Curriculum Design and Implementation of Project-Based Learning for Electronics Engineering Graduates

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Abstract: Design, development and analysis are the integral part of electronics Industry. Majority of Electronics Engineering graduates are working in embedded, VLSI, Automation, and Software Industries. To design industry ready curriculum is a major focus of this paper. To cope with industry requirements theoretical approach of Electronics subjects will not provide required skills and unable to build confidence while working in industry. In this paper we discussed autonomous curriculum which is based on project-based learning implemented from year 2016-17. First year curriculum focuses on to development of social awareness to observe social, environmental and industry needs. Second year has been focused on analog and digital components, sensors, market survey and to develop the small circuitry with PCB design. Main focus on third year is given on controlling parameters, Integrated circuits, controllers design and programming like Python, Raspberry Pi etc. Final year has been planned to make students expertise in domains of Embedded, VLSI and Automation to build social and environmentally sustainable projects. Overall 40 percent credit evaluation is based on project-based learning. In this paper comparison of non-autonomous curriculum and present curriculum of autonomous which is project-based learning with soft and technical outcomes measured through rubrics are presented. During last three years it has been observed that project-based learning approach is developing the technical skills like problem analysis, design and development, problem investigations etc. It also improves soft skills like team working ability, leadership quality, marketing skills etc.

Keywords: Autonomous Curriculum; Industry ready curriculum; Skill development.

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1. Introduction

Modern electronics engineering practice has to deal with projects in which complex and initially unclear requirements have to be met in stipulated time. The professional engineer has to communicate with clients to transform ambiguous verbal instructions to demanding specifications by following a system engineering process [1]. He has to organize his work in collaboration with other specialists to comply with objectives and deadlines. It is not unusual for an engineer to work on a product or solution for a client and, at the same time, control the work subcontracted to providers. Engineering education should prepare students for this scenario. Important ingredients of Project Based Learning method are: to provide the students incomplete information and encourage them to complete the requirements and specifications, to promote self-discipline and self-regulation by allowing the students to define their objectives and commitments, and to promote team work, specialization and inter disciplinary collaboration [2,3]. Project Based Learning (PBL) is a teaching methodology focused on students in which the instructor acts as advisor and facilitator. Students are encouraged to think the need of the society and industry. In the first step they start defining problem statement with requirements and specifications. In second step students in a team share their innovative ideas about solutions and find out optimized and creative solutions. In the third step they start design and development parts with modern tools and technologies. Despite the wide variation in PBL models [4], there still exists some common pedagogical principles to all variations, as follows:

- **Problem-based**: Students have to define the problem statement considering real problem addressing to need of society and industry. So, as this can be more motivating to the students than an artificial problem.
- **Self-directed**: Student are able to design and develop solution for given problem statements freely.
- **Experiential learning:** Through experience and interests' students are able to modify their previous work.
- **Activity-based**: Students are actively engaged in literature review, research, decision-making, writing papers, developing products and applying for patents.

• **Interdisciplinary:** Students should provide solution to the problem typically from different engineering disciplines.
• **Group-based:** Due to industry needs students should work in team to facilitate and encourage and improve communication and teamwork skills.

A. Objective of Curriculum Design and Implementation of Project-Based Learning

The design of the curriculum has accounted for the following pedagogical objectives:

- To develop higher level learning skills like design, apply and analyse.
- To inculcate soft-skills like team building, communication, usage of modern tools, project management & finance, technologies and ethical values.
- Ability to develop interpersonal skills to work in inter disciplinary environment.
- To train the students to think, imagine and create.

The paper is organized as follows: Section II details the curriculum structure and its implementation. Section III describes the evaluation methods of PBL. Finally, Section IV discusses the results and conclusions of the paper.

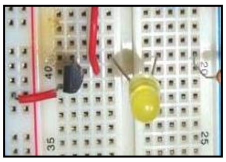
2. Curriculum structure and implementation

The paper discusses the curriculum of Department of Electronic Engineering in the DKTE'S Textile & Engineering Institute, Ichalkaranji. The professors and instructors in the department teach both undergraduate and postgraduate courses in electronics, ranging from electronic circuit design (both digital and analog) to its applications with advanced technology.

