Journal of Engineering Education Transformations,
Volume No 35, January 2022, Special issue, eISSN 2394-1707

Project-Based Learning: Teaching Methodology to Impart Knowledge and Skills

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***Abstract*—**For an enhanced learning experience, along with conventional classroom and laboratory teaching, project-based learning (PBL) has been introduced in the curriculum to motivate students to learn by working in a group cooperatively. However, true learning depends on the successful implementation of Project-Based Learning teaching methodology. In this paper, a case study of the implementation of the PBL over a semester is presented with outcome measurement for the Second Year Electrical Engineering students. Initially, a project-based learning implementation strategy is designed in line with the curriculum prescribed by the Savitribai Phule Pune University (formerly Pune University). It is then carried out over a semester as per the pre-defined schedule. Outcome measurement is done at the end of the semester by collecting course feedback from individual students. The analysis of the course feedback showed the development of knowledge and skills of the subject matter in students.

***Keywords*—**Course Feedback; Outcome Measurement; Project-based learning; Teaching Methodology.

***JEET Category*—Research**

I. INTRODUCTION

PROJECT-Based Learning (PBL) is a student-centric and experiential learning technique encouraging 'deeper learning' by actively involving in and exploring physical-world problems and challenges. The main aim of PBL is to facilitate students' attainment of complex cognitive competencies, e.g. rigorous content knowledge and critical thinking skills. The PBL promotes the active involvement of students in defining problems, designing processes, contextual understanding, and system thinking approaches. In the PBL, learning based on memorization is de-emphasized and more emphasis is given on understanding and application of science, technology, engineering, and mathematical (STEM) design principles (Capraro *et al*., 2013). There are various definitions of project-based learning. Some of them are given below.

1. PBL is a teaching method that encourages learning by actively engaging in real-world and personally meaningful projects (True Education).
2. PBL is a model and framework of teaching and learning in which students acquire content knowledge and skills to answer a driving question based on an authentic challenge, need, problem, or concern (Magnify Learning).
3. PBL is an instructional approach intended to allow students to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world (Power School).

From all these definitions, PBL can be defined in simple terms as a teaching methodology designed in such a way that students acquire knowledge and skills while finding solutions to the complex problems defined in the form of a project. The purpose of the PBL is to make students aware of applying the engineering concepts instead of merely understanding them. Project-based learning is important (Why is Project-Based Learning Important?) because it helps students to acquire skills, such as fundamental skills, 21st-century skills, employability skills, research skills, problem-solving skills, etc., encourages lifelong learning, accommodates students with varying learning capabilities, and provides a true assessment of individual and group of students.

A brief history of PBL is discussed in (Uziak, J., 2016). This also covers the need for PBL in the engineering curriculum. According to the author, PBL should be more than the typical final year project and it should be introduced throughout the curriculum and should start earlier in the program. Some research papers share the introduction of PBL at the program and course levels (Fini, *et al.*, 2018, Fioravanti, *et al.* 2018, Naik *et al*., 2021). However, there are several problems in the effective implementation of the same (Srinivas, 2018). In view of the implementation of the National Education Policy (NEP 2020), there is a need to take a step forward and implement it as a part of the curriculum.

In this paper, a case study of the systematic implantation of a project-based learning course for second-year electrical engineering students is presented. In the curriculum, only the general guidelines are given. These guidelines are elaborated in a more methodical way to develop the PBL implementation module. This module is then executed over the semester. The complete procedure, implementation strategy, evaluation and assessment, and outcome measurement are presented in this paper.

The rest of the paper is organized as follows. Section II briefs about the course. PBL implementation strategy is presented in Section III. Evaluation and assessment are discussed in Section IV. Finally, an analysis of course outcome is presented in Section V followed by a conclusion in Section VI.

II. OVERVIEW OF PBL COURSE

The project-based learning course is introduced in the Second Year (Semester II) of Electrical Engineering in the revised curriculum of the 2019 pattern of Savitribai Phule Pune University (formerly Pune University), Pune (Saviribai Phule Pune University, Syllabus 2020). The details of the course are given in Table 1 below.

