# Project Based Learning Approach in Digital Signal Processing Course for Increasing Learners' Cognitive and Behavioral Engagement to Promote Self-Learning

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Ashwini M. Deshpande
E&TC Department, MKSSS's Cummins College of Engineering for Women, Pune

***Abstract*—Project-based learning (PjBL) is one of the most predominantly practiced forms of active learning pedagogy in higher education. PjBL framework provides an authenticated platform/forum for 21st-century learners to acquire skills for solving real-life complex engineering problems through collaborative and iterative learning. The work presented in this paper describes a PjBL approach implemented as an instructional pedagogy and for a summative assessment of an undergraduate (UG) course on Digital Signal Processing (DSP). Students from Electronics and Telecommunication Department study this course in Third Year Engineering as a core course. The projects are chosen to make students identify and resolve real-life signal processing problems utilizing their subject knowledge and programming skills. PjBL implementation framework and rubrics-based evaluation devised for their summative assessment are discussed along with a study case. Student feedback analysis on the attainment of course outcomes and skills enhanced after completion of the course project is discussed. Through this analysis, it has been found that the effectiveness of the PjBL pedagogy employed has led to increasing students' engagement and interest in learning signal processing topics. It has also grown their self-learning ability and created awareness about the practical applications of the Digital Signal Processing course.**

***Keywords*—Active learning pedagogy; Digital Signal Processing; Outcome-based Education (OBE); Project-based learning; Self-learning**

***JEET Category*—Practice**

## I. INTRODUCTION

Outcome Based Education (OBE) follows learner-centric learning model and aims on assessing learners' performance through outcomes. According to OBE, it is essential to ascertain learners' engagement level and ensure that their competencies are developed as per the Program Outcomes (POs), which are in line to the Graduate Attributes (GAs) as defined by Washington Accord (WA). POs include knowledge, skills and attitudes expected to be earned by graduate engineers after completion of the engineering UG program. These attributes are essential for all graduating engineers of the 21st century as per the guidelines given in (NBA India Documents, 2016).

To imbibe engineering knowledge and skills desirable to cater industrial needs teacher's role is significant. A teacher being a facilitator through the well planned instructional methods and infusing the learning environments to incorporate active learning pedagogies, can implement a workable student-centric learning model as per the OBE requirements.

OBE model allows design of teaching-learning process where learners' engagement will be high as they know desired outcomes which are required to be achieved. It also allows them to realize that they are the in-charge of their own learning, which helps improving their competence for a particular skill, knowledge, behavior, and self-learning abilities(kulkarni & Bewoor, 2017). The extent to which the learner meets the outcomes (in a particular course) can be evaluated using different assessment modes such as case study presentations and analysis, assignments, projects, group discussions, employer feedback, peer reviews etc.

Project-based learning (PjBL) is one of the most effective active learning pedagogy. It aims to foster student-centered learning- as the basic idea is learning by doing (Patange et al., 2019). It stimulates critical and independent thinking, problem-solving ability. It facilitates the teamwork as students have to work together in teams to solve a real-life project.

Digital Signal Processing (DSP) is one of the basic sub-field of Signal Processing. DSP has wide range of applications in the domain of speech, audio, image, biomedical signal processing, sonar, radar, underwater, telecommunication, control systems. Engineers from Electronics and Telecommunication (E&TC) domain often deal with real life signals to process signals and extract meaningful information using signal processing techniques. An Undergraduate (UG) course of DSP mainly covers basic concepts such as analog to digital signal conversion, transform techniques, and noise filtering. Employing PjBL in this course provides students' a working environment where they can apply the theoretical concepts learned in the course on the real-world signals (such as speech, audio, music, ECG, EEG, image), process the signals and thereby associate with real-life signal processing applications.

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## II. LITERATURE REVIEW

A case study conducted at in the Department of Electronic System at Aalborg University in Denmark, as discussed in (Zhou et al., 2012), shown how the engineering students are encouraged to develop a group creativity in a Problem and Project- Based Learning (PBL) environment. Through their findings it was revealed that, even if the time schedule is a barrier for group task implementation, a PBL environment promote student motivation through various engaging activities.