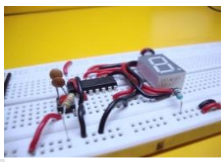
The autonomous curriculum with project-based learning has been implemented from year 2016-17. Project based learning begins with First year. It has been planned to develop social awareness to observe social, environmental and industry issues and needs. From the first year itself they start thinking about the problems related to society. Student visit various places like hospitals, railway stations, bus stations, market, government offices, economical backward areas, farmers, rivers etc. They then discuss these problems and solutions with the instructors which helps to identify technical issues, devolve thinking, collaboration, creative and communication skills. Overall it builds creative energy among the first-year students. They understand social responsibility and develop thought process to provide engineering solutions in societal and environmental contest which is essential for sustainable growth. Student has to implement projects related to social issues in this year. Second year has been focused on analog and digital components along with design and development of small circuitry on breadboard and general-purpose PCB. This is used to develop a strong fundamental electronics engineering knowledge and creates interest in the field of electronics engineering. Main focus on third year is given on microcontroller board design, system design and programming like Python, Raspberry Pi, PLC, and Arduino etc. So as to develop ideas to design innovative projects. Final year has been planned to make students expertise in the fields of Embedded, VLSI and Automation to build social and environmentally sustainable projects with product development. Semester wise detail curriculum of F. Y (B.Tech) and S.Y. (B. Tech) is as shown in Table 1.

Table 1. First year courses and Second year syllabus structure

First year course	
GEP132	Social Innovation
Second Year- Semester-1	
Course Code	**Name of the Course**
ELL201	Engineering Mathematics III
ELL202	**Electronics Devices and Circuits**
ELL203	Linear Circuits
ELL204	Analog Communication
ELL205	**Structured Programming**
ELP206	**Electronics devices and circuits**
ELP207	Analog Communication lab
ELP208	**Structured Programming lab**
ELP209	Circuit Simulation Lab
ELD210	**Mini Project I Lab**
ELL211	Environmental Studies (Mandatory Audit)
Second Year- Semester-2	
ELL212	**Digital System Design**
ELL213	Control System Engineering
ELL214	Linear Integrated Circuits
ELL215	Data Structure and Algorithms
ELL216	**Object Oriented Programming**
ELP217	**Digital System Design Lab**
ELP218	Control System Engineering Lab
ELP219	Linear Integrated Circuits Lab
ELP220	**Object Oriented Programming Lab**
ELD221	**Mini Project II Lab**

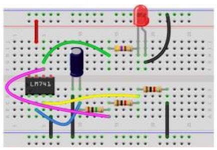


Discrete Component Based Project

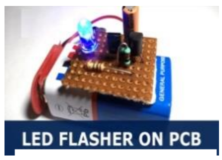


Digital IC Based Project

Mini Project -II



OP-AMP Based Project



Mini Project - I

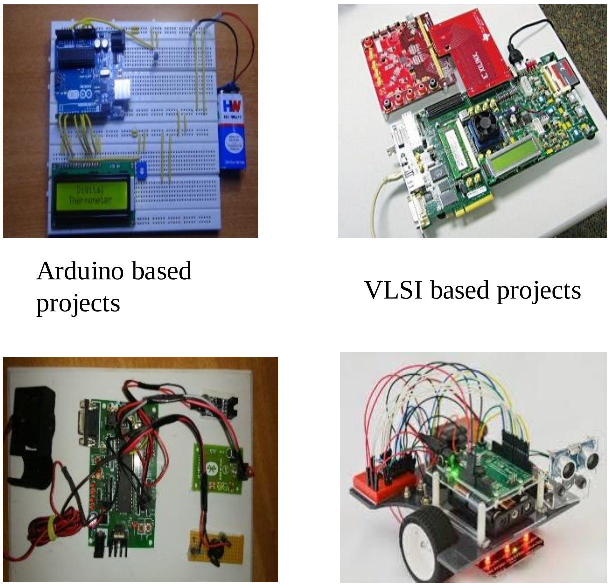
Fig. 1 Projects implemented by second year students.

