Design on Project-Based Learning for Analog Circuits

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***Abstract*— This Work in Progress-Research to practice paper introduces the development of a Project Based Learning course on Analog Circuits. This is a six-credit course of fourteen weeks duration, designed for undergraduate students of Electrical and Electronics Engineering. This paper presents the course structure, project planning and feedback from students. The experience gained by designing and implementing this course will be used to develop improved courses for higher semesters for this batch of students. The overall objective is to help students to design Analog Circuits using discrete electronic components and simple integrated circuits and sensitize them on sustainability goals like power saving by using low power and low-cost components, optimized designs, standard practices and solutions that are useful for society. The Goals, Activities, Products and Assessment (GAPA) for the course are interlinked and logistics planning has been done before the commencement of the semester. The curriculum has been developed to cover the concepts required for developing sustainable products, and the topics discussed involve low power amplifiers, oscillators, wave shaping circuits and filters. The students registered for this course have experienced PBL in their previous semesters and have successfully completed a prerequisite course named Fundamentals of Automation Engineering. They are skilled on using the electronic test and measurement equipment, designing Printed Circuit Boards (PCB) and soldering of electronic components on the boards. Although they are granted autonomy in selecting components and circuit design, project goals are identified by the instructor and evaluation weightage assigned consciously to these goals. Activities are conducted during sessions to help students learn the concepts required for the gradually developing the project. Feedback is required from the students to compare the planned goals versus achieved goals and is analyzed for pluses and deltas. It is also used to monitor the motivation of students, to make the course more interesting for intrinsic learning.**

Keywords*—— *Project Based Learning (PBL), Goals-Activities-Products- Assessments (GAPA

I. Introduction

Analog signals are used in many applications in day to day life- signals from transducers, measuring instruments, telecommunications are few examples. This course has been designed with primary goal of creating competence in engineering graduates for designing and analysing circuits which are used for processing analog signals. It is a core course for second year undergraduate students of engineering. These students have completed fundamental courses of first year using Project Based Learning (PBL) and the enthusiasm shown by them in this innovative learning pedagogy has been very encouraging. Therefore, this course also aims to strengthen the self-directed learning capability as well as experiential learning by students through activities and projects [1]. Note that similar experiences have been reported in [5] and [6].

The rest of the paper is organized as follows the course structure is described in section II, Section III presents projects framework and course progress is described in section IV. Finally, in sections V and VI, student's feedback and concluding remarks are presented.

II. Course Structure

The course has been designed using Goals, Assessment, Activities and Products (GAPA) model where identification of project goals has been done keeping in mind the philosophy that goals should be student centered and situation specific [2]. The assessment, activities and products have been linked to these goals and resources and trade-offs involved have been identified. As shown in Fig 1, GAPA model, two projects were identified for this course: Instrumentation Amplifier and Signal Generator.

The students have been provided with a course file at the start of course, where the syllabus, session plan, references and links to learning resources and the expectations from students and faculty were mentioned. The assessment scheme has been declared in the course file and involves weekly quizzes, periodic assignment of activities, projects and theory examinations. A course portfolio has been created on a Learning Management System [3] and the documents were shared with the students through this infrastructure.

The course has been designed for increasing students' intrinsic motivation in learning the concepts of

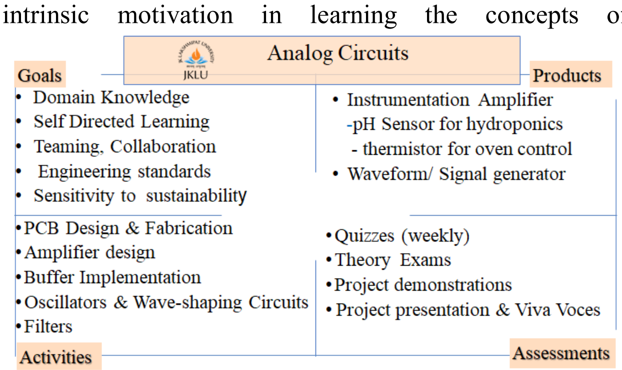

Fig. 1 GAPA model for Analog Circuits Course

Analog Circuits. Instead of having topics discussed serially one after another, the concepts were discussed in a sequence leading to activities and developing the project gradually. The students have been given autonomy in choosing the application-based projects and components, however the learning goals of project were kept common for all teams. The course also inculcates a feeling of relatedness, where students can relate their project to applications which are useful for society. Feedback was taken to assess the Purpose, Autonomy, Relatedness and Competence (PARC) experienced in the projects [4]. The students were asked to rate the parameters of PARC online survey shown in Table I

