The Role of Tutorials in Engineering Design Course

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Abstract— **Engineering Design (ED) is one of the cornerstone courses in mechanical science engineering discipline. The objective of the course is to develop problem solving skills in students through design process. In order to enhance teaching learning process in ED course, new pedagogies are always practiced. The objective has been addressed through one of the most practiced pedagogy, project-based learning (PBL). By the earlier work the authors found that to address the objective of the ED course through PBL alone is difficult. Hence, an effort is made to bring tutorials along with PBL in ED course to improve teaching learning process. In ED course, a tutorial along with two theory classes in a week was introduced for second year students. Usage of decision making tools and methods in course projects was demonstrated in tutorials for a real practical problem. The assessment of the tutorial effectiveness was done on the basis of tools and methods used to take decisions at crucial stages of the course project design. Authors felt combining the pedagogies according to the subject requirement will definitely raise the competency of the students.**

Keywords— ***Engineering design course, Project based learning (PBL), Tutorials, and Course projects.***

I. INTRODUCTION

Freshmen courses are getting importance in today's engineering education, as it lays the foundation to attain Accreditation Board for Engineering and Technology, Inc. (ABET) criteria. It has been believed earlier that capstone and mini projects in the engineering curriculum are the only essential ways to attain ABET's 3c and 3e criteria. However the scenario in recent years has given a proof of attaining these criteria's with adopting innovative pedagogies in teaching learning process to other courses also. Engineering Design (ED) is one of the freshmen courses, which emphasizes to imbibe the problem solving skill through design process with attainment of 3c criteria. To improve teaching learning process in ED course, Project-based Learning (PBL) is used. PBL as course projects in ED course introduced and found students rarely sticking for design process. It was found in earlier work that by the introduction of PBL is not sufficient to enhance teaching learning process in ED. This is due to student's habit of solving problems at the end of the semester. As PBL alone cannot able to succeed to achieve objective of the ED course, other pedagogy along with PBL is a need to fix this problem.

Design engineering is one of the main streams in mechanical science engineering discipline. To meet the ABET criteria the curriculum should require design as a core course [1]. Efforts have been made to meet the ABET criteria, by introducing capstone projects and mini projects in the final and pre-final year of engineering respectively. The students and instructors face problems in implementing the design process methodologically through capstone and mini projects. This clearly shows a gap in understanding of the effective design process. This is in accordance with Duston et al. [2]. Because of which our graduates never ready for the industry, where the challenges are immense in the design field. Hence there was a need of relooking into the curriculum of mechanical science engineering. Introduction of the ED course, in the first or second year of engineering gives the flavour of design as a process rather than only calculations [3]. The efforts were made to teach design process effectively by bringing course projects. Course projects or Project-based learning (PBL) enhanced the student learning and bridged that gap. According to Dym and Little [4], PBL in early semesters of the engineering as a pedagogical tool to teach ED is being practiced by many universities. ED addresses hard problems because these problems are ill structured. ED will be learned by doing [5]. Since the course ED needs practical exposure, PBL is ideal to apply. As per our best knowledge, the earlier contributed papers on PBL demand to increase the competency of the students to the next level due to the need of the present scenario. As more engineers graduate every year, industries demand for high standards especially in competency of the students.

Here an attempt is made to achieve the objective by introducing tutorials along with PBL in ED course. Tutorials purpose is to make students familiar to use tools and methods to take decisions in course projects.

II. METHODOLOGY

The design process adopted for ED course is shown in Fig.1. To develop the skills of using tools and methods in design process effectively, tutorials were introduced. A tutorial in each week along with two regular lecture classes was practiced in ED course for a span of fourteen weeks. Each tutorial was aimed to bring certain skills in students through tasks or activities. To take decisions in each step of the course projects, tutorial activities were framed aligned with the design process. Tutorial activities carried out for students are listed out in Table I.