A new re-design of engineering curriculum at Massey University, New Zealand, its implementation challenges, and best practices are presented in (Shekar, 2014). Author emphasized that preparing engineering students for facing real-world problems as a professional is a need of hour. It is possible by exposing them to a number of projects through project-based learning and different pedagogies, where students learn to frame, design, select and solve a problem, through the engineering design process.

Uziak (2016) stated that a special attention should be given to project-based learning as it provides the engineering students an opportunity to work on an open-ended problem and create awareness about engineering practices required to cater industry needs amongst them. Author discussed aspects of PjBL and insists on need for its inclusion in engineering curriculum.

Cattaneo (2017) presented five active learning pedagogies viz., project-based, problem-based, inquiry-based, case-based, and discovery-based and compared them with the findings that learner-centeredness is a main aim of all pedagogies. Author has deliberated importance of designing learning environments integrating active learning pedagogies. However, underlined the fact that it is necessary to identify limitations of these pedagogy implementations to cater students' needs ("*classrooms with inexperienced or naïve learners may require less active methods"*). Thus, the in depth understanding of each of the AL pedagogies and to which learner group it is to be applied is equally important.

Teixeira et al. (2020) studied effectiveness of Project Based Learning as an inspirational tool for solving Metal industry with the students of Material Engineering. In their methodology they used two phases, where the first phase was to understand the industry problem and in the second phase solution was prepared and presented. PBL with an industry was proven to be an effective instructional approach that boosted academic performance of students' and helped developing their teamwork skills, as well as gaining knowledge for professional training as an engineer.

A DSP course design with combined adoption of software and real-time hardware (DSP processors) is proposed in (Kuo & Miller, 1995) to enhance the theoretical and conceptual understanding. Along with giving course description and list of experiments, some challenging DSP projects such as acoustic echo cancellation, active noise control and image compression are also discussed. This paper demonstrated how a well-organized course structure can blend theoretical concepts to complex DSP applications. A hybrid instructional structure combining traditional lectures with a problem-based element is proposed by Albu and Malakuti, (2009). This combination helped tie together core concepts in signal processing and its practical implication. In this structure, students formulated their problems on their own and prototype of DSP systems was designed using EasyDSP in the area of audio and image processing.

Ambikairajah and Epps (2011) deliberated their two years experiences in development, implementation, and evaluation for Project-based learning in DSP. Through their evaluation it was found that students could attain a greater understanding of the principles of DSP. Also, many students prefer the PjBL learning regardless of the increased effort required. A very detailed discussion on course delivery methods, a project based course design, project development and evaluation, student feedback mechanism stands out as a reference framework to implement PjBL in engineering curriculum.

In (Alqudah et al., 2013), authors reported their experience of project-based learning implemented in a DSP course. With the aim of applying learning of theory to the real world problems practical implementation of a low cost digital stethoscope was built to record heartbeats. DSP techniques were applied to improve heartbeat sounds. The feedback from students supported the usefulness of PjBL.

Babu et al. (2014) presented a pilot study on the DSP course studied by Electronics and Communication (ECE), Electrical and Electronics (EEE), Computer Science (CS), and Information Technology (IT) in Anna University for 3 Engineering colleges. Their initial study shows that the result for this course indicated less scoring by students compared to other courses as compared to other courses. They also collected feedback from some faculties to understand about the course teaching and students' performance. Based on the analysis and survey they suggested Problem-based learning (PBL) as an effective pedagogy to increase students' interest, described few mini projects and its implementation strategies.

Through a literature review conducted on the active learning pedagogy, project based learning philosophy and earlier works on PjBL implementations for DSP course, it was found that PBL/PjBL is the most effective learner-centered active pedagogy. It is one such pedagogy which is closely relevant to engineering practices carried out in industries. It gives an experiential learning to the students while studying the classroom course in their engineering curriculum. With this motivation how PjBL implementation is disseminated for over 3 Years in the DSP course is discussed in the next section.

