Project Based Learning as an Active Learning Strategy in Engineering Education

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Abstract—
Things done are better remembered than things that are just heard or seen. In Project based learning pedagogy, the course content is delivered by assigning problem statements pertaining to real life situations to a group of students. For the assessment and evaluation of the course, the students have to give a presentation and a demo of the solution for the given problem at the end of course. So the students get sufficient time to work on the solution for the given problem. However, the work of the students is regularly monitored which helps in refining the proposed solution, looking for alternative solutions etc. In the process of solving these problem statements, the students apply the knowledge they have gained in various courses they have undertaken. In this process, the problem solving skills and employability of the students is greatly enhanced. In this paper, the authors have implemented project based learning pedagogy for two third year courses in Instrumentation Engineering Curriculum. The paper describes the aptness of this teaching pedagogy for the selected courses, activity planning, formulation of problem statements, progress reviews, and feedback. Through this activity, the authors found out that technical and non-technical skills of the students were greatly enhanced. Technical skills like, Problem formulation, System designing, etc are developed among the students. Effective communication, working in a team, developing a multidisciplinary approach, finance related planning are some of the non-technical skills found to be cultivated among the students. This ultimately develops life learning ability among the students.

Keywords—**Employability; Lifelong learning; Outcome based education; Project based learning; Skill enhancement.**

I. INTRODUCTION

Engineering education is more specifically application oriented. There has been an enormous transformation in the way engineering education is imparted to the students. This has resulted from the expectations of industry from a fresh engineer. More emphasis is on the skills imbibed by the engineering students. This has led to outcome based education. Continual efforts are made in curriculum designing, content delivery and the way the students are evaluated.

As per AICTE guidelines the curriculum must have courses related to basic sciences, engineering sciences, humanities and social sciences, program core, program and open electives along with project and mini project/seminar with prescribed percentage. The program curriculum is to be designed such that the twelve Program Outcomes (POs) laid down by National Board of Accreditation (NBA) must be covered with proper weightage. Out of the 12 POs, the first 5 cater to the technical skill development of the students. The first five are related to applying the basic principles of engineering for problem identification and formulation, designing solutions, and conducting detailed investigation using modern tools. The remaining POs aim at developing non-technical skills such as presentation skills, working in multi- disciplinary team, project planning & management, ethics and providing solutions to society and environmental issues.

For skill development of students in addition to curriculum reform, attention must be given to course delivery and course assessment and evaluation. For course delivery, various teaching pedagogies have emerged and there has been a constant development in these. Choosing the apt teaching pedagogy for a particular course, planning the activities, content/resource generation, execution, feedback are the important phases involved in implementation of any teaching pedagogy for any course.

The traditional paper and pen mode of assessment mainly focuses mainly on remembering skills or is more effective in testing up to L3 level of Bloom's Taxonomy. In this mode, questions covering L6 level of BT can also be designed but time limit for the exam hinders the evaluation of student capability at L6 level. So there is a need to shift to other assessment and evaluation methods.

In this paper, the authors have implemented project based learning (PBL) pedagogy for two third year courses viz Embedded Product Design and Digital Signal Processing in Instrumentation Engineering Curriculum. The course contents of these courses are covered by assigning related problem statements to the students. Resources required solving the

problem statements are provided to the students. Regular review of the work carried out by the students is done. Through these reviews, the queries of the students are solved, alternatives for solving the problem statements are discussed and this leads to refinement of the solution. At the end of the term the students presented the solution and submitted a report of the same. Student feedback received is very encouraging. Through this activity significant improvement in the technical and non-technical skills of the students was observed. This helps to develop lifelong learning skills among the students.

In section I of the paper the need for Project Based Learning (PBL) was emphasized. In the literature review part, concepts of PBL, evolution of it, advantages and limitations brought out by many other authors have been presented. The methodology adopted for implementation of PBL, steps followed, the results observed along with discussion and finally the conclusion are discussed in sections III, IV, V, and VI respectively. The references are given at the end of the paper.