As specified in the curriculum, the objectives of this Project-based Learning course are to

1. Impart technical knowledge and skills, and develop deeper understanding to integrate knowledge and skills from various areas.
2. Build critical thinking, problem-solving, communication, collaboration and creativity, and innovation amongst students.
3. Make students aware of their own academic, personal, and social developments.
4. Develop habits of self-evaluation and self-criticism, against self-competency and try to see beyond own ideas and knowledge.

The course outcomes (CO) are also listed in the curriculum. At the end of this Project-based Learning course, learners (students) will be able to

CO 1: Identify, formulate, and analyze the simple project problem.

CO 2: Apply knowledge of mathematics, basic sciences, and electrical engineering fundamentals to develop solutions for the project.

CO3: Learn to work in teams, and to plan and carry out different tasks that are required during a project.

CO 4: Understand their own and their team-mate's strengths and skills.

CO 5: Draw information from a variety of sources and be able to filter and summarize the relevant points.

CO 6: Communicate to different audiences in oral, visual, and written forms.

Course objectives and outcomes are decided by the Board of Studies (Electrical Engineering) in several meetings of the subject experts. Course procedure, assessment, and evaluation are also mentioned in the curriculum but it does not provide clear-cut guidelines for the implementation of PBL. This provides an opportunity for the department or institute to develop its own strategy for implementation. But then, this may differ from institute to institute affiliated to the same university. Due to which there would not be uniformity in the assessment and evaluation. Here in this paper, an attempt is made to provide general guidelines for implementing the PBL teaching methodology systematically and at the same time achieve course outcomes.

III. IMPLEMENTATION STRATEGY

In this section, the step-by-step strategy for the implementation of PBL is described.

A. An Introductory Session

Department should appoint a PBL coordinator for a class. The PBL Coordinator should deliver a session for all the students and faculties to make them understand the concept of Project-based Learning, where he/she should cover the concept, importance, objectives, and overall flow of PBL right from the problem selection to project completion. If possible, an example of last year's group can be used to demonstrate it in a better way. This session should be delivered in the very 1st week of the start of Academic Semester II. A Review Committee should be formed comprising 2-3 senior faculty members of the department to check and monitor the PBL activity along with the PBL coordinator.

B. Project Problem Statement

Project problem statements for PBL should be displayed to all the students. The project problem statements can be generated based on one of the following ways.

- ✓ Faculties can provide problem statements and these can be discussed and finalized in the faculty meetings.
- ✓ Problem statements can be collected from the students through the 'Call for Challenge Problem' type of competition (conducted in the previous semester) and selected problems can be first discussed, finalized, and then displayed.

These are the indicative ways of identifying the project problem statements. Students can also come up with their own problem statements. For the study reported in this paper, five project problem statements are collected from each faculty member and shared with the students without displaying the name of the faculty. Students were asked to submit 3 choices of the problem statement through the Google form. Based on the first-come-first-serve basis, problem statements are assigned to them.

C. Student Group Formation

Students can be asked to form groups of 4-5 students before or immediately after the introductory session conducted by the PBL Coordinator. Preferably students can be asked to form the groups on their own. In an introductory session, students should be made aware of selecting the group members for this activity.

D. Mentor Allocation

A faculty mentor should be assigned as per the project expertise or the problem statement selected by the students. Maximum two groups should be assigned to a faculty. Faculty members, particularly newly joined, should also be made aware of the PBL objectives, outcomes, and

TABLE 1
DETAILS OF PBL COURSE

Subject Code	Teaching Scheme	Credits	Examination Scheme
203152	Practical: 4 Hrs./Week	Practical: 2	Termwork- 50 Marks

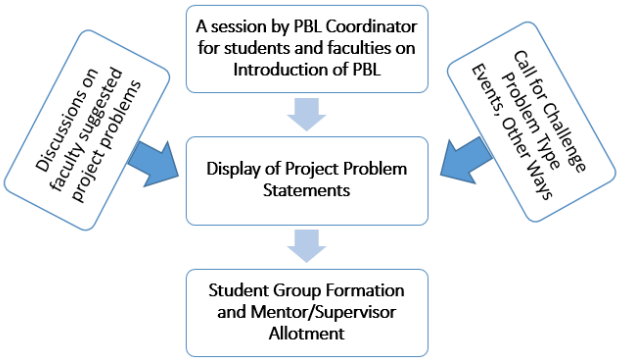


Fig. 1. Procedure for identifying project problem statements

guiding points should be recorded date-wise in the form of handwritten minutes and should be preserved by the group up to the final presentations. All the above-mentioned activities should be completed in the first week after the commencement of Semester II. Points A to D are represented in the form of the flowchart in Figure 1.