## III. PROJECT-BASED LEARNING METHODOLOGY

The syllabus of DSP contain mainly analog to digital conversion of analog signals, time, and frequency domain analysis of discrete time signals and LTI systems, digital filter design and study of DSP applications. Course outcomes (CO) aim that after the completion of this course students' will be able to-

- **CO1:** *Explain the basic building blocks of a DSP system*
- **CO2:** *Apply sampling theorem and convert signals from continuous time (CT) to discrete time (DT)*
- **CO3:** *Apply transformation techniques such as DFT, FFT, Z-Transform on DT signals*
- **CO4:** *Analyze the spectral representation of the signals*
- **CO5:** *Design Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) digital filters*
- **CO6:** *Explain and build real-life DSP systems*

To accomplish these outcomes classroom teaching, tutorial and assignments, multiple-choice quizzes, flipped classroom, demo-based learning are the modalities used. However, to link the theoretical concepts and mathematical problem solving with the real-life DSP applications where these concepts are applied in practice, PjBL as an In-Semester assessment mode is decided.

Fig. 1 indicates PjBL framework employed in the DSP course. This activity in conducted in the three different phases as shown. Students are teamed up into smaller group, in the beginning of the semester. Outline of the entire PjBL implementation is given to the students beforehand.

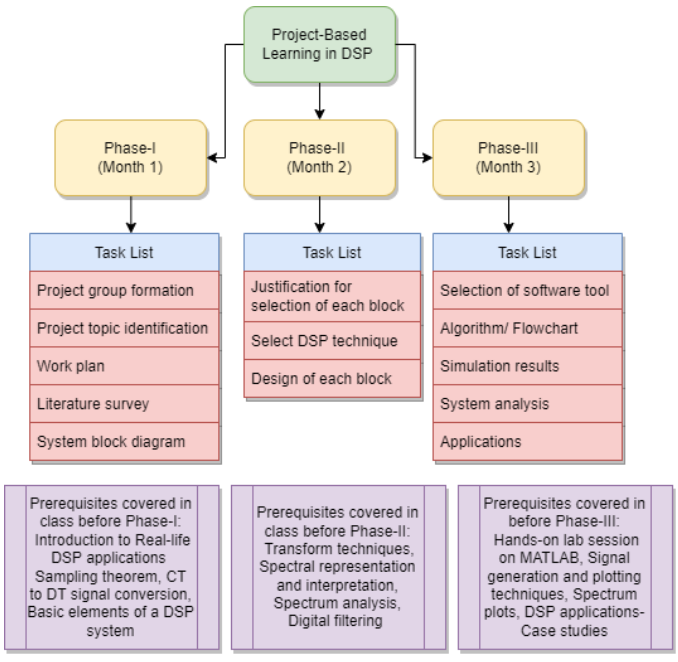



Fig. 1. PjBL framework in DSP course

A course instructor facilitates and mentors student groups throughout the project execution phase. Simultaneously, the instructor also teaches the prerequisites necessary to extend the conceptual understanding about the project topics selected during class room sessions. Some of the project topics as selected by project groups in the past 3 years are listed in Table I.

TABLE I
LIST OF PBL PROJECTS

| Year | Project Titles |
|---|---|
| 2019-2020 | Speech recognition |
| | Gender recognition using speech signal |
| | Noise filtering from speech signal |
| | Tone Generation |
| | Image compression |
| 2020-2021 | Acoustic echo cancellation |
| | Speaker crossover design |
| | Digital audio equalizer |
| | Music synthesizer |
| | DTMF encoder decoder |
| 2021-2022 | Musical swara identification |
| | EEG signal processing and analysis |
| | EMG signal processing |
| | Audio effects generation (echo, reverberation) |
| | Audio steganography |

The PjBL assessment framework as shown in Fig. 2 is pre-defined in the form of rubrics and mapped with the course outcomes.

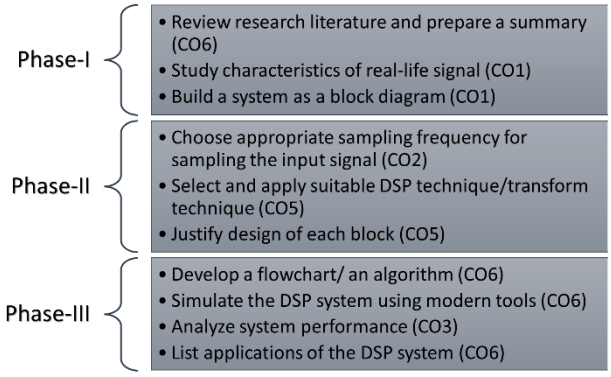



Fig. 2. PjBL assessment framework

The rubrics set for the ISE assessment is shown in Table II where all criterions are well aligned with the course outcomes. Students are being informed about the prerequisites (rubrics) to be fulfilled for each phase PjBL presentation beforehand to ensure their preparedness.