II. LITERATURE REVIEW

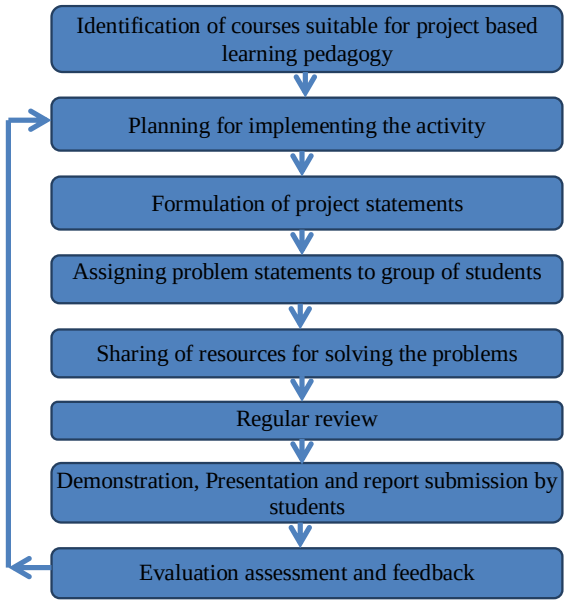
Concepts of problem-based learning are defined by many educators. Howard Barrows defines the concept in terms of specific attributes as being student-centered, taking place in small groups with the teacher acting as a facilitator, and being organized around problems [1]. However, the actual design and implementation will vary from institution to institution [2-5].

Project based learning pedagogy is being used in many courses by universities as a part of student's evaluation. Graaff, Erik et. al. has presented the way in which project based learning pedagogy has evolved since 1960 [6]. In their work they have compared various models of project based learning pedagogy. In their view through project based learning the student can achieve an analytically complex level of comprehension. They commented about the concern of the broader perspective or breadth of knowledge. So they recommended this pedagogy is important for all students, especially as an overstuffed curriculum has long dominated engineering education. Overview of the use of project based education in undergraduate engineering programs was given by Lutfi Al-Sharif in his paper [7]. The author has pointed out the challenges faced during implementation of project based learning pedagogy. It requires lot of extra efforts and time for planning and execution of this activity. The instructor needs to provide continuing support to the project groups throughout the project and respond to queries and suggest solutions to problems. He has to spare time for evaluation. Cost is involved for hardware and software resources for implementation phase of this activity. The benefit students draw from project based learning varies largely and depends to a large extent on how much effort each student puts into the project. Project-based learning provides opportunity to develop professional careers by assisting students to acquire problem-solving and lifelong learning abilities, rather than simply spoon feeding them to memorize prescribed content and design methods [8]. The industry requirements are fulfilled by this pedagogy. G.E. Veselov et.al presented that integration of the project-based learning for the management courses has contributed to an increase in the percentage employment by business companies [9]. Project based learning has also been effectively used in online teaching in amid COVID-19 pandemic [10]. The analysis shows that in spite of the difference in online and offline learning the bidirectional interaction has improved because of this pedagogy.

In all these papers the characteristics, models and analysis of project based learning pedagogy is deciphered in detail. The methodology, experimentation with proofs is not explored. In our paper the advantages of this pedagogy are proved with results and discussion.

III. METHODOLOGY

The methodology followed for implementation of PBL pedagogy is shown in Fig 1.



For implementation of PBL pedagogy, firstly courses suitable this teaching pedagogy are identified.
In the first year engineering curriculum, the students undertake courses related to basic sciences and engineering sciences. Engineering mathematics, Engineering sciences, engineering mechanics, Engineering drawing, etc. are some of the courses. In the second year, stream specific fundamental courses are offered to the students. In Instrumentation engineering curriculum, Sensors and Transducers, Analog and digital techniques, Electronic Instrumentation are some of such fundamental courses. In the Third Year, tools for developing solutions to real life problems are taken up by the students. Embedded System Design, Digital Signal Processing, Programmable Logic Controller for automation are examples of such courses. Also they study elective subjects related different application areas such as biomedical, environmental, industry specific domains like unit operations. With the knowledge of basic concepts, automation tools and various application areas projects can be done. Therefore, for

implementing PBL teaching pedagogy third year level courses were selected.

Digital Signal Processing (DSP) is a mathematical subject and students are afraid of mathematics. So to increase the interest in the subject and remove the fear, a Project Based Learning approach is used for this course. Students realized the importance of the topics like Z Transform, Discrete Fourier Transform when some demonstration of applications are shown and they increase their interest if the involvement is increased by asking them to work on some real time applications. The actual application of the topic taught to solve the real time problem enhances the understanding of the course. We identified some real-time problems which can be solved using the algorithms and transforms which they study in the DSP course.

