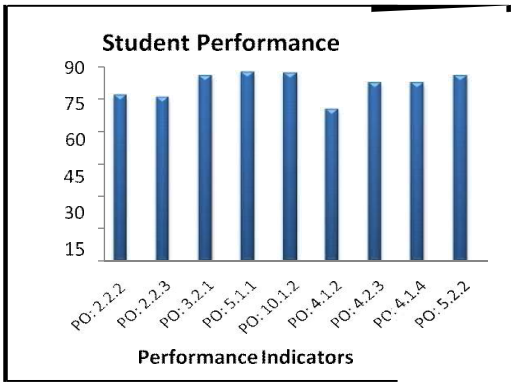

Fig. 4: Overall attainment of performance indicators over a academic year

5. Conclusion

The paper presented the course redesign and delivery, to attain the enhanced learning in Digital Circuits course through pedagogic practices and hands on experience in laboratory. The framework enhanced the understanding of the course beyond the class room teaching. To address the limitations of traditional approaches, an Outcome Based Education (OBE) proposed provides scope for using many pedagogical practices. The paper proposed a framework to restructure the Digital Circuits course w.r.t. to content delivery in the class, course projects and the reframing the laboratory experiments. The contents delivery is supported by expert lecture through videos, course project is aided by concept/prototype development and the lab is formulated to exercise multiple problems on a single topic. The students' attainment is measured and analyzed through examination results and feedback. The technical and professional outcomes are achieved through the proposed framework.

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