Impact of Project-Based Learning for Improving Students Skills by Incorporating Design Thinking Process

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Abstract:
Engineering education is oriented towards active leaning & its implementation and hence project-based learning (PBL) plays a major role to enhance students learning practically. In this context, his study implemented PBL in the course projects for mechanical engineering students and students' learning was investigated. Every project needs roadmap to follow for being on the desired path and gets fruitful outcomes and hence in this study design thinking process was introduced in the course during PBL which helped students to understand the real-time problems which can be solved by applying the knowledge gained theoretically from the courses. Through design thinking process, students got to know the real-time problems and improved their skills to deal with the same by applying their knowledge. Students have improved their understanding to handle real-time problems and at the same time they interacted with community partner that helped them to go in the depth to work on it. This study has shown the importance of design thinking process and its impact on student's learning.

Keywords: PBL, Project Competition, Products, Teamwork.

1. Introduction

Engineering students must be prepared technically to handle any real time challenges. In this context, Outcome based education (OBE) helps the faculty and students to transform engineering education following the practical approach. To achieve the program outcome (POs) defined by national board of accreditation (NBA), the course delivery needs to be reframed so that maximum attributes can be achieved. PBL plays very important role to enhance students learning practically [1].

PBL in India is becoming more popular and adoptable pedagogy to improve teaching and learning process. Most of the industry is demanding students with strong core technical skills. In addition to that students should have critical thinking; innovation-oriented skills and they must also be capable of handling real time projects [2]. Nearly all employability surveys show that hardly 10-25% engineering graduates are employable [1][2]. In this context, Incorporating PBL with design thinking process can make the students to work in real time problems by applying engineering knowledge. To make students industry ready, the authors have introduced the Robocon competition which is one of the recognized competitions in India that promotes the incubation skills of students. This study provided information about the impact on students' learning after being enrolled with the competition.

In one of the studies, the authors trained students on AI technology to experience its real uses and implementation. The aim of this study was to give more opportunities to girl students in higher studies.[3] As a result of this PBL, two girls were accepted to University of California as an intern [3].

PBL is highly recommended to fill the gap between 'Theory" and 'Praxis' especially in a discipline Architecture which is the collaboration of Art and Science.This paper examined the previous research done on PBL and set up their own hypothesis for conduction of PBL [4].

PBL is being used by many researchers for a very long time and there is enough evidence in the literature that supports the fact that the PBL pedagogy enhances students' learning and skills [5-18]. [5] The type of skills and the learning levels that need to be instilled in students, depend on the requirement of the study and the design of the study.

Implementation of PBL requires adequate planning and dedicated efforts in all the phases right from the initial to the implementation phase [19]. In one of the studies, the various challenges faced by instructor have been mentioned [19]. The study focused on different trainings to engineering staff for understanding the importance of PBL and its implementation, where the selected engineering staffs have undergone through various training programs like communication skills, practical hands on trainings, etc.

to make them capable and ready to implement PBL at their institutions [19].

Since it is already mentioned that PBL needs proper planning and structure which needs to be followed for achieving successful outcomes, this study focuses on implementation of PBL by following design thinking process for getting real time projects to be done from students [20]. Design thinking process gives the structure for implementing the PBL that introduced the various steps/phases of engineering process to meet the goal [20]. Each step makes students to perform practical study. At the end we can ensure the successful delivery of the project if we follow the design thinking process from beginning to end.

In PBL approach students learned the importance of teamwork, decision making, leadership skills and time management [21]. After completion of PBL project students have participated in national level project competition which helped them showcase their work with peers and learn from this experience.

This paper explains the real time problem faced by the community which got solved through PBL using the design thinking process. Renewable energy source course contains 5 units, for each unit, we have conducted PBL. After the completion of first unit, the students identified the real time problem in the college surroundings. Before identifying the problem, teams formed such that each team contained 6 members (N=60) for the team design thinking activity to be conducted in the classroom.

2. Method

For PBL methodology, we have followed design thinking process. In the starting of the class we have conducted design thinking activity shown in figure.1 for easy understanding of problem. In this activity, students divided into eight groups, [6] where students actively involved in this activity and learned the design thinking process.