Embedded Product Design (EPD) is a subject involving the concepts of analog and digital electronics related to application based products. It gives exposure to the students regarding the various techniques used for interfacing of analog and digital sensors and output drivers. In order to increase the understanding and interest in the subject students are required to get hands-on experience of designing a system for real time applications. So project based learning approach is adapted for this course. It helps the students to realize and understand various techniques and approaches to implement optimized design of embedded systems.

Thus Digital Signal Processing (DSP) and Embedded Product Design (EPD) were the courses which were found apt for PBL teaching pedagogy.

After identification of the courses in the planning stage, applications to be solved by students using this learning pedagogy are listed out. These problem statements thus identified were assigned to various groups of students. Then the resources that the students will require to refer for solving the statements were shared with the students. Once the students were assigned the work, their work is assessed regularly for solving their queries and improving their solutions to solve the given problem. At the end the students have to present and demonstrate their work. They also submit a report of the work done in a standard form.

The work done by the students is evaluated with the help of rubrics. To test the efficacy of the use of PBL as a teaching pedagogy, feedback from the students is also taken. Based on the feedback changes in the way the activity is executed can done.

PBL is not used as a teaching tool but also as an assessment tool. Comparison of PBL assessment tool with conventional pen and paper assessment tool with respect to Bloom's Taxonomy levels, Difficulty levels and Program Outcomes addressed is also done.

TABLE I
PROBLEM STATEMENTS IDENTIFIED FOR DSP COURSE

Sr. No	Applications	Student Name
1.	Audio Frequency generator	SohaKshirsagar
		Aditi Surnis
		Bhagyashree Bidwe
2.	Removing high frequency noise from ECG	Ankita Abhang
		Kshipra Kamshetty
		Avantika Khose
3.	Gender classification using Voice Recognition	Urvashi Taki
		Saloni Saraf
		Shraddha Amale

IV. IMPLEMENTATION

A. Identification of Statements, groups formation and problem statement assignment

TABLE II
PROBLEM STATEMENTS IDENTIFIED FOR EPD COURSE

Sr. No	Applications	Student Name
1.	Fire pump monitoring system	Gayatri Borul
		Shruti Pawar
		Savani Kulkarni
2.	Parking assistance system	Kshitija Naik
		Srushti Khomane

The identified problems were made open to students and they were allowed to select based on their choice in a group of 2-3 students. Table 1 shows some of problem statements identified for the course on DSP and allotted to the students.

The identified real time problems for the EPD course are shown in Table II. These statements are initially paper-designing and then implemented with the help of electronic hardware which they study in the EPD course.

B. Resources sharing, Progress review and discussion

For DSP course, students were given demonstrations of how to use the algorithms and transforms to solve the real time problems throughout the semester. After the selection of topic students started working on the application. These topics are selected at the start of the semester. After one-month group-wise meetings are taken to review their progress. Discuss and guidance helped to solve the difficulties faced in actual implementation.

For EPD course, students were given demonstrations of how to use different electronic sensors and output drivers to solve problems throughout the semester. Students selected their topic of interest and started paper-designing. After a few weeks' time, group-wise meetings are conducted to review the progress and to guide them in case of any difficulties.

C. Demonstration and Presentation

At the end of the semester each group was asked to present their implemented applications. The presentation involved a PPT presentation, demonstration of the application followed by a question and answer session. Each group also submitted a report based on the application.

Sample Assignment submission:
Application: Gender classification using Voice Recognition

- Problem Formulation:

Say “HEY GOOGLE”. And instantly your mobile phone wakes up. How does this happen? How does the phone understand the voice signal? How did Alexa do what you just asked her to do?
This, document has all the answers. On the upcoming research filed is speech recognition. A lot of data scientists have been working of detection of voice signal and conversion of the same in the text form. The basic motive of doing so is to make our life easier so that is we don’t have to type, we don’t have to do basic tasks like dialing a number, setting an alarm, booking a movie ticket. We just have to say it loud and the task is completed.
In this project the main focus was recognizing whether the speaker is male or female. Male and female voices follow a pattern in their frequency ranges. After observing the pattern of peaks obtained by feeding various voice signals, I came to a conclusion that if the number of peaks in the signal recorded in the duration of 5sec was less than 100 then the speaker is male and if more, than the speaker is a female. This was done by using one of the core building blocks of digital signal processing that is FAST FOURIER TRANSFORM.

