Project Based Learning Methodology: An effective way of learning Software Engineering through Database Design and Web Technology Project

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Abstract: Nowadays, Project-based learning is an integral part of many professional courses in Engineering. Project-based learning is a student-centric approach in which students learn about a course by working in groups to solve an open-ended real world problem. In our opinion, it takes students near to the real world at a very early stage. For students, it acts as a tool to learn concepts and principles, to adapt to the evolving ICT industrial requirements and challenges.

The objective here is to convey our systematic teaching and learning method, based on Project- based learning, to effectively learn the principles and practices of Software Engineering. Also, it prepares students how to apply these theoretical concepts to solve the real world problems by working in a team.

For more than 10 years we are conducting this activity very rigorously for Third Year Computer Engineering students. This activity incorporates applying theory of Software Engineering to develop experiential learning by developing a mini-project using Database and Web Technology. Our 7-point method for development of mini-project has continuous Assessment through critical reviews and presentations by students. We conducted survey for all batches and took their feedback to understand the role of Project Based Learning in their Professional Career. Feedback of these students helps us to update our methodology and/or course contents.

Applying Database technology and getting acquainted with development of user interface is bit easy for students but applying the Software Development Life Cycle [3] learnt in Software Engineering is quite challenging. There are many skills they learn and acquire while developing mini-project like questions to be asked during field work, design strategy and analysis through modelling, teamwork[4], time management, communication skills and many more which takes them a step closer and works as a basic building block for their growth as a software professional. Our survey questionnaire gives insight of all and acts as a measuring tool. This paper addresses our 7-point method, design, our process of evaluation and challenges faced by the students and faculty during this process with the help of representative projects.

Keywords: Project-based learning, Software Engineering, Mini project

1. Introduction

The connected world of today means that software is everywhere. It is a part of our day to day life. The manual tasks that are performed at home, workplaces, small businesses, midsize, or large enterprises can be automated by developing software applications that are meant to make human life easy by performing complex tasks.

Traditionally engineering education was in classrooms and was supported by laboratory sessions. It was always been driven by faculty enforcing rigid course objectives, so students used to acquire theoretical knowledge and in turn were less employable. The various studies conducted to determine the technical and personal abilities required of engineers by today's industry raised concerns such as graduates need to have strong communication and teamwork skills, they need to have a broader perspective of the issues that concern such as social, environmental and economic issues. Lastly, they are graduating with good knowledge of fundamental engineering science and computer literacy, but they don't know how to apply that in practice [6].

It demanded professional knowledge that can master students in critical thinking and life-long learning. New student centric approaches aim at encouraging students to identify problems, analyse it, and finding the solution with the help of faculty guidance. This active learning process is named as PBL.

According to John Savery, Problem-based learning (PBL) is an instructional approach that has been used successfully for over 30 years and continues to gain acceptance in multiple disciplines. It is an instructional (and curricular) learner-centred approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem [1]. PBL model puts teachers in a facilitating role, this task requires more performance, knowledge and experience than traditional teaching.

In the Computer Engineering discipline, Software Engineering is one of the core subject. This course is often

misled by students as theory wherein it is highly practical oriented. To handle this challenge, in our curriculum we have designed a Database laboratory that incorporates mini project development by following the Software Engineering process through our 7-point method.

For Third Year undergraduate students we treat PBL activity as the primary method of teaching Software Engineering.

This paper describes the effective way of using project-based learning for experiencing practical approach towards Software Engineering. The focus of this activity is on critical thinking and problem solving by applying software engineering practices and not on the software product. This paper also discusses strengths and challenges faced during the development of the applications to solve real world problems and life-long learning. To give insights of our methodology we have supported this paper with two case studies of our students from the academic year 2020-21 and 2015-16.

This paper is organised as section 2 describes our PBL process executed at our university. Section 3 describes case studies. Section 4 describes strengths and challenges.

