Enhancement of Multidisciplinary PDR Course

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Abstract— **This paper discusses enhancement in development of project-based 'product design and realization (PDR)' course for undergraduate students. The course offered at an early stage of the curriculum is aimed at providing engineering design and product realization skills to the students. Creating an appropriate learning experience in product design is challenging owing to its multidisciplinary nature. An innovative multidisciplinary design–to-realization approach is adopted in this course and student teams are required to design and build working prototypes for predefined products. This course brings a new perspective to the multidisciplinary approach to teaching product design. Introduction of project based design experience at an early level provides students with an opportunity to develop capabilities to design complex systems in the future. PDR (a 3 credit course) introduced to electrical and mechanical sciences students (EC, EE, IT, IP, A&R, ME) at fourth semester (2nd year) level of engineering in BVBCET, Hubli. The implementation of course is analyzed with respect to attainment of the outcomes (ABET a-k). Also to illustrate the success of the course, the work of students in the form of Product at the end of course is included in results for validation.**

Index Terms—**Design, Electrical and Mechanical sciences, outcomes (ABETa-k)**

I. Introduction

This paper addresses the development of product design and realization (PDR) course offered as an open elective to pre-final year undergraduate students from engineering disciplines of Electrical and Mechanical Sciences. Product design is a complex process requiring a cross-functional team consisting of design engineers from different engineering disciplines. An experience of multidisciplinary nature usually presents itself during the professional career after graduation. To create such a learning experience at undergraduate level is a challenging task. Approaches to address the interdisciplinary challenge are presented in [1-3].

The Department of Electronics and Communication, Electrical and Electronics, Instrumentation Technology, Industrial Production, Automation & Robotics and Mechanical Engineering departments made a combined effort to design and deliver a course that allows the undergraduate student to experience the complete product design and realization process, working in a multidisciplinary environment. The primary objectives of PDR course are: the student should be able to (i) design multi-disciplinary projects culminating in a finished product (ii) engage in a systematic approach towards design (iii) develop a new product or improve an existing product. The students undergoing this course will also be well placed to explore the possibilities of entrepreneurial ventures, since they would be well equipped to handle all the aspects of product design and realization. The scope of PDR in providing integrated learning experience in the undergraduate program is presented here and makes the following main contributions. [11].

- The PDR course is designed to provide experience of 'product' using multidisciplinary teams at the undergraduate level.
- The course delivery uses innovative pedagogical approaches and they are: Processes of reverse engineering, user survey, need analysis, conceptual design and advanced tool learning are integrated into student training, to provide a hands-on experience before the student initiates the process of PDR.
- Sample case studies are facilitated by the course

instructor to provide experiential learning.

- Interactions with local entrepreneurs at their design and production facilities are organized to provide real exposure to the PDR process.
- Attainment of student outcomes, in particular outcome *c, d, e, g, j* and *k* were assessed using continuous review process by an expert review committee comprised of faculty from the disciplines of both mechanical and electrical engineering sciences, is used for continuous improvement of the teaching learning process.

In Section 2 the curriculum design process is illustrated that meets the course objectives. The pedagogical practices used in the course delivery are discussed in detail. Section 3 discusses about one of the case study of the product done by students with all the necessary details. Section 4 gives the evaluation process in detail considering the rubrics for all the 3 reviews and the comparison of ABET outcomes attainment. The conclusion is presented in Section 5.

II. Curriculum Design And Course Delivery

The process of curriculum design began by acknowledging the need for experience of product design at undergraduate level, followed by interaction with prominent academicians and industry personnel. An evaluation of gaps in the skill sets of the graduate engineers was done, and an effort was made to address the issues. The conventional design flow using isolated disciplines / teams would result in increased product design life cycle thereby delaying the final product / prototype. It is important that in this course students become aware of the problems in optimizing the concurrent design processes involving coordination of the multidisciplinary technical functions of design to improve productivity. An innovative multidisciplinary design–to-realization approach is adopted in this course and student teams are required to design and build working prototypes for predefined products. The entire course spanned six weeks during the summer vacation for the student. The first two weeks comprised of:

