

Integrating Various Instructional Strategies with Project Based Learning for Enhancing Knowledge and Employability in Automobile Engineering

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Abstract : Interdisciplinary projects are an ideal way to prepare students of engineering in becoming professional engineers, having necessary graduate attributes (GA) in accordance with Washington Accord. These attributes have been defined for engineering graduates so that at the completion of their graduation they will be industry ready. Projects Based Learning (PBL) is the most appropriate way to prepare students for industries. The study reports the evidences of PBL for a team of 25 students for design and manufacture of a theme based automobile over a period of 10 months conducted under FSAE (Formula SAE). FSAE an interdisciplinary activity where students apply their skills for building a complex engineering product (automobile), which involves real time design, manufacture and assembly. The direct outcome of this study was student's participation in SAE Collegiate Design Series since 2012. Every year a team of 25 students participate in the PBL activity that spans over a period of 10 months. Faculty advisor integrated various instructional strategies like Think Pair Share, Peer Instruction, Out of Class Video, Flipped Classroom with the PBL for design and manufacture of an automobile.

Student participants of the study not only developed thorough analytical and problem solving skills but also the necessary skills to assemble and maintain the automobile. During the entire PBL process it students were assessed for satisfactory learning at all levels of Bloom's taxonomy. Accordingly for 9 GAs attainment was at high level & for 3 GAs attainment was medium.

Keywords- Project based learning, Flipped classroom, Blooms Taxonomy, Graduate Attributes

1. Introduction

Engineering is a field of innovation. Training engineering students to be good designers is both an industry desire and an ABET stipulation (Dym et al., 2005) (McMasters et al., 1996) (Roohshad et al., 2016). Mechanical engineering design education usually provides theoretical knowledge about individual machine parts and the required skills to develop products using methodical design approaches (Krithivasan S et al., 2014). The curriculum often fails to teach the proper engineering design methods from an industrial point of view (Dym et al., 2005) (Devon R et al, 2004). In addition, students often have no contact with actual machine parts prior to their studies. Practical experience is of paramount importance to successfully mechanical engineering design products such as an automobile. Students' lack

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of knowledge of real world engineering practices and this precludes quantitative analysis of design alternatives, and the choice of design solution is based largely on intuition resulting in unsuccessful projects and discouraged students.

Unfortunately, standard university education often lacks courses that impart practical experience. The 'problems' given in text books are often simple arithmetic exercises and do not reflect a real world problem. The dependence on theory based model does not prepare the students for the real world problems they will face in industry. The theory based model has been the biggest weakness in engineering education. Engineering students need an opportunity to apply their science to resolve design solutions. These can be attained through project based learning modules.

Projects will have varying complexity, but all will relate in some way to the fundamental theories and techniques of an engineering discipline. Small projects may only involve one area of engineering specialization, but larger projects will be multidisciplinary not only involving engineers from different specializations but other professional and non-professional personnel and teams. Successful completion of projects in practice requires the integration of all areas of an engineer's undergraduate training (Krithivasan S et al., 2014).

The paper reports the outcome of integrating various instructional strategies with Project Based Learning (PBL) implemented for simulating real-world engineering design project of a themed automobile on student employability. The paper is organized as follows; in Section 2 we describe the need of PBL followed by Literature Review in Section 3. Section 4 explains the details of the PBL strategy. Outcome of PBL is discussed in section 5 followed by conclusion in section 6.

2. Need of Project Based Learning

Mechanical Engineering is typically a theory based model. The structure covers the three aspects of mechanical engineering such as mechanics, thermal sciences and manufacturing. Interdisciplinary subjects such as mechatronics and control systems are also included. Since all subjects are theory based, exposure to practical aspects is very limited. Other than the regular laboratory sessions and field visits students get little hands on experience. Students typically work with text book exercises only and are

not really exposed to real world problems.