2. Project-based learning process (Mini Project)

Project-based learning is the effective way to make students understand about the topic. It is the practical way which promotes the development of critical thinking skills, problem-solving abilities, and **communication** skills. PBL provides opportunities for working in groups, finding and evaluating research materials, and life-long learning [2]. In our approach we encourage students to form a group of 3-4 students and bring their own ideas for developing database applications. They define problem statement by identifying the domain of their interest. For some students we allocate the project and remaining groups work on existing applications. For the existing applications the feasibility study is based on non-existing and/or additional features.

Each team ideally follows the traditional Software Development Life Cycle (SDLC). In order to solve real world problems and develop a software we have designed 7-point methodology that needs to be followed by each team which is **aligned** with SDLC [3]. This methodology is as follows:

Requirement Gathering through Field Work (Review)

i. After initial discussion with the instructor students are instructed to do field work for gathering and understanding precise requirements.

ii. For example, one of our student group worked on *PRISON ACTIVITY MANAGEMENT SYSTEM* for transparent, user-friendly jail work management. For the same they visited Yerawada, Pune, and Maharashtra jail by completing all government formalities.

Problem Statement formation (Review).

iii. At this stage students are ready with the clear requirements and have understanding of the functionalities for further development of the project.

iv. Students are presenting the problem statement

- Requirement Analysis –(Review)
  i. Through review and discussions with the instructor, students define the scope and objectives of the project.

ii. In turn they are in a position to identify functional as well as the non-functional requirements and the constraints of the project.

- Design -ER Modelling –(Review by peer students)
  iii. For good database application the design model we used at this stage include ER diagrams.
  iv. This stage includes review by peer students in which each group presents their project in the form of an ER Diagram, explains their problem statement and the rest of the students give their comments and asks design clarification.

- Implementation- DDL Enforcing constraints–(demo)
  v. Students convert ERD into database scripts and enforce all designed constraints.
  vi. Instructor validates database script and constraints, if found correct ask them to proceed for the front end design.

- Testing Life Cycle
  i. Students are asked to write test cases in the template given and validate them for identifying bugs.
  ii. Test cases are designed for user interface and data validation.

- Report writing (format)
  i. Our major emphasis is on the documentation of the project. We provide them with a standard project report template in which they are expected to document all the work done at all phases of SDLC.
  ii. They are expected to take time to time screenshots for preparing report.

3. Project Based Learning- Case Study

To understand students' perception about PBL activity, every year towards the end of the trimester we collect feedback from the students. For the same we collect sample case studies. From the sample case studies we have randomly picked up 2 case studies from two different academic years.

A. Case Study 1: *COVID PLASMA DONATION DATABASE SYSTEM*

1) Brainstorming on the topic: For the DBMS project we were trying to build something that would benefit the country keeping in mind the current COVID situation. Plasma therapy was the suggested method for fighting against the disease. The first plasma bank of India was also set-up in Delhi recently. So we decided to simulate a system that would make the donation process easy for the donors and the health workers.

2) Distribute project duties among team members: Preparing the basic structure of the database and the tables, UI design and connectivity, DBMS functionalities, these were the various tasks that were to be performed for the project and we divided the work among ourselves. All the team members were supposed to research and tell how and what should be added in the project.

3) Schedule regular team meetings: From the day we formed the group we began scheduling regular meetings. Due to the hectic schedule of the college we conducted

meetings on weekends and allotted tasks to every team member that were supposed to be completed within the week. In the first two weeks we decided the scope and the functional requirements of the system.

4) Propose the time of an initial team meeting with the instructor: We prepared the SRS of our system and in the third week of our trimester we scheduled a meeting with our instructor and presented the idea, the scope and the functionalities that were in our system. She suggested some changes and functionalities that could enhance our project. She also gave us motivation to work hard and prepare a system that she was expecting from us.

5) Generate a preliminary project description: The changes were made and after approval from our instructor we began working on the technical aspect of our system. We then prepared a preliminary project description and the abstract.