In second year, first and second semester Electronics Devices and Circuits (EDC) Digital System Design (DSD) and Linear Integrated Circuits (LIC) deals with fundamentals of discrete devices, analog and digital circuits. These are the core electronics subject and its tutorial and lab sessions are purely designed under the concept of project-based learning. In the courses like EDC, DSD and LIC students develop discrete component-based projects on breadboard and general-purpose PCB. Teacher guide students in understanding various terminologies included in the data sheets so that students get acquainted with using sheets properly. This helps them to compare specifications and cost of various components. Students can take help of internet to do market survey for component selection with such curriculum many electronic applications are developed. In mini-project-I students implement discrete component-based projects like water level indicator, security alarms, power supplies etc. In mini-project-II the focus is given to IC based projects. It includes timer, different wave generators, regulators etc. Structured programming and object-oriented programming courses assist in developing programming skills to develop small software-based projects in group. These skills required to fulfil need of today's IT based companies. In these two-semester out of 50 credits, 20 credits (40%) courses teaching learning and evaluation is based on PBL component. Fig. 1 shows implemented projects by second year students.

Table 2. Third year syllabus structure

Course Code	Name of the Course
Third Year- Semester-1	
ELL301	**Microcontroller**
ELL302	Signals & System
ELL303	Electromagnetic Engineering
ELL304	**VLSI Design**
ELL305	Digital Communication
ELP306	**Microcontrollers Lab**
ELP307	**VLSI Design Lab**
ELP308	Digital Communication Lab
ELD309	**Mini Project III Lab**
ELI310	Renewable Energy Sources (Mandatory Audit)
Third Year- Semester-2	
ELL311	Digital Signal Processing
ELL312	Audio/Video Engineering
ELL313	Power Electronics
ELL314	**Electronic System Design**
OE	**Open Elective**: Hybrid & Electric vehicle PLC & SCADA
ELP315	Digital Signal Processing Lab
ELP316	Audio/Video Engineering Lab
ELP317	Power Electronics lab
ELP318	Electronic System Design (Lab)
ELD319	**Mini Project IV Lab**

In third year, first and second semester project-based courses are highlighted as shown in Table 2. It includes Microcontroller, VLSI design and Electronic system design with major focus on mini project III and mini project IV. These subjects deal with hardware and software component. In microcontroller study student develop their own microcontroller board and learn microcontroller (8051) hardware and its interfacing with display and key board. They perform various projects on this board with embedded C software. In VLSI design student simulated pipeline multiplier, data path design for algorithm, frequency generator etc. In ESD course student build electronic system-based projects like frequency synthesizer, SMPS, DVM, frequency counter etc. In mini-project-III students implement Aurdino based projects. In mini-project-IV focus is given on Raspberry-pi based projects. Open elective subjects like Hybrid & Electric vehicle and PLC & SCADA fulfils the industrial needs. Industry 4.0 plays very important role now a days. So, to fulfil that requirement PLC & SCADA subjects are introduced. In semester V and VI two subjects out of five covers PBL concept. Fig. 2 shows project implemented by third year students.



Arduino based projects

VLSI based projects

Microcontroller based projects

Raspberry-pi based projects

Fig. 2 Projects implemented by third year students.

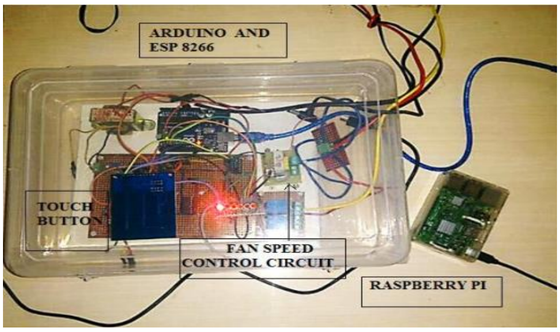


Fig. 3. IoT based automation using Raspberry Pi

IoT based automation using raspberry pi as shown in fig. 3 was implemented by one of the groups from third year. This project won number of prizes in different competitions held at state and national level. Also, this project is converted to commercial product with the help of JANGS Technology, Kabnoor.