- Interactive lecture sessions on product design process, and basics of engineering design
- Active learning sessions on relevant topics of product design: Reverse engineering, User survey, Need analysis, Product planning, CAD tool usage, open-source tools.
- Case studies incorporating idea generation, conceptual design, detailed design and prototype verification
- All assignments carried out as group activity involving teams made up of students from diverse engineering disciplines
- Industry visit to enable interaction with entrepreneurs and get acquainted with state of art industrial production equipments and product design and development
- Interactive sessions on 3-D printing for prototyping

The teams consisting two students from Electrical sciences and two students from mechanical sciences background were formed to ensure that each team has skill sets from both the disciplines. The products to be designed were carefully chosen to enhance the experiential learning process, rather than implementation of hi-tech products. The two products given for the student teams to choose from were:

1. Developing an active toy to foster imaginative play in Children
2. Developing a portable speaker

The institutions adopting the Outcome Based Education framework in engineering education are accredited worldwide as per ABET engineering criteria 2000 (EC 2000) [5] and as per new NBA accreditation in India [6]. Often, the capstone projects are used to evaluate student attainment of technical and professional outcomes [7]. Due to the integrative and multidisciplinary nature, the course helps the student to attain few of the challenging program outcomes specified by ABET. The programs can also use this course as a tollgate course to assess attainment of student outcomes by using proper assessment rubrics. Developing an Active Toy to Foster Imaginative Play in Children is presented here as a case study.

III. CASE STUDY: AN ACTIVE TOY TO FOSTER IMAGINATIVE PLAY IN CHILDREN

3.1.1 Need analysis :

Exercising a critical cognitive skill known as divergent thinking is very important to improve the creative quotient in children.

In creative play there will be prototype, test, and iterate on the designs exercising and training for future lab experiments and boardroom brainstorms.

The children need an active toy which has digital technology and interacts with the kid and may help in creative play. The toy should be based on a standard platform so that the toys can be easily plugged into each other and become a new toy. The toy should help the kids to collaborate, create and play. The toy should be safe and mobile. The toys should meet the regulatory constraints and should also be durable, reliable and attractive at the same time. You may provide additional features to make the toy attractive for the middle class urban user to buy. The toy should consume less power and work on battery cells for longer periods. Parents are looking for opportunities to play and co-create with their kids and these toys should help the parents to play with their kids.

3.1.2 Product Planning and Market Analysis:

The next phase is to estimate the time required for the product design and realization in the form of a Gantt chart highlighting the multiple tasks which could be either sequential or concurrent. Apart from user survey, the students conduct a market survey in the resident city, and arrive at an estimate for the market consumption and approximate pricing.

3.1.3 Conceptual Design:

This involves listing of all the functions and sub-functions of the product in the form of morphological charts for both electrical and mechanical domains.

TABLE 1: MORPHOLOGICAL CHART (ELECTRICAL)

Functions	1	2	3	4	5
Active	Mechanical(rolling)	Electrical	Motion		
Interactive	Speaking	Display			
Display	LCD	Screen	7 segment	LED's	Holography
Sound effects	Speaker	Buzzer			
Memory	Internal memory	External memory (SD card)	Hard Disk	pen drive	
Power supply	Rechargeable batteries	Disc batteries	AAA batteries		
Mode of operation	Remote control LED	Touch panel	Mechanical operation	Voice recognition	Gesture control
Casing	Metal	Fiber	Plastic	Wood	Fabric
Connectivity	USB	Bluetooth	Wi-Fi		
Thought provoking	Riddles	Puzzles	Art	Creative	Educational
Heat dissipation	Heat Sink	Coolers			
Ability to modify	Easy to collaborate	Upgradable			
Platform	Discrete component	Microcontroller	Arduino	Digital	

TABLE 2: MORPHOLOGICAL CHART (MECHANICAL)

Functions	1	2	3	4	5
Casing(Protection)	Fiber	Wooden	Plastic	Metal	Alloys
Heat dissipation	Coolant liquid	Vent	Fan	Heat Sinks	
Fitting	Glue	Straws	Nuts & Bolts	Soldering	Welding
Base for resting	Providing legs	Hanging	Wall fix	Flat base	Curved base
Movement	Wheels	Sliders	Springs	Manual	
Vibration control	Damper				
Speaker slots	Square	Circular	Hexagonal	Elliptical	
Mode of Operation	Keyboard	Joystick	Touch		