E. Time Table of Presentation

Thereafter timetable of all the activities should be displayed to students. The overall PBL should include four presentations in front of the review committee. This should include topic approval presentation, progress presentation 1, progress presentation 2, and final presentation. Timeline and content coverage in all these presentations is given in the next section. Apart from these presentations, it is expected that the student groups meet the respective mentor on weekly basis and update the work completed by them. In these meetings, students should answer the following questions.

- ✓ What have you read?
- ✓ What have you understood?
- ✓ What proofs/results/simulations have you repeated?
- ✓ What knowledge can be used for the project?
- ✓ What is the next plan?

Record of all these should be preserved for final assessment in the project workbook or student notebook.

F. General Guidelines

Further, the general guidelines for the department, mentor/supervisor, and students are given below.

1) General recommendations

1. Appoint the Coordinator for the Project-Based Learning course.
2. Constitute a Review Committee with two senior faculty members.
3. Arrange sessions for students and faculty members defining the concept, importance, objectives, and procedure of PBL.
4. Display Project Problem Statements on notice board, online platform, department blog, etc.
5. Design a PBL workbook and share it with students and
6. Display the schedule of all the presentations on the Notice Board, online platforms, or department blog.
7. Arrange student progress presentations as per the schedule.
8. Give PBL workbook and report writing guidelines and share respective templates.
9. Support students through guidance, orientation programs, appropriate resources (laboratory and e-resources), and services.

2) Guidelines for Mentor/Supervisor

1. Help students define the project problem statement in a meaningful way.
2. Guide students to define the objectives, scope, and outcomes of the project.
3. Support students to develop a work plan for completing the project within time.
4. Decide goals and milestones in the project.
5. Take a weekly review of the project and guide students on the project. (Refer to the questions in Section III.E)
6. Help them to identify useful resources required for the project.
7. Identify potential and strengths of individual students and groups of students and provide proper feeding to acquire new skills or enhance existing skills.
8. Ensure active participation of all the students in the group activity.
9. Assess the performance of an individual student and a group of students and provide feedback.
10. Maintain a record of all these activities.
11. Evaluate the processes being used by students to carry out the project and how well project teams are working together.
12. Share weekly assessment with Review Committee during progress presentations.
13. Motivate students to participate in competitions, paper presentation activities, etc.
14. Encourage students to come up with a prototype, working model, demonstration, new processes, algorithms, etc. at the end of the project.
15. Check the project report thoroughly and give constructive comments to add value to the project.
16. Encourage students to take this project forward for real-time implementation, hardware or product development, research publication, patent, etc.
17. Mentor/Supervisor should empower students to
    - ✓ Explain the mathematical and scientific principles used in developing the project.
    - ✓ Justify or explain decisions related to design, selection of parameters, components and alternatives analyzed during the design process.
    - ✓ Discuss various solution alternatives and how well they meet the selected design.
    - ✓ Evaluate their progress in both completing project tasks and developing new knowledge and skills.

TABLE 2
PRESENTATION GUIDELINES

Presentations	Contents for Presentation	Timeline	Assessment	Expected content coverage
Topic Approval Presentation 1	1. Project title 2. Problem definition 3. Objectives 4. Feasibility check 5. Expected outcomes	2nd Week	1. Idea Inception (I-5) 2. Problem Definition (T-4) 3. Objectives (T-3) 4. Outcomes (T-3)	✓ Identify the project problem ✓ Define objectives and scope considering all the stakeholders of the project ✓ Identify assumptions, constraints (limitations), and criteria (desirable characteristics of the final product or solution) ✓ Refer to related available books, research papers, theories
Topic	If the topic is not			