Table 3. Final year syllabus structure

Final Year- Semester-1		
Course Code	**Name of the Course**	
ELL401	**Embedded System**	
ELL402	Power Electronics & Drives	
ELL403	Computer Network	
ELLEL1	**Elective I**	
ELP407	**Embedded system Lab**	
ELP408	Power Electronics & Drives lab	
ELP409	Computer Network Lab	
ELPEL1	**Elective I Lab**	
ELD413	**Project Phase I**	
Final Year- Semester-2		
ELL414	Image Processing	
ELLEL2	**Elective II**	
ELLEL3	**Elective III**	Consumer Electronics
		Digital Marketing
ELP423	Image Processing Lab	
ELPEL2	**Elective II Lab**	
ELPEL3	**Elective III Lab**	
ELD432	**Project Phase II**	

In final year project-based learning courses are increased up to 60% as shown in Table 3. It has been observed that during last five years maximum students get placement in the domain of Embedded system, VLSI and Automation. Electronic industry is rapidly growing in these areas. To make students expertise in these fields elective subjects are streamlined. Elective I and II are horizontally linked to each other as shown in Table 4. Project-I implementation steps are survey, problem definition, block schematic, viability of project, finalization of problem statement through presentation and discussion. It has been also evaluated and modified by external industry expert's opinion. Project-II has been allotted more credits (8) compared to project-I (4 credits). In this they carry out project with the steps circuit finalisation, PCB design & fabrication, soldering and software programming simultaneously in a group. Finally testing and troubleshooting of project is done. This process is supported by arranging regular workshops and events. Every year department conduct Multisim workshop, PCB designing workshop, Aurdino workshop, Raspberry-pi workshop and Project Extravaganza to provide hands on experience. The students take participation in various state and national level project competition and build their confidence in various technical and soft skills.

Table 4. Elective linkage

Elective I	**Elective II**
Automation & PLC Programming	PLC based industrial applications
Internet of Thing (IOT)	Embedded based applications
Digital CMOS Design	Advanced VLSI design

B. Percentage of project component

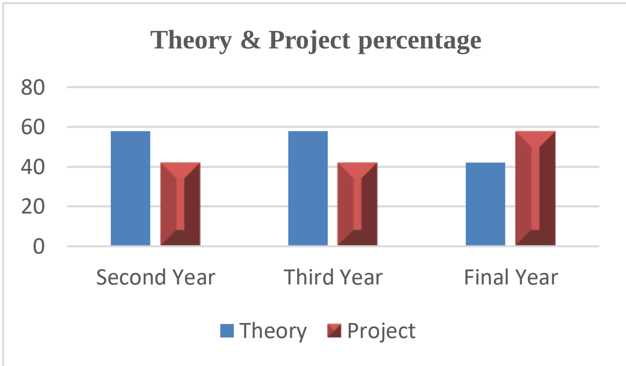


Fig.4. Class wise theory and project percentage

In second and third-year learning through PBL component is around 40%. In final year, it is increased to 60% by increasing project component in more subjects. Fig. 4 shows comparison of theory and project percentage in curriculum.

3. Evaluation of PBL

Course outcomes (CO) are statements that describe what learners are able to do by the end of course (subject). As shown in Table 5 Program outcomes (PO) are short term outcomes describing what students are expected to know and able to perform at the point of graduation. Attainment is measured as value of skills they have learned in alignment with COs. CO attainment is calculated through various evaluation methods and these COs are aligned with POs at different levels level 1: Slight (low), Level 2: Moderate (Medium) and level 3: Substantial (High).

Table 5. Program Outcomes

PO no.	**Program Outcomes**
PO1	Engineering Knowledge
PO2	Problem Analysis
PO3	Design and Development of solutions
PO4	Conduct investigation of complex problems
PO5	Modern tool usage
PO6	The Engineer and Society

PO7	Environment and Sustainability
PO8	Ethics
PO9	Individual and Team Work
PO10	Communication
PO11	Project Management and Finance
PO12	Life Long Learning

A. Sample Rubrics and PO Attainment

Some sample rubrics are presented here for mini project which is filled by students. The mini project evaluation which is part of curriculum can be evaluated using rubrics. Table 6 shows the rubrics designed for mini project evaluation wherein attributes like teamwork, presentation skill, time management and lifelong learning are measured. The attainment of these soft POs is presented in Table 7. Number of students considered are 64 for filling rubrics in the scale of 0 to 5. At the end average of each PO is taken and converted it to percentage. Appropriate percentage is converted to attainment level according to levels decided initially by course co-ordinator. e.g. Initially one can decide the range as follows: 40% to 50% is considered as level 1. 51% to 60% considered as level 2. 61 % and above is considered as level 3.