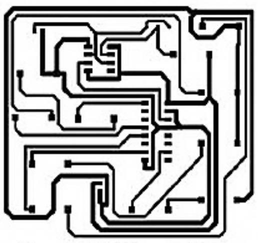

Figure 1: PCB layout of Dice

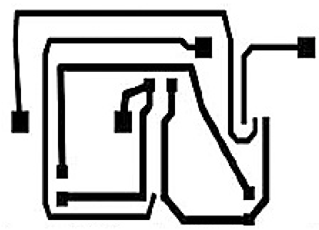

Figure 2: PCB layout of Music generator

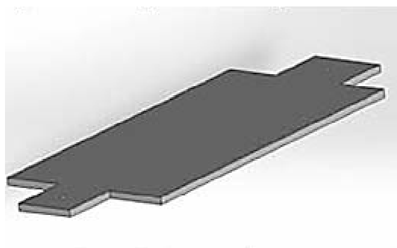

Figure 3: Battery plate

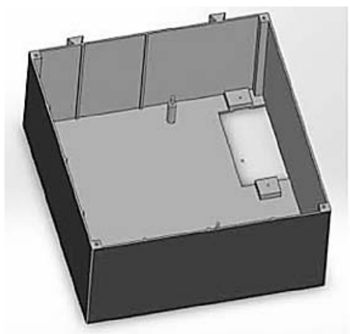

Figure 4: Bottom panel

Figure 6: O coin

Figure 7: X coin

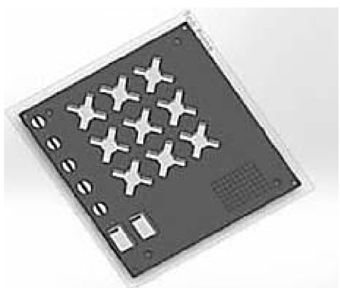

Figure 5: Top panel

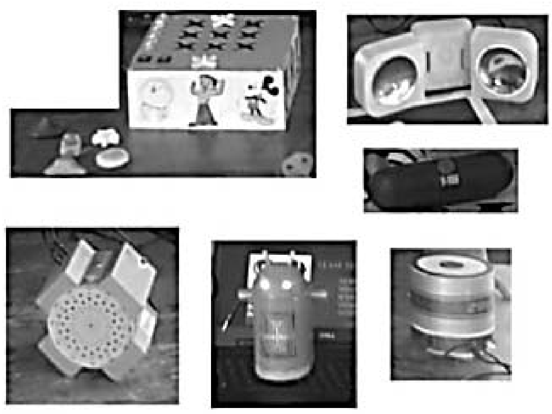

Figure 8: Collage of all the products of PDR-2014.

TABLE 3 : EVALUATION RUBRICS FOR REVIEW 1

Evaluation Rubrics For Review 1- PDR 2014				
Assessment Factor	Rubrics	Best (5)	Average (3)	Poor (1)
Product planning	• Preparing Gantt chart • Level of creativity in the proposed plan of execution	Identifying all the tasks & processes	Not elaborate enough	No planning
Need Analysis	• Diversified Professional customer feedback form • Listing maximum number of attributes taking aid of customer feedback and literature survey	>10 forms + >20 attributes	8-10 forms + 15-20 attributes	<10 forms + <15 attributes
Identifying Attributes	• Classifying the identified attributes into objectives, Functions, Constraints and Means • Prioritising the objectives using PCC	Perfect OFMC chart and PCC	Needs improvement	Not up to the mark
Revised problem statement	• Should be the outcome of the analysis of the PCC and OFMC chart • Scope for implementation (Implement ability- i.e to say is it implementable?)	clearly complementing OFMC chart and PCC	scope for improvement	Not up to the mark
Team Dynamics	• Following the proposed Gantt chart • Work Breakdown Structure(WBS) among team members • Maintaining a "Bluebook" • Team co-ordination (team interactions / tradeoffs etc.)	• Before time • Full compliance • Evidence presented	• on time • Partial compliance • Partial evidence	• Behind Schedule • No compliance • No evidence