To be industry ready, students should not only be thorough in subject knowledge but need to possess relevant technical and soft skills. This can be effectively imparted through PBL. PBL is especially true for disciplines involving complex interdisciplinary products such as Automobiles, Aircraft and Industrial Machines. Almost all products developed under the mechanical engineering are interdisciplinary. Pedagogical research in engineering education has shown the importance of Project Based Learning (PBL) in creating industry-ready engineers (J. E. Mills and D. F. Treagust, 2003) (Stanford PBL Lab, 2014). Research in this area points to the fact that even though PBL has no direct bearing on student grades, it has impact on development of required skills (A. S. Blicblau and D. J. Richards) (J. Strobel and A. van Barneveld, 2009).

There are very few mechanical engineering competitions based on PBL, compared to the several competitions on robotics and programming. The best resource for PBL in Automobile Design and Manufacture is the SAE Collegiate Design Series. The SAE Collegiate Design Series is an intercollegiate engineering design competition for undergraduate and graduate engineering students. The object of the competition is to simulate real-world engineering design projects and their related challenges. Each team is competing to have its design accepted for manufacture by a fictitious firm. The students must function as a team to design, build, test, promote and compete with a vehicle within the limits of the rules, also to generate financial support for their project and manage their educational priorities. Each team's goal is to design and build a prototype of a vehicle based on the theme of the competition. In India, the series includes Mini Baja and FSAE competitions along with smaller themes such as Efficycle (Electric tricycle) and Go-Kart

The main impetus behind starting PBL activity at WIT was to develop a system of learning which will cover all major levels of Blooms taxonomy and Engineering Graduate Attributes as stated by NBA and Washington. The main objective of this activity was to increase employment in core mechanical engineering sector.

3. Literature Review

There are several reports about PBL in robotics and

this has been discussed extensively by Krithivasan S et al., 2014 & S Chandrasekaran et al., 2012. Several robotics based PBL activities have been carried out over the last decade and its results have been well documented. Robotics being an interdisciplinary field comprising of computer science, mechanical engineering and electronics serves as a great foundation for project work. Robotics PBL methods on robotics have gained a lot of interest from colleges and universities. Universities see these as a good environment for problem based learning as well. The projects involved are complex and the learning has real life applications. There are several robotics challenges and competitions all over the world. These competitions motivate students to work in a team within strict time frames and deadlines (S Chandrasekaran et al., 2012). Many competitions such as e-Yantra offer their own standardized platform to participants. Arduino based platforms are also very popular and extensively used. Though these competitions have been an effective platform for development of skills the lack of industry cooperation and evaluation methods means that the skills developed may be generic and not necessary what industry needs (S Chandrasekaran et al., 2012). Most robotics PBL events have evolved over the years into a well-defined process. Universities and colleges can use these competitions as template for implementing robotic education and projects. E-Yantra is one such competition which as documented the results of this competition and the methodology can serve as a good reference for robotics based PBL activity (Krithivasan S et al., 2014). The results from this activity have shown marked improvement in their fundamental knowledge in robotics and electronics, problem solving ability and reasoning skills (Krithivasan S et al., 2014). A unique feature of the E-Yantra is that the project has been broken down into tasks which have measurable outcomes. The study also emphasizes the need to map activities to tasks to make the outcomes meaningful.

There isn't much documentation about PBL in mechanical engineering involving manufacture of a themed automobile.

There are different ways in which PBL can be implemented. The typical models are: (i) PBL through an online course, (ii) PBL through a standalone competition and (iii) PBL through a classroom course incorporating the competition as a course project. All these competitions have one major limitation when it comes to mechanical engineering. Even though the

robotics competitions are open to mechanical engineers the main focus of these competitions lies in programming and interfacing and not in the mechanical and structural aspects of robotics. The second point is that the mechanical engineering work is hardware intensive and the projects are complex and expensive. With mechanical engineering evolving into mechatronics engineering these projects have become even more complex and interesting.