6) Drawing the plan of work: We made a list of the languages and the courses that were required for this project so that we could start learning the different facets and get hands on it. One of the members drew the ERD and the other member made the tables and inserted dummy values into it for testing purposes. Once the tables were ready the other two team members simultaneously started working on the UI of the project. We were learning different things and side by side implementing it in our project.

7) Students developed code: One of the team members learnt the Django framework that was used for connectivity. Three members of the team learnt the web designing and helped each other to prepare the final UI design. We were learning the backend part that is MySQL in the course of the trimester and were implementing everything that we were being taught.

8) Drawing up a test case plan: Once the UI design was ready and the tables were created and the connectivity also established the entire team reviewed and tried to enhance the system as per the user requirements. For the testing, we also asked people other than our team members to test the system in order to get their opinions. We also used automated software called selenium for testing. After successfully testing, we added PL /SQL procedures and functions, triggers and advanced DBMS functionalities for the ease of the users.

9) Making a list of conflicts that were in the team. Describe why they were conflicts, based on psychological characteristics of a team member: We faced several internal conflicts in the team as well. In the COVID affected world as we were not able to meet physically we faced communication gaps too. Also when one team member suggested modifications the other one didn't agree to it and suggested other alternatives. Nevertheless we combined all the ideas and modifications by the team members and completed the system and prepared the report

10) Compiling list of lessons learned and good practices gained during project development: The biggest advantage of this project was that all the team members learnt the front end and the back end development. We learnt UI designing, Database scripting, Python Django framework and many other supplementary technical skills. Apart from these technical stuff we also learned how to collaborate with each other and work as a team. We also learned time management and built in ourselves an eagerness to learn new things. We have also developed project management skills.

11) Obtaining feedback from other student teams: We showed our project to other friends as well and received quite a good feedback. They said the system worked very well, the idea was unique, the report made was also structured and Descriptive.

B.   Case Study 2: *EVENT MANAGEMENT SYSTEM*

1) Brainstorming on the topic: We listed down the potential topics which we can take as the DBMS problem statement. After discussing among the team, we all decided on a problem statement which we thought was challenging and would tackle a real-world problem. That was we decided to develop an event management system for local events happening across the city. The thought process behind this project was to make people aware of the local events like art exhibitions, sports competitions, etc. happening across the city which are not advertised. The project also intended to provide event organizers a platform where they would showcase their events.

2) Distribute project duties among team members: We were a team of three. While chalking out the basic work that would be required, we divided the work in three sections:

UI: Which would involve developing the basic forms like login and registration and the designing of the website.

Backend: Backend would involve database management and coding of interface which would enable interaction of UI with the database.

Documentation: This work would involve documenting all the work right from chalking out basic entities, preparing basic layout of pages, writing down unit test cases that the system should satisfy and finally a project report that would describe all the work which was done as part of the project.

In order to get experience of all the three sections, it was decided mutually that each one of us would do some work from each section.

3) Schedule regular team meetings: The team used to meet every Friday to discuss tasks for the coming weeks that each person must complete. We used to meet on a required basis if a team member would face any issue that would be a blocker.

4) Propose the time of an initial team meeting with the instructor: For the initial meeting, we were asked by our instructor to come prepared the problem statement and the abstract of the project. The problem statement was then discussed and approved by the instructor. We would meet our guides during the DBMS laboratory sessions where each team would meet the guides and discuss their progress on the project. The instructor would have a look at our project and would give her review about the same.

5) Generate a preliminary project description: As a part of preliminary project description, our team had submitted a problem statement, an abstract which would describe what the project plans to achieve. We had also submitted the sample forms that would get used in the user interface and

entity diagram showing how every entity involved in the project interacts.