3) Guidelines for the Students

1. Form a group of 4 students.
2. Select a project problem statement.
3. Discuss the project problem statement among the team members and ideate on it.
4. Research on the project topic through existing theories, literature, technologies, patents, etc.
5. Define objectives, scope, outcomes of the project.
6. Decide a work plan in consultation with Mentor/ Supervisor and adhere to it.
7. Meet Mentor/Supervisor on weekly basis and update the progress.
8. Maintain a notebook to keep records of all the meetings, discussions, notes, etc. This is to be done by the individual student separately.
9. Remain present for all the progress presentations and have healthy interactions with the review committee.
10. Identify opportunities for self-learning and upgrading skills.
11. Actively participate in all the activities related to project-based learning.
12. Document the project in the form of a hard-bound report at the end and submit it to the department.
13. Prepare a prototype, working model, demonstration of the project to display during the final presentation.
14. Participate in project competitions, paper presentations, etc.
15. Maintain an institutional culture of authentic collaboration, self-motivation, peer learning, and personal responsibility.

IV. Assessment and Evaluation

In this section, the assessment and evaluation guidelines are elaborated. These guidelines are presented in Table 2. Table 2 also provides guidelines for the timeline, contents of the presentation, assessment criteria, and expected coverage of the presentation. Table 2 is shared with the students and mentors. So that mentors can help students to understand the evaluation and assessment procedure and students can prepare accordingly. Although the expected coverage of the presentation may be different for different groups, whatever is relevant and applicable should be included in it. The mentor should ensure the same. This will also help to write the project report. Assessment can be done continuously by preparing a Google spreadsheet and sharing it with all the mentors. Apart from this, individual mentors can have their own assessment records for their group of students for the weekly interactions and meetings. The distribution of marks is given in Table 2. Total assessment is done for 100 marks and then it is rounded out of 50.

V. Outcome Measurement Analysis

After adopting the implementation strategy discussed in Section III and carrying out evaluation and assessment as presented in Section IV, the outcome measurement is done by collecting the course feedback from the students. The questions in the course feedback are designed to map the course outcomes listed in Section II. These questions are given in Table 3. The course feedback form is circulated to all the students in the form of Google Form after the final presentation. In this feedback, students were informed to submit the confidence level of the outcome, in which 5 is indicated as a high confidence level and 1 is indicated as low.

There are two divisions of the Second Year Electrical, i.e. Division A and Division B. Student strengths of these two divisions are 80 and 75 respectively. Feedback of the two divisions is taken independently. Feedback of 69 students from A and feedback of 70 students from B are collected. Analysis of this feedback, for each question listed in Table 3, is given in Figures 2 to 13.

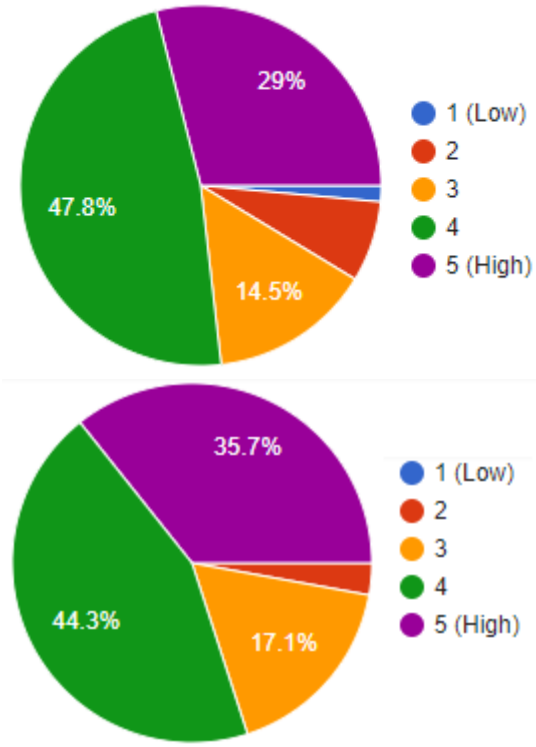
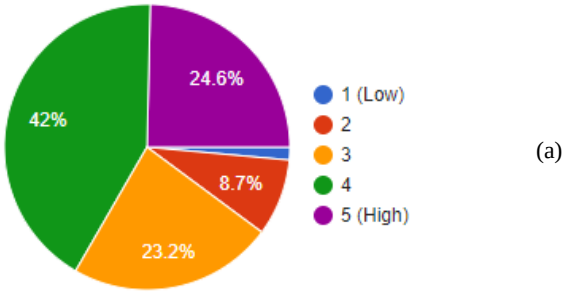


Fig. 2: Responses for 'Are you able to identify and formulate a problem statement for the project?' (a) Division A and (b) Division B

Pie Charts in Fig. 2 indicate the responses of the students for the first question in Table 3. Maximum numbers of students have achieved the confidence levels 5 and 4. Out of this, confidence level 4 has been acquired by more students compared to level 5. Confidence level 1 is identified in Division A and not in Division B.