- Selection and application of appropriate functions for application:

Fast Fourier Transform is used in many engineering applications like spectral analysis in RF communication, frequency domain analysis, to obtain the frequency response of the system. In this project FFT has helped in obtaining the frequency domain of the recorded input signal. On further synthesis of the maximum peaks from the Fourier domain signal we could predict whether the speaker is a male or female.
While working in the frequency domain, the signals tend to be abrupt and discontinuous due to which finding peaks from the signal becomes difficult. To solve this problem use of window function is done here where the main aim is to reduce abruptness and improve the frequency response. Here hamming window is been used. Hamming window shapes the other samples besides cutting them out or making them zero. In order to ensure that the voice data isn’t lost the use of hamming window was best suited. Before making this selection, same voice samples were tested for 4 windows being:
1. Rectangular Window
2. Hamming Window
3. Blackmann Window
4. Hanning Window

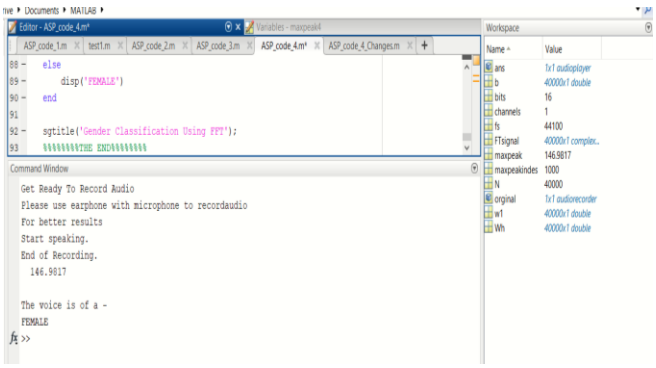
The observations were studied and then the choice of hamming window was made.

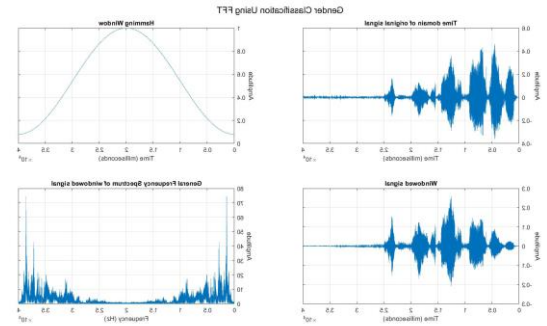
- System Overview

The steps involved in the developed program are shown in Fig 2. The recorded audio signal is multiplied by the generated hamming window. Then the FFT of the windowed signal is computed. The count of the maximum peaks is then compared with the target value to classify the signal.

- DSP MATLAB Code and Results for the application

The algorithm is coded using MATLAB software. Fig 3. shows the code developed. The results obtained is as shown in Fig.4





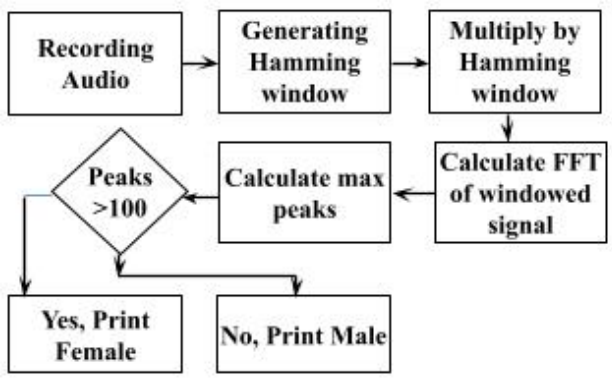


Fig.2: Block diagram of the system

Fig.3. MATLAB code

Fig 4: DSP MATLAB Result

- Conclusion:

After performing this assignment, I have gained a deep understanding on how the concepts in have learned during the course of this semester actually work. There were a lot of new functions that I have used and achieved hand-on experience with MATLAB.