Handouts have been provided to students well in advance to help them with self-directed learning. The concepts explained include Electronic devices, Integrated Circuits, Operational Amplifiers and their applications, stability of amplifiers, waveforms generators, oscillators and filters. Activities have been done using low cost, low power consuming analog components from Texas Instruments (TI) as the university has developed an Innovation Center with TI University education program. Printed Circuit Boards (PCBs) have been designed such that Integrated Circuits (IC) are mounted on bases where they can be removed and reused, while discrete passive components are directly soldered on the PCB.

The assessment rubric was disclosed as the start of course and is shown in Fig 2. 10 % weightage has been given for activities and 40% for projects, whereas Quiz and Theory exams constituted 50% of the evaluation. Thus, equal emphasis has been given to concept learning through theoretical as well as practical work. The projects were evaluated for various parameters, namely, optimization in circuit design, use of low cost and less power consuming components, tools used, skills developed, time management, presentation skills etc.

III PROJECT GOAL FRAMEWORK

Two projects, each having weightage of 20% each have been planned in this course. The first project is to design an Instrumentation Amplifier to amplify signals from any sensor and send this amplified signal to a processor for conversion to digital form and display. The second project is designing Oscillators and Wave shaping circuits used for many applications like the analog modulation for communication, test and measurement equipment, clock signals for digital systems.

TABLE I MOTIVATION EVALUATION GRID

S. No	Parameter to access	1:	2:	3:
1.	Purpose: I am able to learn interesting things in this project			
2.	Autonomy: I have choice over project design with common goal			
3.	Relatedness: My work done in this project will be useful for some real-life application			
4.	Competence: I get positive formative feedback on my learning process, not just my performance			

1: High, 2: Moderate, 3: Low

The goals for both the projects were determined as per the framework proposed in [2], and are shown in Table II and Table III, respectively. Both the projects are of duration 4 weeks each and activities for the projects were performed in the other 4 weeks, total course duration being 12 weeks.

The second project was originally planned to be implemented using hardware, however, the goals of the project were modified due to lockdown at university due to COVID-19, effective mid-semester. The goal - hands-on learning was modified as students have now used Microcap -12 software and are performing simulation for the project instead of building it on hardware. Self -directed learning

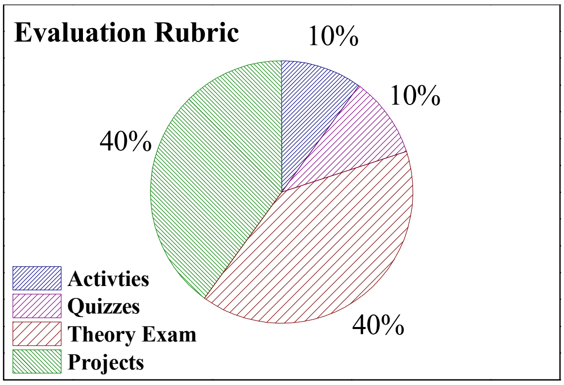

Fig. 2 Assessment Matrix for the course

TABLE II PROJECT GOAL FRAMEWORK FOR PROJECT I

Project Title:- Instrumentation Amplifier		
Project Duration:- 4 weeks		
	Planned Goals	Rate
1.	Domain Knowledge in context of following topics	
	(i) Wein Bridge circuit	5
	(ii) Operational amplifier Buffer	5
	(iii) Differential Amplifier	5
2.	Design using Low power components	5
3.	Hands-on-Learning	
	(a) Using Digital Storage Oscilloscope	4
	(b) Printed Circuit Board Layout design	3
4.	Real-World Application	4
5.	Professional Skills (Communication, Teamwork, and Problem Solving)	4

TABLE III. PROJECT GOAL FRAMEWORK - PROJECT II

Project Title:- Oscillator and Wave-shaping Circuits		
Project Duration:- 4 weeks		
	Planned Goals	Rate
1.	Domain Knowledge in context of following topics	
	(i) Series and Parallel Resonance	5
	(ii) AC analysis for oscillators	5
	(iii) Multi-vibrators	5
2.	Design using low power components	5
3.	Hands-on-Learning Using Microcap Simulator	4
4.	Self –Directed Learning	5
5.	Real-World Application	4

has been given high weightage as students have been shared with handouts for concepts and these have been discussed through virtual meetings. Activities have been conducted for the concepts using the simulation software and students have submitted the snapshots of the results on LMS Infrastructure