Industry projects are project activities in partnership with an industry organization or sponsored by the same. Students work on a research project on an industry problem in a direct or assisting role. The project may involve a research or product development depends in upon the industry concerned. The client organization will receive the final project report detailing appropriate and actionable conclusions and recommendations. Students work must meet requirements of the industry sponsoring the project and the University's academic requirements (S. Chandrasekaran et al., 2012).

In community projects such projects students work closely with other students from different disciplines such as arts and humanities to develop socially relevant projects. It involves issues relating to the community and the environment. The key emphasis in community project learning is that of shared benefit for the student the University and the participating organization (S. Chandrasekaran et al., 2012).

Graduate Attributes (GA) has been gaining attention in higher education since last couple of decades because it was realised that there is a mismatch between the skills students develop during their studies and the skills that employers need (Richie Moalosi et al., 2012) (Job Outlook 2012 report, 2011).

The integration of the graduate attributes has led to a range of variations from teacher-centred to learner centred approaches and the learning community engagement approaches resulting in the improvement in the achievement of learning objectives (Barrie, 2004).

4. PBL @ Walchand Institute of Technology

PBL was introduced at WIT via participation in SAE Baja and FSAE competitions. FSAE and Mini Baja are student design competitions organized by SAE, the governing and standards body of Automobile engineering. These are the only projects

which have been designed keeping in mind learning requirement of automobile and mechanical engineering disciplines. These competitions have been around in Europe and the US for many years now but have been introduced in India recently. The project revolves around a product and the students need to design and manufacture this product.

PBL was implemented by designing and building a themed automobile from a scratch. Incorporating PBL as part of a National Level Competition has several advantages. First of all the problem is clearly defined and the constraints are explicitly stated. The problem is a simulation of a typically industrial scenario and hence covers both the theoretical and practical aspects of the study. The competition runs over a period of 10-12 months and thus is a very good platform for students to develop skills and gain lasting knowledge. Some of the projects related to the vehicle can be taken up as final year projects.

4.1 PBL Implementation

A team of 25 students participated in the PBL activity via participation in SAE Baja and FSAE competitions. Before the students began to work on the project, they have spent at least 6 months working alongside seniors in order to get an orientation of what is to be achieved. Initially students assist an ongoing project. During this period the students were not actively involved in the decision making but were encouraged to give their opinion about any matter pertaining especially to the technical aspects of the project. Since the projects were automobile based thorough knowledge of the automobile and automobile maintenance skills are a must. Based on the individual interest ,motivation and predefined criteria these students were further sub grouped into different product based functional domains .These product based functional domains are power trains ,chassis, suspension ,brakes, ergonomics, electrical and safety which are independent products. In each product domain the student group was allotted the task to design, manufacture, assemble and maintain the product throughout the entire project time frame. These all independent products were finally assembled together to complete the automobile for functional verification and testing for the pre-defined criteria. The various sub groups were mentored by a faculty advisor in challenging technical aspects of the project.

During the same period students attended lecture

sessions on diverse topics which were done with the intent of introducing them to the Automobile as a product and as a manufacturing industry.

Students needed to start early because subjects such as Automobile Engineering, Internal Combustion Engines, Automatic Control Systems, FEM and CFD which are necessary of the execution of the project are taught in the final year of engineering. The students also are given mini projects in Computer Aided Design and Finite Element Analysis in the second year itself. Some of the topics that were covered in the lecture sessions are DFMA, FEA, and Advances in Automobile Technology, QFD, G8D, Six Sigma, and Product Design. These subjects are those that were not covered by the standard mechanical engineering syllabus but are absolutely essential for developing a career in the automobile industry.

By acquiring these skills well in the second and third years, the students are prepared with all the necessary computer tools required to solve complex interdisciplinary problems encountered in Automobile Engineering. The teaching program during the pre-project and the project phase is not the typical classroom program but it has employed various teaching strategies such as Flipped Classroom, Self-Paced Learning, Peer Instruction, Simulation, and Problem Based Learning integrated with Project Based Learning.