The code and the algorithm are for basic audio processing and frequency domain analysis. The accuracy of the designed system is around 65-80% depending on how the user speaks. All the windows taught so far were practically observed using MATLAB before making the selection. Due to which the working of the windows is now clear.

The students were assessed using rubrics based on following criteria:

- Define the problem statements based on given application
- Select and apply appropriate method for solving the problem
- Design the system for solving given problem
- Analyze the results of designed system.
- Report writing and presentation

The rubrics levels and allotted marks are as given below:

- Proficient (4-5)
- Moderate (2-3)
- Needs improvement (< 2)

Fig 5 shows the screenshot of a sample evaluation sheet carried out on Google Classroom.

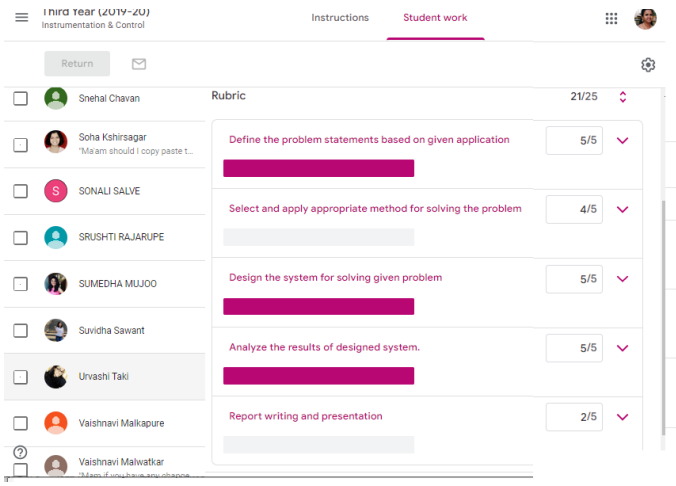


Fig.5. Screenshot of Rubrics based evaluation sheet

D. Feedback

After the completion of the activity feedback was taken from the students. Responses of the students for Problem Based Learning activity is shown in the form of graphs in Fig6, Fig 7 and Fig8.

Q1. Did the application developed made a value addition in your practical knowledge?

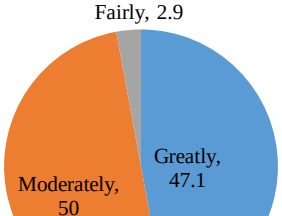


Fig 6: Feedback to Q.1

Q2.Were you able to develop the ability to suggest realizable solutions to engineering problems related to the course?

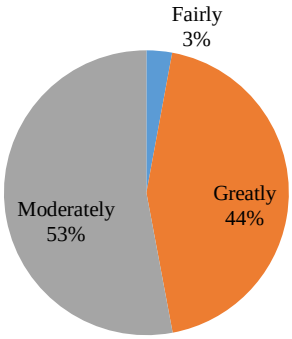


Fig 7: Feedback to Q.2

Q3. Were you able to create effective reports &/presentations and design documentation during your application development

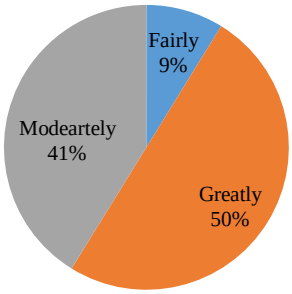


Fig 8: Feedback to Q.3

The graphs show more than 50% of the students agree that the activity has enhanced their practical knowledge. It has also developed the ability to realize the solution of a real time problem. It has improved their presentation and report generation skill. These skills are not enhanced in the conventional teaching. Through the feedback given we noticed that the student felt the timely submission of the activity was hectic in their busy schedule of regular curricular activities. Students appreciated this activity in the feedback. They also suggested conducting this activity for other courses.

V. COMPARATIVE ANALYSIS

Comparative analysis of PBL and Conventional pen and paper mode of evaluation is done. Following were the observations

- Due to time limit L6 Bloom's Taxonomy level questions could not be covered in conventional pen and paper mode. In PBL mode, the students had to design and implement the solution to real life problem statements. Also sufficient time was given to them. So it was possible to address L6 Blooms' Taxonomy level. Fig 9 shows comparison of

BTLs covered in conventional pen and paper mode and PBL mode.