TABLE 4 : EVALUATION RUBRICS FOR REVIEW 2

Evaluation Rubrics For Review 2 - PDR 2014				
Assessment Factor	Rubrics	Best (5)	Average (3)	Poor (1)
Functional Analysis	• Deriving functions using Morphological chart for functional analysis • White box, Flow of Energy, Material, Signal	Comprehensive Analysis	Needs improvement	Not up to the mark
Engineering Specifications	• Deriving block level specifications • Listing maximum number of specifications taking aid of functional analysis, customer feedback, patent search, constraints, regulations etc.	>10 specifications	8-10 specifications	<8 specifications
Conceptualization	• Arriving at more meaningful concepts taking aid of functional analysis performed • Evaluation of concepts using matrix methods and hence arriving at final design	>5 Concepts to one Best design	4-5 Concepts to one Best design	<4 Concepts to one best design
Preliminary Designs	• Computer models of your chosen design • Working simulation model of your chosen design	Best Design + Perfect simulation results.	Good design + Perfect simulation results	No results
Team Dynamics	• Following the proposed Gantt chart • Work Breakdown Structure(WBS) among team members • Maintaining a "Bluebook" • Team co-ordination (team interactions / tradeoffs etc.)	• Before time • Full compliance • Evidence presented	• on time • Partial compliance • Partial evidence	• Behind Schedule • No compliance • No evidence

TABLE 5 : EVALUATION RUBRICS FOR REVIEW 3

Evaluation Rubrics For Review 3 - PDR 2014				
Assessment Factor	Rubrics	Best (5)	Average (3)	Poor (1)
Prototyping	• 3D printing and PCB implementation.	perfect casing + minimal sized working PCB	good casing + average sized working PCB	Not upto the mark
Testing	• Partial demonstration of working of the product • Integration of working PCB and designed casing • Aesthetics of the product • Cost analysis	Perfect integration+ Minimal cost+ Aesthetically pleasing	Perfect integration+ Average cost+ Average looks	Not upto the mark
Need Mapping	• Completion of design loop by demonstrating to the user and getting feedback. • Refinement of design / Identification of possible improvements	Comprehensive Analysis	Needs improvement	Not up to the mark
Documentation	• Documenting all the design steps and iterations. • Oral / Visual Presentation	Comprehensive Documentation & Presentation	Needs improvement	Not up to the mark
Team Dynamics	• Following the proposed Gantt chart • Work Breakdown Structure(WBS) among team members • Maintaining a "Bluebook" • Team co-ordination (team interactions / tradeoffs etc.)	• Before time • Full compliance • Evidence presented	• on time • Partial compliance • Partial evidence	• Behind Schedule • No compliance • No evidence

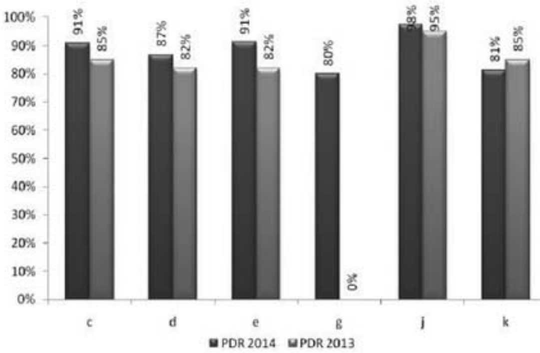

Figure 9: Comparison of ABET outcomes Attainment of PDR 2013 with PDR 2014

3.1.4 Detailed Design

This section gives the snapshots of the PCB layout and 3D model of the product mentioned in case study.

IV. Evaluation

The evaluation of the product is done in three different phases with rubrics meeting the ABET outcomes. The rubrics for all the three different reviews are given in Table 3, 4 and 5 respectively.

As it is evident from Figure 9 that the attainment of ABET outcomes for PDR 2014 is enhanced compared to PDR 2013 the main enhancement is in outcome '*g*' which was not incorporated in PDR 2013.