The entire PBL project was broken down into smaller projects based on functional sub systems such as brakes, suspension, chassis, and power train. A group of 2 to 4 students will be assigned a subsystem and must cover all aspects of the subsystem such as survey, bench-marking, design, simulation, manufacture and maintenance. The team would also comprise of a cross functional team whose task is to ensure a handshake with other groups.

In the past students formed generic groups such as Design, Manufacture, Maintenance and Manufacture. This had the disadvantage that a few students would attempt to design everything and then another group would manufacture and maintain. Marketing became an exclusive task and was often considered trivial. This type of grouping meant that there was very little handshake between the design and manufacturing groups and students remained ignorant about other aspects of engineering. By forming vertical groups aligned with individual products (sub-systems) students in a group had developed thorough

knowledge of their own systems and design & manufactured the components themselves.

In order to implement PBL we have integrated various instructional strategies for design, development and manufacture of an automobile. This PBL integration activity can be broadly divided into 4 phases:

1. Acquisition of Domain Knowledge
2. Formulating Concept Design
3. Simulation and Iterations for Design Improvement
4. Vehicle Manufacture & Tests

Each stage had a predefined task, instructional strategy and learning outcome. These stages have been designed keeping in mind Blooms Taxonomy and Graduate Attributes.

PBL Phase I: Acquisition of Domain Knowledge

It is important that all students have through knowledge of its domain and the product. For example even if a student is working on the domain aerodynamics, it is obvious that he has developed knowledge pertaining to all disciplines of aerodynamics such a fluid mechanic, thermodynamics. The must also have sound understanding of the product which in this case is the automobile.

Instructional Strategy: Flipped classroom

Flipped Classroom was mainly used to enhance student's knowledge about the automobile. The faculty advisor shared videos that covered all aspects of automobile engineering such as engines, handling, performance, aerodynamics and manufacture. During this stage all students have taken a quiz which covered all aspects of the product. There was no objective assessment here. The students continued taking the quiz till he achieves a 100% score. This ensured adequate knowledge of the entire product and this served to improve teamwork during the later stages. Activities during this stage involved extensive use of videos, magazine articles and text books. This stage was planned to cover the first level (Recall) of blooms taxonomy.

PBL Phase II: Formulating Concept Design

During Formulating Concept Design stage the

students started working on the vehicle concept. The groups were formed mainly based on the student's choice and ability. Grade in test were not for certification. However these grades were mainly used for the purpose of evaluating percentage knowledge acquired and also to identify weakness in the subject knowledge which was an iterative process till the student attained the requisite level of domain specific knowledge and its applications. This check was provided in the system so that students were not allowed to make any major changes during manufacturing. This ascertained the confidence level for execution. During Formulating Concept Design stage the students worked on enhancing their knowledge about their respective domains such as brakes, suspension which are product in itself.

Instructional Strategy: Problem Based Learning

Problem Solving is one of the fundamental learning goals of engineering education (Krithivasan S, et. al., 2014). During Formulating Concept Design stage the students were given an open ended problem to design the various sub systems of the vehicle. Students started the design process with extensive survey and research of various components of the vehicle. Various design aspects of the vehicle were analyzed and key design elements were finalized. The concept was sketched on paper sheets and was assessed by the instructor for predefined criteria. This stage was planned to cover the second (Understand) and third level (Apply) of blooms taxonomy.

PBL Phase III: Simulation and Design Finalization

One of the main objectives of the PBL was to develop strong CAD/CAE skills which are indispensable today in the field of mechanical engineering for product development. In Simulation and Design Finalization stage the students developed extensive and accurate CAD models of their respective products (sub-systems) to build a virtual prototype of the automobile. The point here was to use virtual prototyping and experimentation extensively to evaluate design and perform iterations.