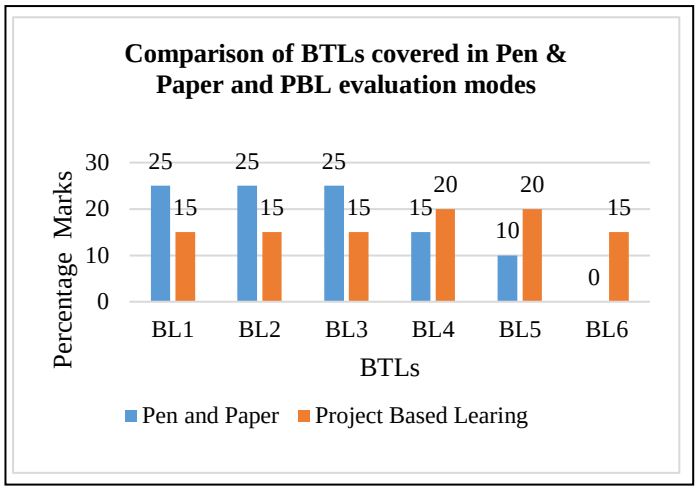


Fig 9: Comparison of BTLs covered in Pen & Paper and PBL evaluation modes

As seen from the graph in Fig 5, the conventional pen and paper assessment mode could cover BTLs up to level 5. Also weightage of marks (data labels on the graphs) for lower BTLs are more. Using PBL assessment mode, all the BTLs are covered with more weightage for higher cognitive levels.

- Questions in the question paper are mapped to three difficulty levels viz Low (L1 and L2 BTL), Medium (L3 and L4 BTL) and High (L5 and L6 BTL). High difficulty level questions are mapped to L5 and L6 Bloom's Taxonomy levels. Comparison of PBL and conventional pen and paper evaluation modes with respect to Difficulty levels is shown in Fig 10.

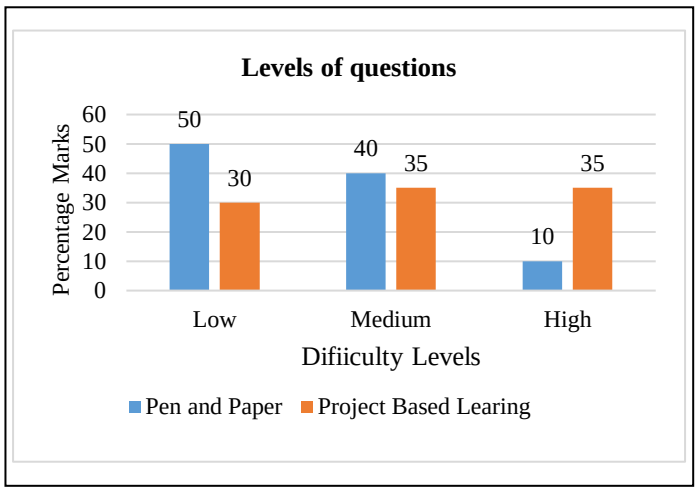


Fig 10: Comparison of BTLs covered in Pen & Paper and PBL Assessment Modes

As seen from the graph in Fig 10, in conventional pen and paper question paper mode, marks for high difficulty level questions were 10 %. In PBL, the marks (rubrics used) allotted for higher difficulty level is 35 %. Table III shows the sample question paper for conventional pen and paper mode.

TABLE III
SAMPLE QUESTION PAPER FOR CONVENTIONAL PEN AND PAPER MODE

Sample Questions	**% Marks**	**BTL**	**Difficulty Level**
Comment on the performance of use of different transforms based on frequency response of the filters/systems	10	L5	H
Analyse the given transfer function of the system and comment on the stability/Linearity of the system	15	L4	M
Select appropriate FIR/ IIR filter for given specifications	25	L3	M
List / Describe three properties of Fourier Transform, Z Transform	25	L1	L
Define Time variant & time invariant system, Linear Systems, Quantization	25	L2	L
Total	**100**		

- Comparison of Program Outcomes addressed in pen and paper and PBL evaluation mode was also done. Fig 11 shows comparison of Program Outcomes covered in conventional pen and paper mode and PBL mode of evaluation. The number 1 as data label in the graph indicates that the particular PO is addressed and a '0' indicates that the particular PO is not attained. In conventional mode the program outcomes addressed were from PO1 (Engineering Knowledge), PO2(Problem Analysis), PO3(Designing Solutions), PO4(Detail Investigation). In PBL mode, PO1 to PO4, PO5 (Modern Tool usage), PO6(Engineer and Society), PO9(Team Work), PO10(Communication), PO11 (Project management & Finance) and PO12(Life Long Learning) are addressed.