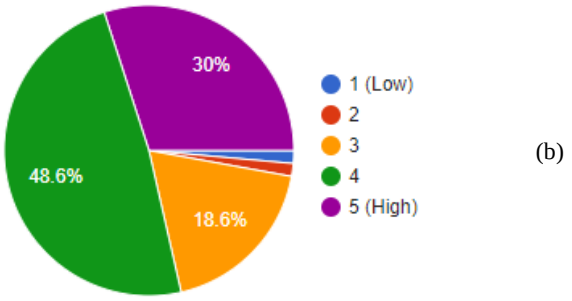


Fig. 3: Responses for 'Are you able to apply the fundamentals of science and technology to find the solution to the problem?' (a) Division A and (b) Division B

Pie Charts in Fig. 3 depict the answers of the students for the second question in Table 3. Here also, maximum numbers of students have achieved the confidence levels 5 and 4. For Division A, almost equal numbers of students have achieved the confidence level of 3 and 5. In Division B, around 50% of students have gained confidence level 4.

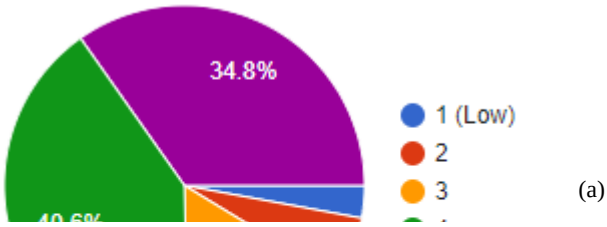


TABLE 3
QUESTIONS IN COURSE FEEDBACK

Q. No.	CO	Questions asked in the course feedback
1	CO1	Are you able to identify and formulate a problem statement for the project?
2	CO2	Are you able to apply the fundamentals of science and technology to find the solution to the problem?
3	CO3	Are you able to work in a team for carrying out different tasks during the project?
4	CO4	Are you able to identify your own and your teammate's strengths and skills?
5	CO5	Are you able to select appropriate resources and summarize the relevant points?
6	CO6	Are you able to use different audio and visual tools to present your project?

Fig. 4: Responses for 'Are you able to work in a team for carrying out different tasks during the project?' (a) Division A and (b) Division B

Fig. 4 presents pie charts for answers of the students for the third question in Table 3. Here, nearly 50% (i.e. 47.1%) students have achieved confidence level 5 for Division B, and for Division A, it is 34.8%. Confidence level 3 is the same for both divisions.

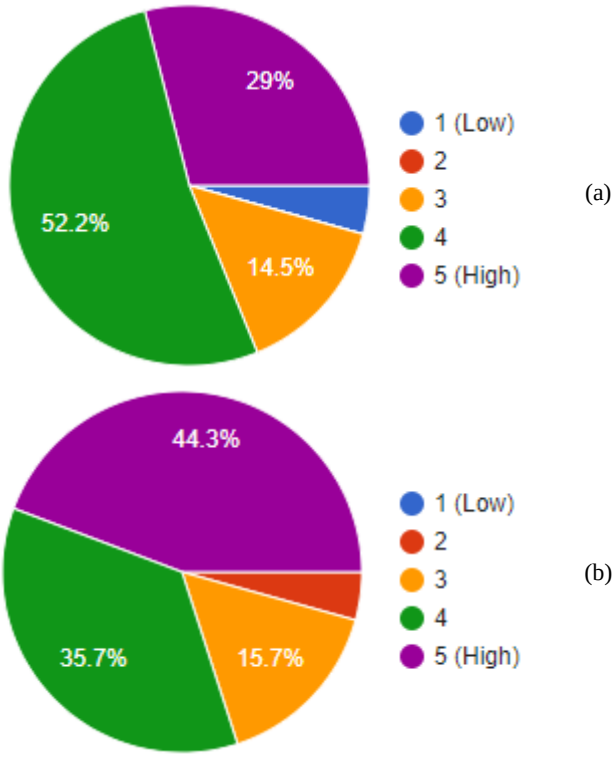


Fig. 5: Responses for 'Are you able to identify your own and your teammate's strengths and skills?' (a) Division A and (b) Division B