IV. COURSE PROGRESS

(A) Project I

The students could decide the real-world applications, and the teams suggested applications like thermistor control for ovens, pH sensor amplifier for hydroponics, flexible tactile sensors for gesture recognition. The students developed concept map for this project based upon their learnings on domain knowledge. Sessions have been conducted for 6 hrs/ week where activities were conducted that lead to building the project. Feedback was taken during these activities to monitor the motivation level of students. This feedback has been analysed using the Motivation Scale framework questionnaire of Table I. The PARC Analysis shows that this could be since students had autonomy in selecting the components and as well as high relatedness of the project. The students developed hand -on -learning in doing measurements using Digital Storage Oscilloscopes (DSO) they enjoyed making track layouts for component connections using Printed Circuit Board (PCB) software. Fig 3 shows the process and sample PCB made by one of the teams for this project. Teams of size -two students were made, and report of the projects were prepared team-wise. Peer evaluation was done for project report as well as presentations were made by individual members on their role in project.

(B) Project II

The students have seen many challenges in second project as this work is done from home. The university campus has been locked down since 15 March 2020 and the students had to vacate the hostels as an unexpected move. However, the teaching was resumed through online mode within 5 days. Initially there were some students who experienced some problem in connecting for online classes due to bandwidth limitations in their network, however this was resolved by their choosing higher data packages. Students could download the simulation software -Microcap 12 and were shared videos tutorials for using the tool. Fig. 4 shows the modified project goals and the activities have been completed using simulator. The students have shown great

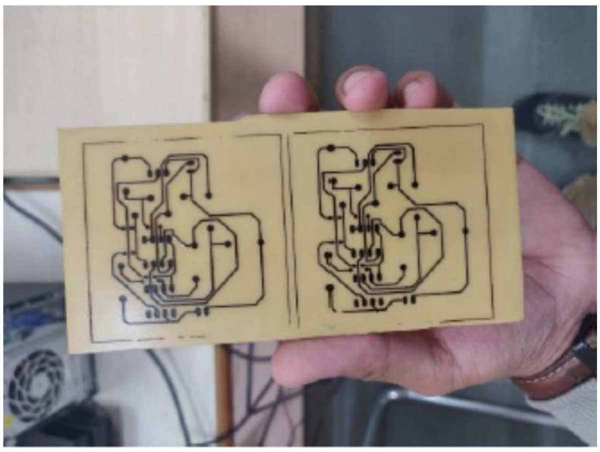

Fig. 3 PCB fabricated by students for the first project

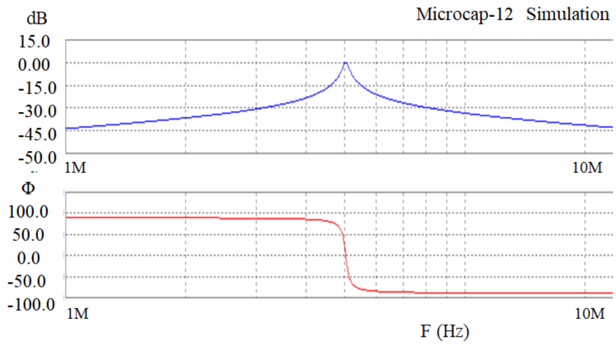

Fig. 4 Snapshot of an activity on Bode Plots done by a student using Microcap-12 simulator

enthusiasm in familiarization with the simulation software and have uploaded the snapshots of the simulation results on the LMS. A sample snapshot on simulation for resonance in series RLC circuit is shown in Fig.4 and this activity has been done individually by students.

V FEEDBACK & ANALYSIS

The feedback given by students for the PARC questionnaire is shown in Fig 5 (a) which shows that the 80% students enjoyed the autonomy for deciding what components were to be used for the project and related the project to real world application. The competence developed by students was high as they had already learnt PCB processing steps using chemicals during a previous course. They improved their hands-on skills as they learnt on doing track layouts using CAD software. The feedback on understanding of three concepts listed in the Domain Goals is shown in Fig 5(b) and reveals that their understanding of concepts was good in 80% students, though 20% students need some more help on understanding some concepts. Feedback on Hands-on skills developed shown in Fig 5(c) indicates that some more practice is required for making measurements using Digital Storage Oscilloscopes (DSO). Feedback on goal -Design skills shows that students acquired high level skills in PCB layout as it was partially automated, and their layout track were neat. Fig. 5(d) shows that 60% students could do self-directed learning whereas 40% sought help on learning the Concepts shared through handouts. Team and Collaboration skills were high in 60% students and moderate in 40% as the choice of grouping the students in team was with the instructor.