Instructional Strategy: Blended learning using CAD/CAE simulation software.

During Simulation and Design Finalization stage the students have designed a prototype from the concept developed in the previous stage. Several application software tools were extensively used while designing

a product in automobile industry during this stage such as ANSYS, SOLIDWORKS, CATIA, MATLAB, SIMPACK, ADAMS along with MS Project and MS Excel. The advantage of using industrial simulation software was that the model created by the student could be controlled explicitly by the student as per his design intent. The instructor then evaluated the computer models for dimensional accuracy and rule compliance. This stage planned to cover the fourth (Analyze) and fifth level (Evaluate) of blooms taxonomy.

PBL Phase IV: Vehicle Manufacture & Tests

During manufacturing and testing stage major parts of the vehicle were manufactured and assembled in house. The manufacturing and assembly of the sub components was done parallel to save time. The manufacturing activity was coordinated by a Cross Functional Team which comprised a member from each group. The team served as a liaison to the other groups. Once the main chassis frame and the sub components were ready they were assembled. The assembly of the automobile was carried out according to a predefined checklist. Students manufactured most of their components with the exception of those that required special machinery such as Laser cutting etc. Students got themselves acquainted with the actual manufacturing process occurring in the industry.

Instructional Strategy: Collaborative Learning through Industrial Visit and Interaction with Industry Experts

Field visits to industries (both large and small) are organized by the faculty instructor before the start of this stage. This was done so that the manufacturing techniques and standards used by the students are similar to that used in actual industry. In addition to filed visits industry professionals from the manufacturing sector are invited for a guest lecture during this stage. Students collaborate with industry experts by having discussions and oral feedback regarding their manufacturing. This stage covers the last level (create) of Blooms Taxonomy and the culmination of the entire Graduate Attributes for Engineers as stated in Washington Accord.

5. Outcome of PBL Education at our Institute

Graduate attributes play paramount role while planning the curriculum of any university undergraduate programme. The attributes demanded

by industry are twofold: technical knowledge and skills, and generic attributes. Integrating various instructional strategies with PBL had significant effect on student's knowledge across various levels Blooms Taxonomy. They have marked improvement in student's core domain knowledge and their engagement. There is considerable literature to support the fact that, there are benefits in integrating graduate attributes with the curriculum (Barrie, 2006; Holmes, 2002; Bowden et al., 2000; Hogarth, 2007; Goldsworthy, 2003; Hager & Holland, 2006).

Table 1 shows the correlation between the twelve Graduate attributes and the four phases of our PBL activity. The scores have been assigned as a measure of achievement of the particular GA and the phase of the PBL.

Table 1: Mapping PBL Activity with Graduate Attributes

GA	GA Descriptors	Phase 1	Phase 2	Phase 3	Phase 4	Total	Correlation
		Blooms level					
		Recall, Understand	Apply, Analyse	Evaluate	Create		
1	Knowledge	5	5	5	3	18	H
2	Problem Analysis	1	4	5	4	14	H
3	Design	1	5	5	3	14	H
4	Investigate	1	4	5	4	14	H
5	Tools	2	5	5	4	16	H
6	Society	2	2	2	4	10	M
7	Environment	1	2	3	4	10	M
8	Ethics	1	3	3	3	10	M
9	Team	1	5	5	5	16	H
10	Communication	1	4	4	4	13	H
11	Projects	1	5	5	5	16	H
12	LLL	5	5	5	5	20	H