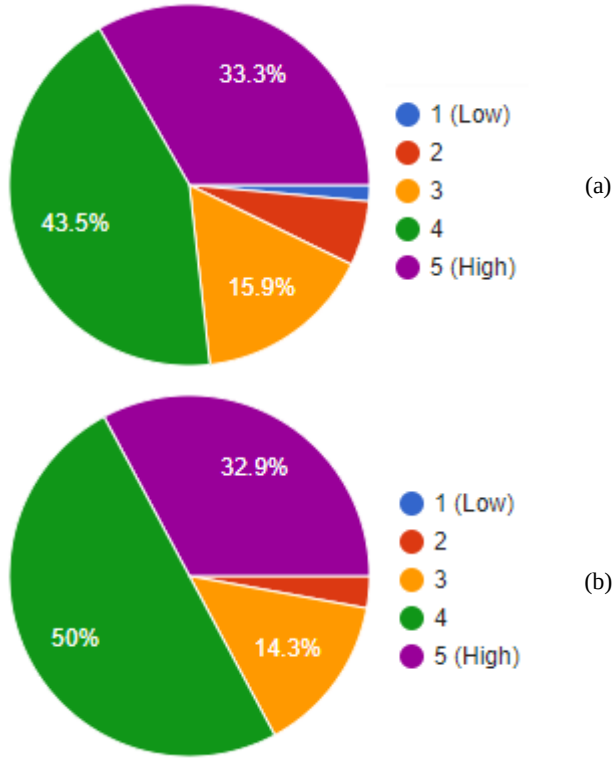


Fig. 6: Responses for 'Are you able to select appropriate resources and summarize the relevant points?' (a) Division A and (b) Division B

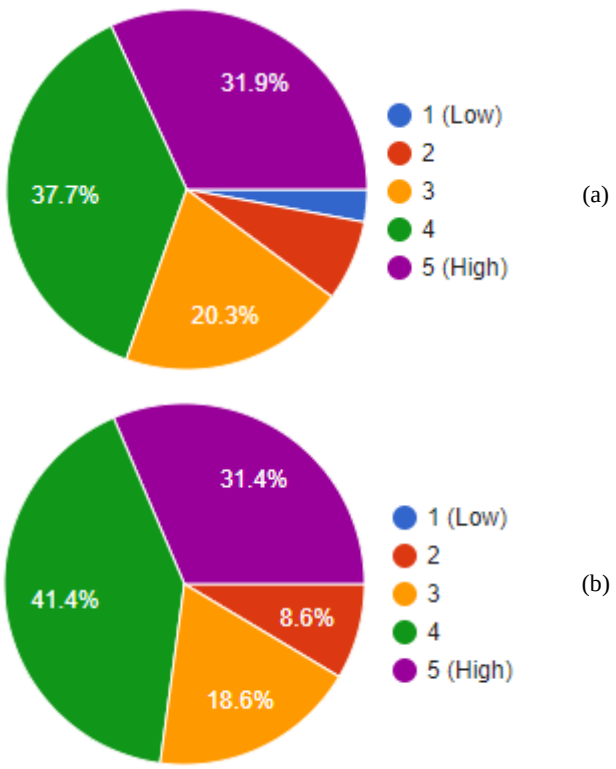


Fig. 7: Responses for 'Are you able to use different audio and visual tools to present your project?' (a) Division A and (b) Division B

Fig. 5 illustrates answers for the fourth question in Table 3 in the form of pie charts. More than 50% (i.e. 52.2%) students have achieved confidence level 4 for Division A and Division B, which is 35.7%. Confidence level 3 again is the same for both divisions.