6) Drawing the plan of work: After getting approval on the forms and entities, the team began preparing for the project. First, we finalized the technologies we would be using for the project. We decided to use MongoDB as the database, PHP as the scripting language which would develop the business logic for the project. For UI, we decided to make use of Adobe Dreamweaver to design website in order to enhance the user experience. We then prepared the wireframes of screens to get an idea how the screens should look like and interact with the end user. From the screen, we identified the functions like button clicks, etc. where there would be a call to the backend and where our PHP code would fit in. After identifying all these areas, we began coding for the project.

7) Students develop code: After designing the system, we proceeded with the implementation. Initially, we made all the connections to the database so that we could easily use these connections directly in the code. Then every week we used to target one wireframe screen and used to complete all the required work related to that screen including the backend and HTML and CSS of the same. Some functions developed in the backend were reusable in other screens. After all the screens were done, we integrated each of the screens developed to form the whole system.

8) Drawing up a test case plan: Initially while designing the system, we had prepared some same test cases based on what the user is expected to see when he performs a particular action on the screen. While development we added the unit test cases in the backend components. Later after integrating the screen, we used to do a round of integration testing to check whether the integration is working fine. After complete integration, we tested the use cases which we had initially written to check whether the system was working as expected. We recorded the actual and expected results of these test cases in a table which was added in the project report.

*9) Making a list of conflicts that were in the team. Describe why they were conflicts, based on psychological characteristics of a team membe*r: Our team had done a lot of projects together before and hence our sync was pretty good as the three of us were well versed with each other's skill set. So, there were hardly any big conflicts in the team. The main conflict for us was the different work time. The three of us used to code at different times and that sometimes used to create issues especially while integration as we had to adjust our work timing to get things done.

10) Compiling list of lessons learned and good practices gained during project development: In this project, we followed a lot of good practices. We did not hop on coding directly. First, we finalized the entities that are involved and how they would interact. Then we prepared proper interaction diagrams and listed basic use cases. After this we decided the technology stack to be used. After that we proceeded with the coding phase. Even in the coding phase, we ensured best practices were followed and code was optimized, and unit test cases were in place. The project was developed iteratively, and feedback received by the instructor was also accommodated.

11) Obtaining feedback from other student teams: Other groups in our batch were very helpful and approachable. They were ready to give feedback and gave feedback on code as well as the project report prepared at the end. The comments were taken into consideration whenever possible and changes were made accordingly.

4. Observations

A. Strength and Weaknesses of our approach

Together we are conducting this activity from the year 2008 till today. In these twelve years we have handled almost 300 groups and observed some strengths and weaknesses of this activity from the students' point of view which have been listed below.

Strengths:

• This activity helps students correlate theory with real world problems.

• Through this activity students get to improve critical thinking and problem solving skills.

• They are encouraged to work on their own.

• In spite of having different views and perspectives, students learn to work collaboratively.

• Since the students are working in a team, it increases the sense of responsibility and understanding among them.

• It also increases the confidence and leadership quality among them.

Challenges:

• Balancing theory and practice is a real challenge in Software Engineering at the undergraduate level [5]. Initially students face difficulties coping up with this process.

• Field work is a very challenging process for students as this phase requires asking right questions to the end user.

• They are required to put an extra effort towards the design phase of SDLC to make the information system more accurate and effective.

• This PBL activity is very rigorous and demands continuous follow-up by instructors. For the successful delivery of the mini-project it is essential to take into consideration proper Time management or else whole schedule collapses.

• Also, if students remain absent, for some reason, they lag behind with some stages in the development, due to which they face difficulties coping up with their peers.

• Students are enthusiastic towards the first 6 stages of our 7-point process but feel the last stage as less important and unnecessary.

By understanding the students' challenges and instructor challenge of getting done all project successfully we developed this 7-point method. During execution of this 7-point method instructor used to schedule 1 day per week 4-5 hrs for reviews where status of their deliverable was taken. Students have to face reviews and critical comments from not only instructors but also by their peers. These continuous reviews helped us in mitigating many challenges discussed above. Mainly Time management is critical issue in

successful delivery of the mini-project. These reviews helped us tackle this problem to great extent.