TABLE II
RUBRICS FOR PBL ASSESSMENT

| Criteria | Excellent | Satisfactory | Fair/Needs Improvement |
|---|---|---|---|
| Literature review and summary of findings with proper understanding | Minimum 3 research articles referred, clearly understood and summary is presented neatly | Research papers referred but summary is not available | Not referred any research paper and summary is not available |
| A) Understanding of signal characteristics | A) Real-life signal characteristics are well studied and displayed as plots | Real-life signal is plotted but signal characteristics are not studied | Both real-life signal plots and signal characteristics are not evident |
| B) Development of system block diagram | B) Detail system block diagram is drawn and demonstrated | Missing DSP technique from system block diagram | System block diagram is not clearly shown and demonstrated |
| A) Justification for selection of each block and selection of sampling frequency | A) Justification for selection of each block is clearly explained and sampling frequency selection is correct | Either the justification or sampling frequency used is only evident | Both the justification and sampling frequency selection is missing |
| B) Apply transform technique or suitable DSP technique | B) Selection of suitable transform technique and signal transformation is clearly shown | Transform technique is selected, but signal transformation is not shown | Signal transformation or signal generation is missing |
| C) Design of each block | C) Design steps are clearly understood, appropriate and found correct | Design steps are included but they are not relevant | Design steps are not included |
| Algorithm and Simulation results | Algorithm is included, explained properly and simulation results are evident | Either an algorithm or simulation results are missing and not explained clearly | An algorithm and simulation results are not explained clearly and available partially |
| System analysis | Spectrum analysis/ Z-domain analysis is clearly indicated with proper understanding | Spectrum domain plots are shown but analysis is not available | Both plots and analysis are missing |
| System applications | Minimum 3 applications of the system are identified and explained in detail | Less than 3 applications are listed, and explanation is done partially | Applications are not listed and explained |

## IV. A CASE STUDY

As a case study an example of one the projects that the students have implemented is discussed. Title of the project is '*Gender recognition from speech signal*'. After selecting this title, a group of 4 students have come up with the week wise work plan and task distribution per group member. It is depicted in Table III.

TABLE III
WEEK-WISE TASK DISTRIBUTION IN A CASE-STUDY

| Week | Task distribution |
|---|---|
| Week 1 - 2nd March to 8th March | 1. Develop a work plan<br>2. Assign and distribute the tasks<br>3. Literature Review (Different Methods applied for Gender Recognition)<br>4. Decide the objectives of the system<br>5. Design a block diagram of the system<br>6. Data Gathering<br>7. PPT - Phase 1 |
| Week 2 - 9th March to 15th March | 1. Study speech characteristics<br>2. Check the recording. Plot the signals<br>3. Pre-process the audios if needed<br>4. Analyze the spectral components |
| Week 3 - 16th March to 22nd March | 1. Identify suitable methods/DSP technique to differentiate male and female voice<br>2. Define/Identify system specifications<br>3. PPT - Phase 2 |
| Week 4 - 23rd March to 29th March | 1. Decide and develop the algorithm<br>2. Train the dataset, obtain simulation results<br>3. System testing and analysis |
| Week 5 - 30th March to 5th April | 1. Debug/ Improvise/Extra Additions<br>2. Designing of GUI<br>3. PPT - Phase 3 |

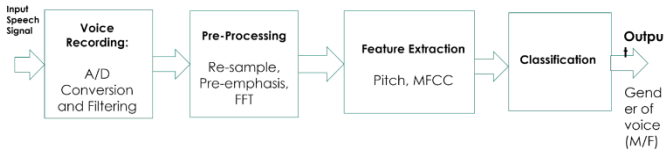
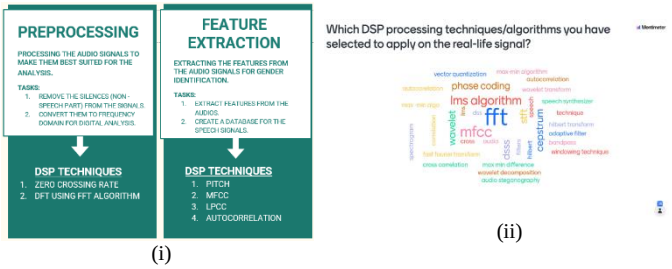