The feedback received for the second project is shown in Fig. 6. The feedback shows that 88% students are of opinion that simulations are helpful for learning concepts. In response to question "how well are you able to do self-learning in this course with the resources shared with you?", 63% have replied saying they could do self-directed learning very well, whereas 25 % could do it moderately, while 12% needed help during learning concepts. The intrinsic motivation for project II is also found to be moderate and needs to be explored. The general remark by some of them was that they were comfortable with the course discussions and enjoying doing the activities, despite the social distancing. This confidence build in the students has been a very positive experience of the course

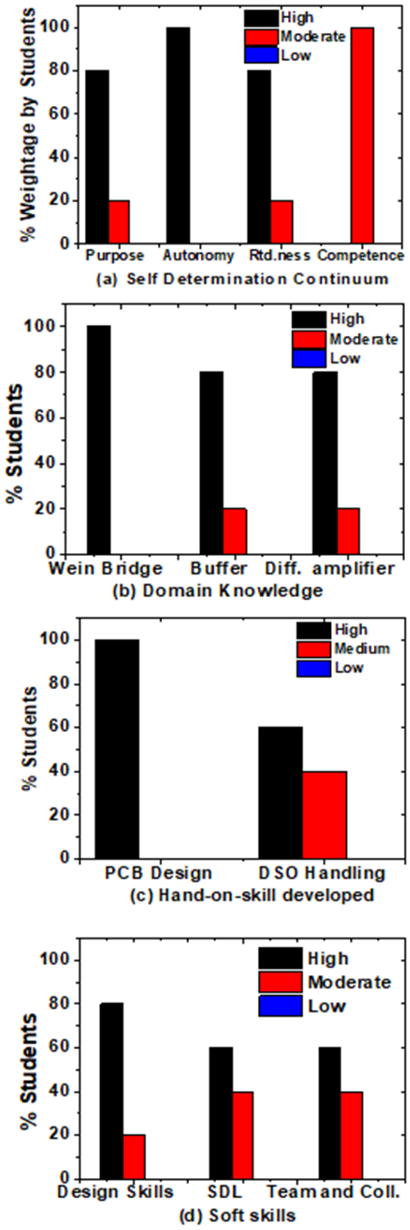

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Fig. 5 (a) PARC Feedback (b) Feedback on goals set for Project I (c) Hands-on skill developed

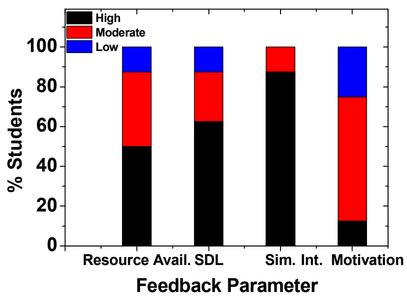

Fig. 6 Feedback for Project II, completed on 31 May 2020

III. .VI OBSERVATIONS AND LESSON LEARNED

A very encouraging observation in this course has been that the structural planning done for the PBL course has helped to incorporate flexibility and modifying the course goals for the 50% course. The second project was initially planned to be implemented using hardware is being done using simulations. The learnings through simulations have been appreciated by students. When asked "How helpful are the simulations for learning the concepts?", students have given an overwhelming positive response. Despite the restricted resources due to lock down, students have continued to perform activities. The self -directed learning built-in this batch since freshmen days has helped these students to stay motivated and achieve competence in learning new concepts and skills. However, given the feedback received, we think that this area needs improvement in future. The PARC questionnaire for Self -Determination Continuum has been found useful to understand the students' expectations from course and thereby improve the course further. The relatedness of projects done by students to real life applications are useful for identifying the types of projects that can be used for startup ventures. The application of PBL research methodologies and modular planning have helped to make this course flexible and sustainable learning even during the global crisis of COVID 2019.

ACKNOWLEDGMENT

The authors acknowledge the management at JK Lakshmipat University for their motivation and support for the new pedagogy which has been implemented for 2018-22 batch of undergraduate students. The support by laboratory staff of Electrical & Electronics Engineering at the Institute of Engineering &Technology is highly appreciated and valued.

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