A score of 4 & 5 shows high attainment of the graduate attribute where as a score of 3 shows medium attainment and a score of 2 & 1 shows low achievement. For example in the first phase of the PBL activity which covers the Blooms Level of Recall and Understand the instructional strategies chosen such that students acquire thorough domain knowledge. Hence for this level we have given a score of 5 when it comes to achieving the first GA. Similarly during this phase students work alone and not in

project groups and hence we have scored 1 point for GA 10 and 11. The remaining marking is done in a similar way. The cumulative score for each graduate achievement across the four phases is computed and scores of above 12 indicate high level of achievement. If the score is between 8 and 12 we have graded it as medium achievement which can be interpreted as partial fulfilment of the GA. A score less than 8 indicate minimal achievement of the GA. Our findings from the PBL activity reinforce the facts that extensive PBL address the entire GA as required by industry ready engineers. This fact is evident from the placement data given in Tables 2 & 3. Not only was the percentage placement higher in students who had participated in PBL but majority of the students from PBL got placed in core mechanical engineering companies.

By integrating graduate attributes in the curriculum, the institutions of higher learning will be in a position to meet employers' needs by producing a competent workforce. These professionals will possess broad capabilities in addition to discipline-related skills.

The employability of students participating in the PBL activity has been covered as follows. The comparison was made on the following three points.

1. Average Percentage Placement of PBL and Non PBL Students
2. Percentage placement in core engineering of PBL and Non PBL students
3. Comparison of placement status of students of PBL and non PBL students falling in the same zone of academic performance.

The total strength of student in the final year is 120 whereas 20 students from the final year participated in this activity. The data refers to activity done during the years 2011-12, 2012-13, and 2013-14. The breakup of the employment status within one year of graduation is as follows:

Table 2: Comparative Employment of PBL & Non-PBL students

Year	No of Students in PBL	No of PBL Students employed	% PBL Students Employed	Number of students not in PBL	No of non PBL students employed	% Non PBL Students Employed
2011	20	14	70	100	45	45
2012	20	14	70	100	50	50
2013	16	10	63	100	35	35
2014	12	12	100	100	40	40

It is clear from the above data that employment of students doing PBL is much better than those who did not participate in PBL. Many students who participated in the PBL activity chose to pressure higher education specifically in Automobile Engineering or a topic which they studied during their PBL activity.

Majority of the students who participated in PBL activity sought and achieved in core mechanical engineering industries especially automobile and automobile related industries. The breakup of the employment in core engineering within one year of graduation is as follows;

Table 3: Comparative Placement of PBL & Non-PBL students in Core Mechanical Engineering

Year	Total No of Students in PBL Employed	No of PBL Students in Core Engg.	% PBL Students Employed in Core Engg	No of students not in PBL Employed	No of non PBL students Employed	% Non PBL Students Employed in Core Engg
2011	14	8	57	45	6	13
2012	14	10	71	50	8	8
2013	10	10	100	35	8	8
2014	12	8	67	40	10	10

The data clearly shows that consistently majority of the students who participated in PBL were placed in core mechanical engineering companies. In comparison only 10% of non PBL students were employed by core mechanical engineering companies. This finding has been consistent since 2011.

6. Conclusion

The study has demonstrated that well managed project based learning can assist students in higher learning institutions in attaining graduate attributes. Graduate attributes are the generic skills that employers are looking

for in employees in the ever-changing work environment.

Institutions of higher education have a major responsibility for the smooth integration of graduates into professional

life and society. Graduate attributes have now become one of the core sets of professional education outcomes

that every graduate should possess. Integration of graduate attributes in the curriculum ensures that students develop skills that will better equip them for the work environment and self-employment. PBL resulted in significant development in students' domain knowledge, critical thinking, and problem solving ability and team work which ultimately increases their confidence, motivation and creativity. It was a challenging task for the faculty advisor to implement a larger PBL approach and integrate various instructional strategies. The main challenge was to create the right environment for learning without micro managing the whole project. PBL provides a foundation imparting through knowledge and hand on training significantly improving employability and career quality. PBL has increased the employability potential of students in core engineering in the era of ICT. By implementing PBL more number of outgoing graduates are attracted towards the core engineering and this has mitigated the trend of migration to the IT sector. This in turn will encourage and promote local manufacturing as envisioned in the Make in India policy of our government.

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