Fig.1 Design Thinking Activity

Fig.2 Wallet Activity

To understand the community related problem, wallet activity was conducted for students shown in figure 2 [22]. The students design of the wallet depends on community partner requirement, and from this process students know about how to interact with community partner, how to design the product and provide solution to the community partner.

- Problem Identification

Design process in shown in fig.3, the heart of the design thinking process is stake holder or community partner. After the completion of the first unit, students' task was to identify the problem exploring the nearby villages. Some of the problems identified in the surroundings villages are shown in Table.1

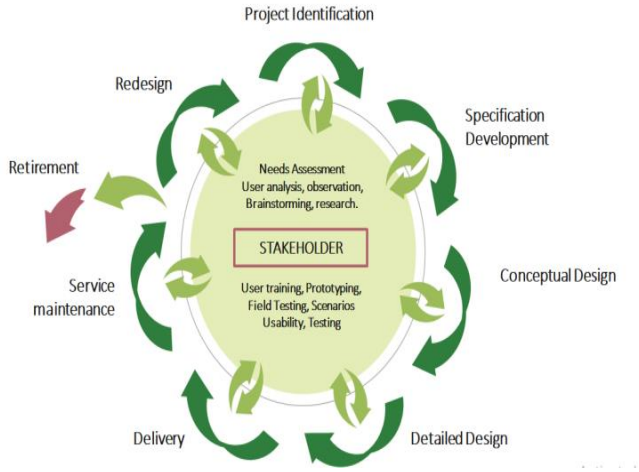

Fig.3 Design process

Fig.4 Grass cutter

Fig.5 Problem identification in surrounding villages

Table.1 Problem Title

Sl.No	Problem Identification	Project Title	Team Number
1	The old technology involved manual powering of pottery wheel this was done either with sticks or legs. Over the years although there has been a lot of progress in technological aspect, a larger community of rural potters still rely on the old technique	Solar Pottery Maker	1
2	Our Community Partner Mr.Bhoomaya is 67 yrs old person shown in figure.4. His work is to trim & clean the grass of the lawn for every alternate day. While doing this work, he is facing problems to push the heavy weight machine and carrying a direct AC power supply wire all over the lawn. It is time consuming work for him	Solar Powered Grass Cutter	2
3	Our community partner is karthikprabhu. His occupation is selling the sugarcane juice. 1.More expensive. 2. Requires continuous power supply. 3. Hand injuries occurred due to existing juicer machine. 4. Maintenance is very high.	Solar Suger Cane	3
4	Our Community Partner Mr.RamuGoud staying in D Pochampally village. They have a lake in their village which is ill maintained, people find it difficult to clean the lake, due to its depth. He wishes for a machine which can clean the lake without risking life of anyone during its cleaning.	Solar Aqua Skimmer	4
5	Our community partner is Mr.Balaswamy working as a farmer in Kolanupaka village, Remote area. He used to spray the fields for his daily wages, carrying the fertilizer tank on his back to the fields. He is facing the problem of unavailability of electricity as well as suffering with back pain & skin allergy.	Solar Fertilizer Sprayer	5
6	Our community partner Mr.Bhoomaiah is the village water supplier of the Gowdavelli village. His job is to supply water to the 5000 odd families of his village. He faces a problem with the overflow of water while he fills the village tanks. By interacting with him we also came to know that he would like to get the job automated so as to prevent the wastage of water caused during the filling of tanks.	Solar Dustbin	6

- Specification development

After identification of problem, team went through the product survey to identify the solution for the problem. Students interacted with the community partner and noted down the problems which is shown in figure.5. In the product survey, the students will the available product, patent number, key features and the drawbacks of the available product shown in Table.2.