Table 7. Attainment of Program Outcomes through Mini Project Activity (Number of students considered = 64)

Program Outcomes evaluated →	**PO2, PO3**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
Average marks	4.16	3.69	3.95	3.98	3.91	4.02
Average attainment percentage (%)	78.48	85.90	72.26	55.62	69.48	76.68
Attainment Level	3	3	3	2	3	3

B. Mega Project evaluation methodology by faculty:

Mega projects are evaluated through following steps:

1. Formation of course (project) outcome.
2. Mapping of course outcome with POs.
3. Decide assessment parameters for project evaluation.

For example, one of the course outcome is "*A team of students will decide a Project topic and define problem statement" Similar* kind of methodology is followed for remaining COs of project. These COs are mapped to respective POs. Deciding assessment parameters and project evaluation is carried out with four attributes (R1, R2, R3, R4) as shown in Table 8.

Table 8. Assessment parameters for project evaluation.

Attributes	**Assessment Parameter & PO Mapping**
R1: Project synopsis approval	Identification of Problem Domain and Detailed Analysis (PO1)
	Study of the Existing Systems and feasibility of Project Proposal (PO2)
	Objectives and Methodology of the Proposed Work (PO2)
	Presentation (PO10)
R2: Midterm Project Evaluation-I	Formulating the Methodology (PO2)
	Building and Testing of Hardware & Software Modules (PO3)
	Planning of Project work (PO11)
	Project Demonstration (PO10)
R3: Mid Term evaluation-II	Project Execution (PO3)
	Integration of Hardware & Software Modules (PO3)
	Result Interpretation (PO4)
	Project Demonstration (PO10)
R4: Final Project Evaluation	Project Execution (PO3)
	Modern tool usage (PO5)
	The engineer and society (PO6)
	Sentimental Aspects (PO7)
	Ethics (PO8)
	Teamwork (PO9)
	Oral Communication (PO10)
	Project Report Evaluation (PO10)
	Project Management (PO11)
	Evidence of Learning PO12)

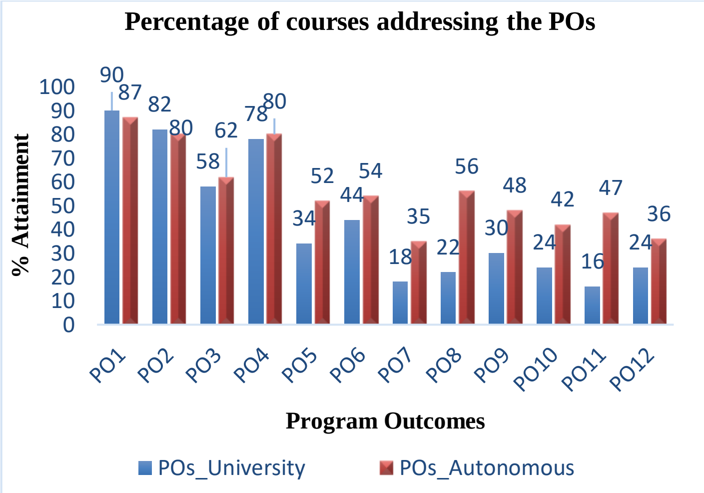


Fig. 5 Comparison of university and autonomous PO attainment.

Fig. 5 shows curriculum program outcome (PO) attainment of non-autonomous structure (University curriculum) and Autonomous curriculum for the year 2015-16 and 2018-19 respectively. Percentage of design and development is only 58% through various subjects. Percentage as shown in fig. 5 for non-autonomous are below 50%. Few of them are below 25%. Theoretical subjects are not supportive to improve these POs. Major areas where these POs get improved is only through projects. So, after autonomy decision has been taken to implement PBL in curriculum design. The program outcome statements are as per NBA norms [5].

PBL implementation in autonomous curriculum for the year 2018-19 has been improved. Percentage of attainment of PO4, PO5, PO8, PO9, PO10, PO11 and PO12 shows significant improvement. For example, PO8 of non-autonomous was 22% it is increased to 56% in PBL autonomous curriculum. Ethics can be assessed very easily through projects.