Fig. 6 shows answers for the fifth question in Table 3 in the form of pie charts. In this, 50% of students have achieved confidence level 4 for Division B, and for Division A, it is 43.5%. Confidence level 3 is more or less the same for both divisions.

Finally, in Fig. 7, answers for the sixth question in Table 3 in the form of pie charts are represented. In this, confidence level 5 is the same for Divisions A and B. Confidence level 4 is more or less the same for both the divisions and also same is the case with confidence level 3. The overall analysis is given below.

1. Maximum achievement is obtained for the confidence level 4 and thereafter for level 5. This is about 70-80% of the total strength. And, the remaining 20-30% of students have confidence levels 1 to 3.
2. Confidence level 1 is observed only in Division A students, which emphasizes the need to work on these students.
3. Confidence level 3 is observed to be the same for all the divisions except for question 2. These are categorized as slow learners. These students can be trained separately.

One more analysis is carried out based on these feedback forms. In this, the percentage of students with confidence level 5 for all the six COs, confidence level 5 for five COs and level 4 for one CO, confidence level 5 for four COs and 4 for two COs, likewise is plotted in the form of bar chart shown in Fig. 8. Around 65.5 % of students are covered in these levels. The

remaining students need to be identified and need to address separately. The result analysis is als o carried out based on the University result declared in September 2021. The marks obtained in the university examination are based on the continuous assessment carried out over the semester as given in Table 2 in the form of Termwork. The overall result is found to be 100%. An attempt is made to map the course feedback and the result of the individual students. But no specific relation is found. This may be because of the reason given below. Course feedback is submitted by the individual students, i.e. it is the assessment of an individual student for himself or herself. However, continuous assessment is carried out by the PBL mentor or supervisor for the students under his/her guidance. So these two perspectives are different and that's why this cannot be mapped.

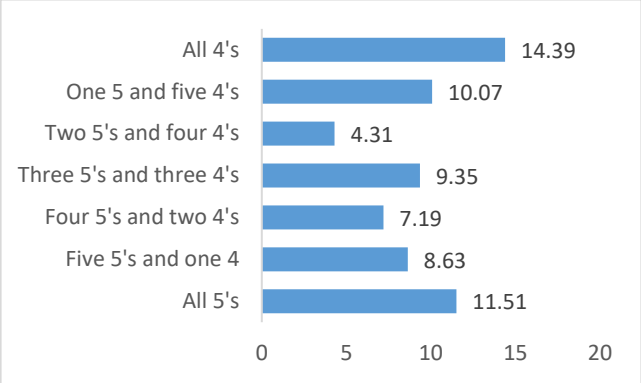


Fig. 8: Percentage of students with various confidence levels.

VI. Conclusion

In this paper, an attempt is made to develop the implementation strategy for adopting project-based learning at the department level. First of all, a guiding document is developed for the PBL at the department level by discussing it with faculty members. Then it is implemented over the semester for all the students. After that, course feedback is collected from all the students. The course feedback forms are analyzed. From this, it is observed that almost 65.5% of students have acquired the required skills and knowledge at a satisfactory level. However, post-PBL a strategy is required to be designed to address learning issues of the students gaining confidence levels 1 to 3 for the remaining 34.5% of students. Nevertheless, the complete implementation strategy can be useful for the first-time implementation of the PBL at the department. This further will evolve over the period. Once the process and practice are matured, it will help both faculty members and students to achieve the common goal of achieving sustainable development goals.

Some of the challenges faced in this complete process are listed below and will be addressed in future work.

1. The whole implementation is done in the online mode due to pandemic. Hence there were limitations for the resources as students were at their homes and were working most of the time in isolation. Post-pandemic this will improve and more promising results may be obtained.
2. Since it was the first time for faculty members as well, the learning on their part is also done. However, more guidance is required to be given to the faculty members on choosing the project problem.
3. A few more questions can be included in the course feedback. Also, the feedback of a group can be taken separately to understand peer learning. Further, feedback of the mentor or supervisor about the students and feedback of students about the mentor or supervisor can also be taken to analyze both sides of the coin.

Acknowledgment

The author wishes to thank Prof. Ganesh Jadhav and Prof. Nayana Jangle for helping in designing and collecting the PBL course feedback. The author also wishes to thank all the faculty members for helping to implement the PBL strategy at the Department.

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