Table.2 Product survey of Solar Grass Cutter

Product Name	Patent Number	Key Features	Draw Back
Ride on grass cutter	US2865159 A	1. More Manoeuvrability 2. Batter Handling	Not Suitable for small field as it is bigger size 1. Requires fossil fuels which in term emit toxins 2. Maintenance cost is high 3. Mess with oils & lubricants 4. Risk with the oils
Automated grass cutter	US5974347 A	1. Operating time can be set 2. No emissions 3. Saves time	1. Requires a perimeter wire 2. Maintenance cost is high 3. Battery consumption is more
Hybrid Remote control grass cutter	US7677344B2	1. Flexibility	1. Fossil fuel required starting engine 2. Expensive 3. Maintenance cost is high

- Conceptual Design

Table. 3 Decision matrix of Solar Dustbin

Criteria	Weight	Idea 1	Idea 2	Idea 3
Maintainability	5	3	3	5
Economical	5	5	5	3
Feasibility	5	4	4	5
Sustainability	5	5	5	5
Physical effort	5	4	4	5
Total		105	105	115

Fig.6 Prototype of Solar Dust bin & Solar Aqua Skimmer

On completion of product survey students solved the problem through decision matrix shown in Table.3, where students identified multiple ideas to solve one problem. Depending on the idea, students started working on the prototypes shown in figure 6. Through decision matrix, students gave the preference to the solution having more weightage over the others. Depending on the total weightage marks and after taking feedback from the community partner, students convert prototype into products [6].

- ❖ Possible Ideas:
- ➢ Tilt Mechanism
- ➢ Pedal Mechanism
- ➢ Solar dustbin – messaging device.

- Detail Design

After taking the feedback from community partner the detail design was done in the Catia mechanical software.

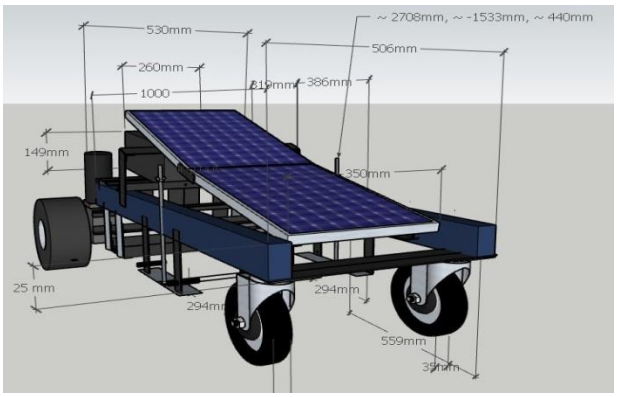

Fig.7Solar powered grass cutter design

- Delivery

Figure.8 & Figure.9 shows the PBL project is delivered to community partner. With the feedback from the community partner, Figure.9 fertilizer sprayer tank is placed on a frame to reduce the physical stress (like back pain or skin diseases) of a community partner.

This frame is not only useful to carry fertilizer tank but also useful for carrying any seeds to the field for planting or manures to feed the plants and to carry vegetables after harvesting up to 50kg.

Fig.8 PBL Project Solar Grass Cutter delivered to community partner

- Service & Maintenance.

Service will be done once in 6 months, if product fails in one year it will be redesigned again

Fig. 9 PBL Project Solar Fertilizer Sprayer delivered to community partner

There were 2 different stages of project review and for each phase's assessment rubrics were shared with the students before they startedworking on the project to set the expectation clear. The rubrics of step 1 and 2 are referred in table 4 and 5.

After conducting the PBL and community feedback on product, the feedback was collected from students, to know if students clearly understood the activity, and the technological approach while following the PBL pedagogy.

3. Results

Fig.10 Students Participating in National Level Project Competition

In this study, it was found that design thinking process made students to prepare a detailed plan to implement an activity following the PBL approach with appropriate deadlines. Each phase of design thinking process had some milestones that were achieved by students successfully. In addition to that, students experienced the journey of solving community-based problems by applying engineering knowledge. Almost all 6 projects completed the detailed design and were successful in building the working prototype.

Furthermore, students participated in various competitions and performed well as a result one project "solar pool skimmer" got award for innovation in "water problem" category from Telengana state shown in figure.10. It was pleasure to see that one product" cordless grass cutter "handed over to the community partner and worked well for handling real time problems. Now the same product is going through redesign phase to achieve the maximum accuracy for cutting grass effectively. Overall, all projects will be carried forward for the next semester for its further improvements to solve the actual need.