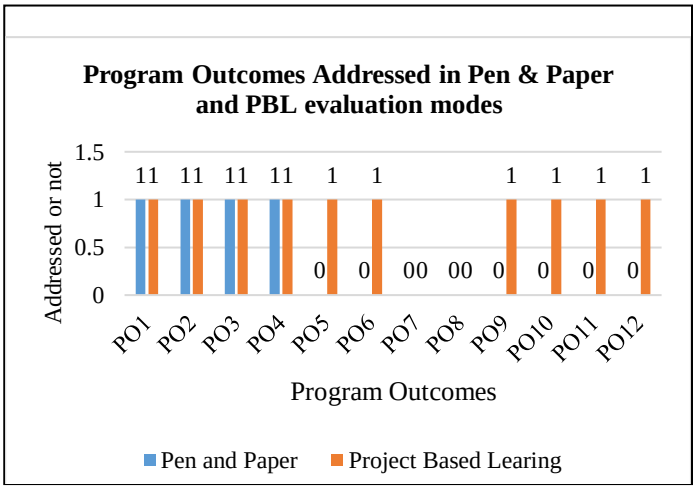


Fig 11: Comparison of Program Outcomes addressed in pen and paper and PBL evaluation mode

VI. Discussion on Findings

Through this activity the students could clearly identify and state the aim and objectives of the problem assigned to them. They explored the related literature and applied the theory

studied to propose a solution to the given problem. They compared to select appropriate methods to solve the given problem. The results thus obtained were analyzed and evaluated for refinement of the solution developed. Thus they could finally design a system or algorithm to solve the assigned problem. In the problem statements related to the Digital Signal Processing course the students used modern software tools to implement the algorithms. Thus through Project Based Learning teaching pedagogy, the technical Program Outcomes (POs) laid down by NBA were achieved (PO1 to PO5). The statements given to the students were related to societal use. The students, through the entire activity were working in a team. They prepared a report of the work they carried out and presented it too. Their presentation, technical writing and documentation skills enhanced. For the problem statements related to Embedded Product Design the students had to procure hardware components to build the proposed solution. This activity contributed towards building self-learning ability among the students. Thus this teaching pedagogy helped to accomplish the non-technical POs (PO6 to PO12) of NBA.

In the regular paper pencil mode of assessment lower Bloom's Taxonomy Levels covered. Questions related to Higher Bloom's Taxonomy Levels can be asked but there is a time limit for this. In this pedagogy, as they define the problem statement, do the literature survey, apply that to propose a solution, analyze and evaluate the various methods to solve the problem and finally design a solution for the given problem, all the Bloom's Taxonomy Levels are covered.

This activity can be a stepping stone for mini-project and major project taken up by the students in their curriculum. Also this has helped them in participation various project competitions. Some of students have also presented conference papers on the work they have carried in this activity with some additions.

VII. CONCLUSION

Project Based learning pedagogy was implemented for two courses at third year level of Instrumentation engineering curriculum. While implementing this pedagogy we observed that student involvement was more. Teacher was more as a facilitator. Students were able to identify the need of the project, apply theoretical concepts studied to design and select appropriate components/ algorithms/ blocks solving the problem statement. They could test and troubleshoot the developed system. Also they developed multi-disciplinary approach towards problem solving and got of experience of work distribution, planning, coordination while working in a team. Their communication skills developed through presentations and report writing. Project Based learning pedagogy makes teaching more students centric. It promotes self-learning ability among students. This self-learning ability is an important attribute which student needs once he or she steps into an industry. So this contributes to increase in employability of the student.

Due to this activity, significant improvement in the quality of work in mini and major projects is seen. Also there is a rise in the number ofpublications and participation in project competitions.

The major challenge observed for effective implementation of this pedagogy is that extra time and efforts are required. High student motivation is essential for fulfilment of the objectives behind this activity. Implementing this activity on a class of large number is very challenging.

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