Fig. 3. DSP system block from a case-study




(i) (ii)

Fig. 4. DSP techniques studied and implemented: (i) In a case-study example, (ii) In the class as answered by students in mentimeter poll

Fig. 3 displays the DSP system block diagram developed by students to implement the gender recognition task from speech signal. They studied and implemented DSP techniques for pre-processing and feature extraction step as shown in Fig. 4 (i). Some of the techniques (time domain and spectral analysis) are covered in the curriculum, while some new DSP techniques they explored and learned together through peer learning, also reflecting their self-learning ability.

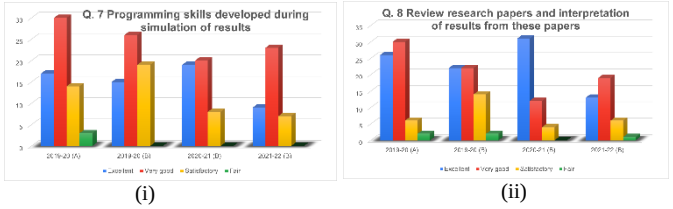
Fig. 4 (ii) shows a word cloud indicating students responses to the mentimeter polling question- '*Which DSP techniques you have selected to apply on the real-life signal*?' Through the answers all the students came to know about variety of DSP techniques. Conducting such polls occasionally boosted peer learning and keep them actively engaged.

## V. STUDENT FEEDBACK AND ANALYSIS

After the completion of PjBL projects student feedback on their learning experiences is collected for the three academic years (2021-22, 2020-21, 2019-20). Total of 124 students responded to survey questions in 2019-2020, and 47 students responded in Year 2020-21 and 2021-22 respectively.

Fig. 5, Fig. 6, and Fig. 7 exhibit student responses marked on the rating scale as- *Excellent*, *Very good*, *Satisfactory*, *Fair*.


Fig. 5. Student responses on survey questions about enhancement of course knowledge after completing PjBL projects



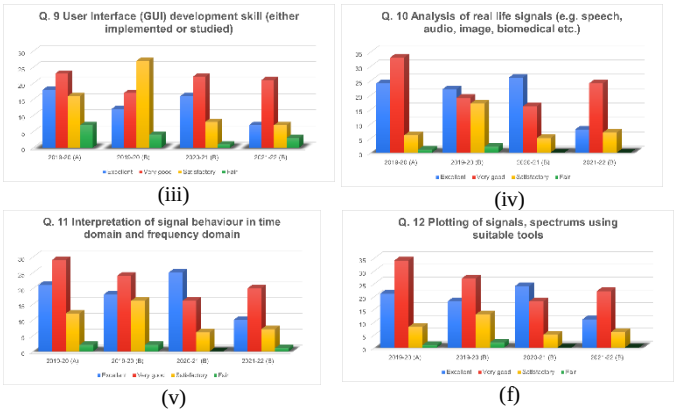




Fig. 6. Student responses on survey questions about learning abilities developed after completing PjBL projects