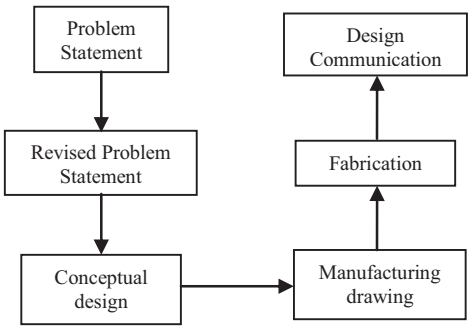

Fig. 1 ENGINEERING DESIGN PROCESS

TABLE I. ACTIVITIES/TASKS IN ENGINEERING DESIGN TUTORIALS

Sl. no	Activity/Task	Description
1	Identification of the problem	Each team will give at least five social problems which can be solved by engineering design process.
2	Literature survey & Need analysis	Various products already available in the market to solve the design problem and justify the need of solving it again.
3	Writing Revised problem statement	Developing objective tree, combined tree, constraints and removing errors in the client's problem statement to get Redefined problem statement.
4	Developing Metrics for objectives	Developing the scales or assessment for the objectives set by the design team.
5	Developing the functions	Applying different methods (black & transparent boxes, function means tree etc.) to obtain set of primary & secondary functions.
6	Reverse Engineering	Selecting the product from the market which satisfying the design problem & disassembling of the product to see how well they have achieved each function.
7	Generation of Alternatives	Developing Morphological chart for the current problem.
8	Expanding the Design Space (DS)	Applying the external constrains, team's expertise to restrict DS & applying 6-3-5/Gallery method to expand DS.
9	Selection of feasible & preferred design	Applying the Numerical evaluation/Best of class chart method to select best design among alternatives.
10	Applying the equations and principles for the project	Equations usage for the project, which they have learnt in other fundamental subjects.
11	Orthographic views for the design	Draw the orthographic views for the design with proper dimensions and wring the information related to it.
12	Fabrication processes required for the project.	Mentioning the fabrication processes required for the design and justifying it.

Course projects were introduced in ED course having sixty percent of continuous internal evaluation. Twelve teams were formed containing five students in each team. Course project was split into two phases. First phase was to arrive at the conceptual alternative solutions within eight weeks and submitting the project report on the same. Second phase was to obtain fabrication drawing details and a prototype of the selected design.

III. RESULTS & DISCUSSION

Tutorial activities were implemented each week for a common problem. The activities were performed for the common problem by using tools and methods of the design process. The common problem selected for tutorial is to *design an adjustable podium for the classroom*. In line with the tutorial the students executing design solutions for their respective projects. Assessment of the tutorials effectiveness was measured through rubrics set by the course instructor during tasks execution in tutorials and project phase reviews. The following sections are discussing the performance of students in both tutorials and course projects.

Tutorial activities and tasks were designed in such a way that students have to perform as a team. The students were made to sit with their teamates to perform activities and tasks in each tutorial. The grades were assigned for each team according to their usage of tools and methods in every activity. The grades obtained for twelve teams were listed in Table III. Rubrics were set for each task and activity to decide the understanding of the students about the tools and methods of design. Table IV showing the sample of rubrics followed for literature survey and need analysis tutorial activity.

TABLE III. TEAM GRADES FOR PERFORMANCE IN TUTORIALS

Activity No.	Team No.											
	1	2	3	4	5	6	7	8	9	10	11	12
1	A	A	A	A	B	B	A	A	A	B	A	B
2	A	B	A	B	A	A	B	A	A	A	B	A
3	B	A	B	B	A	B	A	B	A	B	A	B
4	A	A	A	A	A	B	B	A	A	A	A	A
5	A	A	A	A	A	A	A	A	A	A	B	A
6	A	A	A	A	A	A	A	A	A	A	A	A
7	A	A	A	A	A	A	A	A	A	A	A	A
8	A	A	A	A	B	A	A	A	A	A	A	B
9	A	A	A	A	A	A	A	A	A	A	A	A
10	B	B	C	D	C	C	C	C	C	C	D	D
11	A	B	B	B	B	B	B	B	B	B	B	B
12	A	B	A	A	A	A	B	A	A	A	A	A
A-Exceptional				B-Good			C-Average				D-Poor	

TABLE IV. RUBRICS FOR TUTORIALS

Activity	Grades			
	A	B	C	D
Literature survey & Need analysis	Information collected through: - internet, marketing people, feedback from potential users and expert view. (all 4)	Information collected through: - internet, marketing people, feedback from potential users and expert view. (any 3)	Information collected through: - internet, marketing people, feedback from potential users and expert view. (any 2)	Information collected through: - internet, marketing people, feedback from potential users and expert view. (any 1)

From the table III, it was clear that students were under performed in some tutorial activities. This was indicating the poor understanding by the students to perform a task using tools and methods. The identified gap from each tutorial, dealt separately in lecture classes with more elaboration and some

practical examples. At the end of fourteenth week student teams were familiar with design process having design of adjustable podium in the drawing sheets.