V . Continuous Improvement

Curriculum design is a continuous process, and must evolve with the needs of the industry and skill levels of the students for a multidisciplinary course like PDR. The need to redesign the curriculum arises from many factors such as: Evolving global ecosystem of product design and development: Emerging technologies that enable multiple solutions to the problems encountered during product design and development: Redeployment of skills training in evolving regular courses in the undergraduate engineering curriculum: Overcoming the shortcomings of the previous courses based on the feedback from all the stakeholders. The feedback analysis of the overall course experience is summarized in Figure 9, 10, 11.

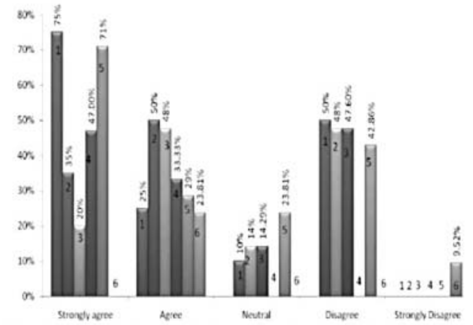

Figure 10: Feedback of students for the questions shown in table 6 which shows different stages of PDR.

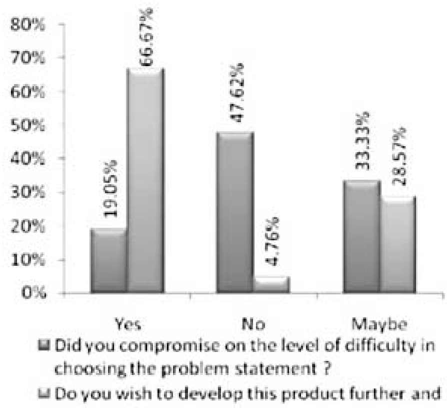

Figure 12: Student feedback

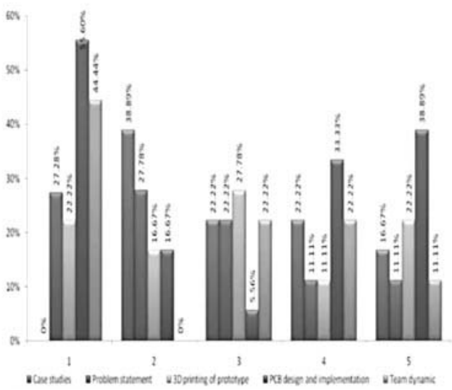

FIGURE 11: FEEDBACK OF STUDENTS FOR DIFFERENT STAGES OF PDR

VI. Challenges

One of the important challenges we faced is in building a teams and assigning a mentors for each team because total 67 students 67 and 13 mentors as shown in table 7. It was challenging to decide case studies and problem statements given for PDR. Most of the teams followed the design procedure strictly though they did not get the final output, but few teams were seen skipping intermediate steps and jumping into getting the solution for the defined problem. However care was taken in the reviews to reward the students who have followed the design procedure correctly.

TABLE VI : FEEDBACK QUESTIONS FOR STUDENTS

1	The case studies where a small product was prototyped using 3D printing helped in understanding the pitfalls and challenges for your chosen product.
2	The faculty assigned to you mentored your team in an effective way
3	The review process considered all aspects of product design and development, including team dynamics and presentations
4	The reviewers provided valuable inputs for your product design process
5	The PDR course provided scope for lateral thinking
6	The interaction among multidisciplinary students was very minimal

TABLE VII : NUMBER OF STUDENTS REGISTERED FOR PDR COURSE

Department	Total Students
Automation & Robotics	03
Automobile	02
Electronics & Communication	14
Electrical & Electronics	07
Industrial & Production	05
Instrumentation	20
Mechanical	16
Grand Total	67
	13 Batches

VII. Conclusion

This course brings a new perspective to the multidisciplinary approach to teaching product design. Introduction of project based design experience at an early level provides students with an opportunity to develop capabilities to design complex systems in the future. An attempt is made to bridge the gap between the skill level of the graduates and the industry expectations, so that the students are industry-ready. The outcome assessment meets the requirements of most of the ABET outcomes adequately, and provides inputs for continuous improvement of the course. The future work is to share the experiences with the industry stakeholders and incorporate the suggestions into subsequent courses.

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