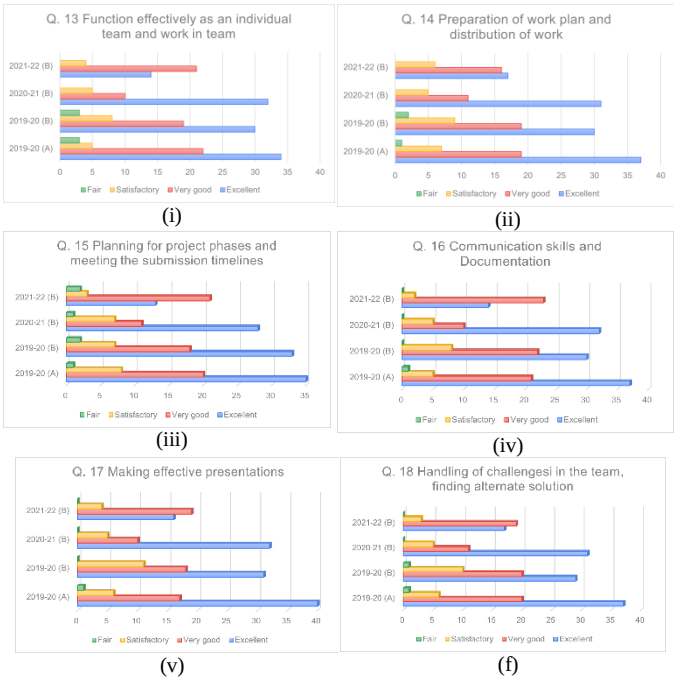



Fig. 7. Student responses on survey questions Project Management skills acquired and applied after completing PjBL projects

Third Year (E&TC Engineering) students were actively engaged to fulfil the PjBL tasks in each phase. Fig. 5. displays student responses on survey questions about enhancement of course knowledge after completing PjBL projects. Responses on survey questions regarding the learning abilities developed after completing PjBL projects are compiled and shown in Fig. 6. Survey questions are based upon the Program Outcomes (PO1-PO12) as per the National Board of Accreditation (NBA). Upon implementation of this active learning pedagogy, it is realized that due to the learning by doing approach of PjBL framework, and complex problem handling by students applying the known course knowledge or self-learning exploration of new techniques, mapping of PO1 to PO5 becomes feasible. Responses shown in Fig. 5 and Fig. 6 reveals the same.

While working in the teams, each project group has a team leader to coordinate the activities. Fig. 7 exhibits student

responses on the survey questions about the Project Management skills acquired and applied after completing PjBL projects. It implies that Program Outcomes PO9 to PO12 can be mapped substantially in the course with the aid of PjBL support. Fig. 8 indicates learners' poll responses towards their choice of learning towards PjBL/PBL activity as compared to traditional learning, as they found it engaging, and increased their level of understanding.

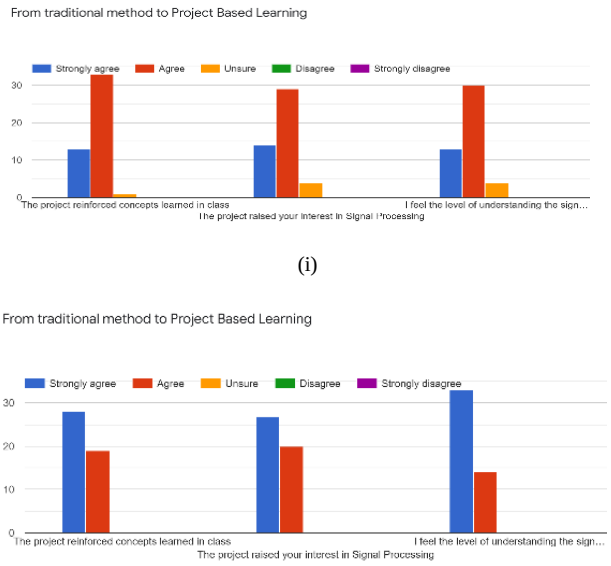



Fig. 8. Students' feedback on PjBL activity: (i) Year 2021-22, (ii) Year 2020-21

## VI. CONCLUSION

The work presented in this paper reported a course level project-based learning framework adopted and implemented in the course of Digital Signal Processing. Learners are evaluated for their In-Semester examination on the basis of the course outcomes based rubrics. Being a semester long duration project implementation even though the framework is designed such that students will undergo a systematic phase-wise execution, sometimes students might feel it exhaustive. But in turn the skills and knowledge they acquire by putting hands-on efforts collectively to solve a real-life signal processing problem is valuable. Many revelations are noted during this exercise where students have learned to build Graphical User Interfaces (GUI) for demonstrating their applications or attempted to process real-life signals such as active volcanoes or stock data and performed signal processing on them. It signifies that this activity stimulates critical thinking and higher order cognitive level thinking and promotes self-learning in these 21st century learners. Project based learning truly joins together the theoretical concepts and real-world applications of those concepts and hence is an effective active learning pedagogy.

## ACKNOWLEDGMENT

Author would like to thank to all the stakeholders for their support and promoting active learning pedagogy and a students from Third Year (E&TC) Engineering for their active participation.

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