4. Conclusion

Students are benefited significantly through project based learning curriculum of Electronics Engineering. It also builds confidence to serve electronics industry by improvement in fundamental knowledge and communication skills. They also start developing their idea through innovative thinking. In autonomous curriculum it has been observed that there is significant improvement in various PO attainment as compared to university curriculum. Modern tool usage (PO5) has improved by 50%. PO6 deals with engineering and society which shows rise by 22%. PO7 improved by 50%, PO8 increased by 150%, PO9 improved by 60%. PO10 improved by 75%, PO11 improved by 200% and PO12 improved by 50%. PO8 signifies professional ethics which is improved due to various PBL component in each semester. PO11 relates with project management and finance which is improved significantly because a greater number of group projects done by students in each semester. PO10 relates with communication which also shows improvement because students have to work in group and present their work number of times in each semester. From above results we can conclude that PBL based curriculum is better than another curriculum structure.

References

[1] Castro, Manuel & Sebastian, Rafael & Quesada, Jerónimo. (2010). A systems theory perspective of electronics in engineering education. 1829 - 1834. 10.1109/EDUCON.2010.5493063.

[2] Macias-Guarasa, J.; Montero, J.M.; San-Segundo, R.; Araujo, A.; NietoTaladriz, O., (2006) "A project-based learning approach to design electronic systems curricula," IEEE Trans. Educ., vol.49, no.3, pp.389,397.

[3] Martinez, F.; Herrero, L.C.; De Pablo, S., (2011) "Project-Based Learning and Rubrics in the Teaching of Power Supplies and Photovoltaic Electricity," IEEE Trans. Educ., vol.54, no.1, pp.87-96.

[4] E. Graaff and A. Kolmos, (2003) “Characteristics of Problem-Based Learning,” *International Journal of Engineering Education*, vol. 19, no. 5, pp. 657-662.

[5]https://www.nbaind.org/files/NBA_UGEngg_Tier_II_Manual.pdf

Table 6. Rubrics for evaluation of Mini Project

Rubrics for Evaluation of Mini-Project					
Sr. no.	**Assessment Parameter**	**Excellent (5-4)**	**Good (3)**	**Average (2)**	**Below Average (1-0)**
1	**Basic Knowledge regarding design and analysis of basic electronics circuits (PO2, PO3)**	Demonstrated extensive knowledge about the project work undertaken.	Demonstrated good knowledge about the project work undertaken.	Demonstrated basic knowledge about the project work undertaken.	Lacks basic knowledge about the project work undertaken
2	**Ethics (PO8)**	Student is always on the task, never needs remainders to do the work and encourages other group members to do the work.	Student is usually on the task, seldom needs remainders to do the work	Student is sometimes on the task, seldom needs remainders to do the work	Student is never on the task, constantly has to be remained to do the work
3	**Working in a group (PO9)**	Executed the assigned task completely & contributed significantly to the group.	Partially executed the assigned task & moderately contributed to the group.	Merely executed the assigned task & some-what contributed to the group.	No responsibility towards assigned group task & hardly contributed to the group.
4	**Presentation skill (PO10)**	Prepared excellent presentation and also presented it well. Answered all questions with proper explanation very fluently	Prepared good presentation but moderately presented it. Fails to elaborate entire project fluently.	Poor preparation of project presentation. Lacks presentation skill reflected through the inability towards expressing and answering questions.	No efforts at all towards preparation of Project Presentation. Completely lacks presentation skill
5	**Time Management (PO11)**	All modules/parts of the project and project report completed in time.	Most of the modules/parts of the project and project report completed in time.	Some of the modules/parts of the project and project report completed in time.	No modules/parts of the project and project report completed in time.
6	**Lifelong learning (PO12)**	Excellent responsibility for learning & personal development through complete involvement in PCB design and project report formation.	Somewhat good responsibility for learning & personal development through complete involvement in PCB design and project report formation.	Poor responsibility for learning & personal development through complete involvement in PCB design and project report formation.	Very poor responsibility for learning & personal development through complete involvement in PCB design and project report formation.