B. Evaluation of our work

To understand to what extend we succeed in this activity, we used to ask students to fill up a questionnaire after their graduation. The questionnaire has been replied from almost 140 students. Table 1 includes the questionnaire prepared by the instructors.

Table 1. Survey questions

Sr. No	Questions
1	Student First Name
2	Student Last Name
3	Year of Admission
4	Year of Graduation
5	Kindly provide Post Graduation details if any
6	Currently Employed?
7	If Yes Provide Company Name
8	Professional Experience(in years)
9	Are you Self Employed (Entrepreneur)?
10	If Yes provide details(Company Name, Place)
11	Title of the Miniproject
12	Miniproject Problem Statement:
13	Share your experience:
14	Challenge faced during the Miniproject development
15	What do you like most about Project Based Learning? (Project Based Learning is a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an engaging and complex question, problem, or challenge.)
16	How this mini-project helped you in clearing theoretical concepts of Databases and Software Engineering
17	Did you feel Field work contributed in understanding the requirements better?
18	Can you provide details as where and how did you do field work?
19	Do you feel this mini-project contributed in getting placement and critical thinking?(you can support your answer with description)
20	Do you feel mini-project helped in developing Teamwork spirit, project management skills and improved your communication skill ?(You can share your experience here)
21	Do you feel you were prepared in problem-solving and general technical knowledge?
22	Do you feel mini-project development experience helped building you profile and can be considered as an important milestone of your career?
23	Do you feel it helped you in the development of communication and interpersonal skills
24	Do you feel it helped you in industry to work with all sorts of teammates (Teamwork)
25	Do you feel your group was a good blend of teammates with different technical strengths and it helped you in the development of mini-project
26	Do you think Project Based Learning is relevant to current Industry requirements
27	Do you feel Project Based Learning(Mini-project) is important in the curriculum and is value to the current undergraduates?(Question for only Alumni)
28	What did you like most about working on this project? Select all that apply.
29	What did you like least about working on this project? Select all that apply.
30	Overall, are you satisfied with your experience using Project Based Learning, dissatisfied with it, or neither satisfied or dissatisfied with it?

As shown in figure 1, 77.8% of the 140 students felt that problem identification and critical thinking to reach a

solution is a bit challenging as compared to Data coding which is very well put up by Roger Pressman in his book. Also, Data collection and Visualisation phase is very critical as compared to other phases.

Teamwork is the next critical aspect as your best friend may or may not be your best project mate. This important lesson students learn before taking up their Major project.
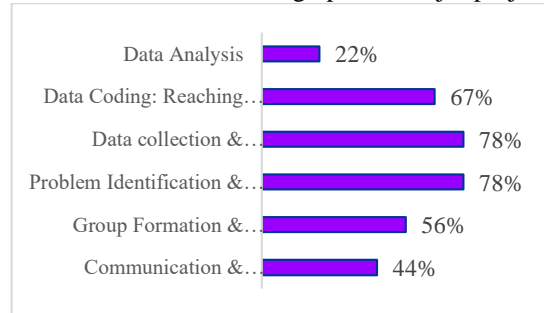

Fig. 1 Challenges faced during the application development

5. Conclusions

Our survey shows a positive response of the PBL method, and it has increased students' interest to apply theory, principles and practices of Software Engineering to a practical software development project. This approach motivates students to do self-study, solve real life problems and collaborate working in small teams. Project based learning method helped students to actively participate in learning the theory concepts of Software Engineering, and better learning at the application level. Students expressed that by doing this project they got to know about various concepts of Software Engineering, Database design and programming, Java programming and how these concepts can be applied at application level.

Few students even expressed that they could make an application which really made their parent's/relative's life easy. This gave them confidence, satisfaction, improved communication skills as well as a new perspective towards their own life.

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