Table.4 Rubrics the evaluation Phase 1

PROBLEM IDENTIFICATION	**Interaction with the Community (3 Pts)**	**3 pts. = Clear Documentation of Community interaction with visual proofs**	**2 pts. = Clear Interaction with community with an appropriate document**	**1 pt. = Oral representation of community interaction (no proof)**
	Problem identified (3 Pts)	3 pts. = Clearly addressing the problem by statistical representation of either human, educational, health or environmental community	2 pts. = Mentioned without statistical representation.	1 pt. = Does not mentioned the clear need of the community
	Stakeholder Identification (3 pts)	3 pts. = Clearly identifies a specific and real user or organization, by name, which can provide feedback/suggestionfor the team and receive the project once completed.	2 pts. = Mentioned the community but not a specific user who can provide suggestions or feedback over the project	1pt. = No clear details of community or specific user
SPECIFICATION DEVELOPMENT	Measurable requirements (3 pts)	3 pts. = Clearly describes at least 5 measurable requirements depending on the project	2 pt. = Less than 4 described specifications or the ones described are not measurable	1 pt. = At least 2 specifications listed
	Identification of existing solutions (3 pts)	3 pts. = Identification of existing solutions addressing the similar problems with appropriate documentation	2 pt. = Identification of existing solutions addressing the similar problems with no appropriate documentation.	1 pt. = No clear identification of existing solutions.
	Gaps in existing solutions (3 pts)	3 pts = A clear explanation/ analysis of gaps with the documentation by using the appropriate case studies.	2 pts = A marginal explanation/ analysis of gaps by using the appropriate case studies.	1 pt = No appropriate case studies for justification of gaps.
	Poster Presentation (Mandatorily) (3 pts)	3 pts = Creative poster presentation	2 pts = Good oral presentation	1 pt = Either Creative poster or good oral presentation

Table.5 Rubrics the evaluation Phase 3

Assessment Parameter		**Good**	**Average**	**Poor**
Design (15M)	Product architecture (5M)	Product architecture manual with measurement	Without manual and measurem	Without manual /only Architecture (2M)

		2D or 3D (5M)	ent or Related Proofs (3M)	
	Design skills (5M)	Providing proofs of number of Iterations covered (5M)	Number of iterations without proofs (3M)	Not covering number of Iteration directly jumping in to design (2M)
	Working status (5M)	Working of the product (5M)	Partially working (3M)	Not working (2M)
Testing (10M)	Product demonstration(3M)	Product demonstration (3M)	Without product demonstration only video presentation (2M)	No video or product demonstration (1M)
	User testing (4M)	Efficiency and safety usability to community partner (4M)	Not mentioned the safety and usability (3M)	No safety and life span of product (2M)
	Feedback (3M)	Details of providing community partner feedback , NGO and photo (3M)	No community partner feedback but only photo (2M)	No community partner feedback and photo (1M)

4. Discussion

PBL is one of the effective pedagogies which make the students to improve their various skills. In this study we have implemented various assessments (direct & indirect) to evaluate student's skills towards getting placement in MNC [2]. However, the paper neither mentions the placement number nor internship. On the other hand, this study focused on participating in competition to improve student's technical skills and make them capable to perform in real time world [3]. However, they have not mentioned the assessment part for conducting the PBL**.**

In this study, the authors emphasized more on solving the real time problems which were taken from the community. In addition to that rubrics were framed to evaluate the performance of each student. Design thinking process helped student to understand actual need and solving identified problems by providing engineering solution.

5. Conclusion

Implementation of PBL improvised the student's technical knowledge and learning's. It attains the maximum PO's attributes which are required to have for engineering graduates that are not able to achieve through basic curriculum.

Incorporating design thinking process can provide the roadmap to identify, think, design, analyse and develop solution for real time problem.

This study also leaves scope for future work and some direction towards that include, a quantitative study to investigate the effectives of the project-based learning used with the design thinking process. It would be interesting to explore students' abilities in performing all the phases of the design thinking process through a survey [23-24]. Also, critical insights on the PBL approach with the design thinking process can be further investigated using a qualitative study by conducting rigorous interviews with students [25-26].

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