Students learn concepts better when they try to apply to real application problems. PBL as course project was introduced in this regard for the ED course. The tutorials built the confidence in students in parallel to the course project. Teams were formed at the earlier week of the course commencement. Care was taken to balance the competency level by adding at least a diploma lateral entry student in each team. Course project was divided into two phases and the following sections are discussing the effort of the same.

1. First phase

As students were given the freedom of forming their own teams, they gelled well and selected the problem statements in the first week. The project problem statements selected for the course projects are listed in Table V.

TABLE V. PROBLEM STATEMENTS SELECTED IN ED COURSE PROJECT

Sl. no.	Problem Statement
1	Design and Fabricate a device for the water to purify with other contaminates while travelling/emergency needs.
2	Design and fabricate a device for the cutting of grass in different length and in different shapes.
3	Design and fabricate a device for opening of the Tender coconut and make ease to remove cream milk from the same.
4	Design and fabricate a device for the lifting of the goods/household items in the apartments.

To increase in cognitive levels of the students and avoid copying in usage of tools and methods, each problem statement was selected by three teams. Though we were assessing design approach to the problem not merely a solution at the end, first phase was targeting at innovative conceptual designs by each team. After each tutorial, teams were able to apply outcome of the performed activities to their project problem and get to know the significance of each tool and method. First eight tutorials were addressing to arrive at the generation of design alternatives for the problem. Difficulties in applying the tools and methods to the problem were discussed in free hours with the course instructor. To communicate effectively with teammates and with others modeling software was used to generate alterative solutions. A predefined project format was given to the teams to follow and the teams submitted the first phase work in that format.

A review was conducted to check the contribution of the each student in team activities. Emphasize was given to check the decision making process during each design step and allotted the marks.

2. Second phase

The first phase was on exploring the thinking process of the students about the design. The key factor was performing as a team. In second phase, students started with having many alternatives for the problem. Brainstorming sessions were held to get clarity about the design alternatives. Teams selected one feasible conceptual solution for the project problem by applying the constraints of the project such as money constraint, time to manufacture the prototype, team's expertise etc. Teams began to refine the chosen design and optimized it with the help of basic equations learnt in other fundamental subjects. Students were aware of fabrication difficulties associated to prototype creation, so some teams preferred to make models. Once teams were confident enough to take fabrication, they were allowed for fabrication by the course instructor. Few of the snaps taken during project exhibition are shown in Fig.2.

Fig.2 SNAPS OF ENGINEERING DESIGN PROJECT EXHIBITION

IV. CONCLUSION

The discussion in this paper majorly contributes to the student's learning enhancement through tutorials along with PBL. PBL alone had the advantages of increase in competencies of the students earlier but difficult for large classrooms. With the introduction of tutorial made the course instructor to handle large classrooms and address student's queries effectively. Intern the tutorial enhanced the student's usage of tools and methods to take decisions at crucial stages in their course projects. A comparison is given in Table VI for usage of tools and methods for their course project by the teams with and without tutorials for successive years. Though course project was the main target to assess the problem solving skill by using design process, authors felt students imbibe that skill through tutorials. The reflection of the tutorial outcomes seen through the project report quality and reviews during project exhibition. The project problem being common in tutorials, team role and effort was tremendous as the information gathered to take decisions for a common problem

kept secretive to other teams. Since the rubrics demands unique and innovative product, this made them as a team player and leaders to take decisions in the process.

TABLE VI. TOOLS & METHODS USAGE BY THE STUDENTS FOR SUCCESSIVE YEARS

Decision making tools/methods	Percentage of usage in 2012-13	Percentage of usage in 2013-14
Objective tree	90	100
Metrics for objectives	40	80
Black & Transparent box	40	80
Function Means tree	5	70
Reverse engineering	20	60
Morphological chart	100	100
Evaluation Chart for selection of Best design	70	100
Modeling software usage	50	90
Note: Based on the project report observations.		

Authors feel, as long as pedagogies are modified according to geography and cultural changes the learning will enhance in a measurable quantity.

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