The Capstone Design Experience in the Mechanical Engineering Department at California State University, Fullerton

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Abstract

The terminal learning experience in the mechanical engineering program at California State University, Fullerton is the series of two design classes: ME 414 and ME 419 taught respectively in the Fall and Spring semesters. These two courses have the goal of immersing the students in the real-life engineering problems where they are engaged in systematic application of the principles of design and solving open-ended problems for specific situations and/or needs and in utilizing knowledge acquired during their studies at the University. Design is about testing ideas, failures and successes and solving problems as these appear during the semester. Decisions have to be made at each step of the process, compromises must be reached among the team members, optimization of components is done and ultimately the project must be fabricated, tested and it must perform as stipulated, that is the requirement that the department has imposed on each and every design project. The principal objective of this sequence of courses is for the students to develop an understanding of the design process as it applies to a serious mechanical engineering project. Students must to be able to select standard off-the-shelf components as well as design non-standard mechanical sub-systems. One of the key features of these two courses is the creative utilization of contemporary software packages i.e. Pro-E, Fluent, Ansys, Solid Works as well as MathCad, MatLab, AutoCad and Project Management software. Simulation is readily utilized and the students readily appreciate ability to virtually analyze a real system rather than engage in costly sequence of physical prototypes designed iteratively by intuition and/or trial-and-error prior to building a physical prototype. Strict requirements are maintained in developing the RFP and subsequently the proposal for the projects, maintaining the documentation of the progress, adherence to the Gantt chart and communications with the vendors and/or fabricators. Cost issues are carefully evaluated and teams are mandated to stay within the allocations given either by the instructors or industrial sponsors. Project teams are strongly encouraged to seek additional funding from sources within and without the University, i.e. from chapters of professional organizations (ASME, SAE, SAMPE), Orange County Engineering Council - the umbrella organization of all engineering societies within Orange county and from major industrial corporations such as Boeing, Fluor, Parsons, General Dynamics, Lockheed-Martin, Hughes etc. The projects given to the teams vary so as to meet their individual interests ranging from biomedical projects, automotive (Mini Baja, Drift Car, Formula One), avionics, renewable energy, equipment for the handicapped... Teams are carefully created with the intentions of balancing students' talents and skills as well as their desires to work with their friends. The penultimate results are a working prototype and a portfolio detailing all elements of each of

the design projects. The Power Point or similar presentations which take place at the end of the semester in front of Design Juries is the climactic event of the courses where the defenses of the projects are conducted and which is a significant component of the grades given to each design team member for their performance and contributions to the project.

Introduction

Contemporary work environments request/mandate that engineers be able to participate in work on diverse projects and make their contributions to the effort. Therefore it is incumbent on the Universities teaching design to provide the requisite learning experiences preparing the future engineers to hit the ground running and deliver what is expected of them. The Capstone Design experience at California State University, Fullerton has as its goal to provide this experience[2]. The theme of the experience is set jointly by the students and faculty during the beginning of the first class. Interests of the students are explored and evaluated and ideas for projects requested. Subsequently, additional ideas are brought for consideration by the teaching faculty. Usually, these are projects obtained from local industry or from different parts of the University. The discussions about which projects to select are an integral part of the course as the financing of the projects with respect to the ability of the department to fund these is of course quite limited. The current financial circumstances in the university and the inability of the department to provide any funding whatsoever curtails the ability of engaging in more ambitious and more complex projects. That placed tremendous pressures on the instructors of the course to obtain the requisite resources for the conduct of the classes. Prior to the day the projects were actually assigned to the students another serious aspect which had to be considered was that not all students came with identical background, but with a wide array of talents, manual and computer skills, experiences, cultural backgrounds etc so that creating teams that could and would function harmoniously presents a rather complex task. An additional aspect to the original purpose of the capstone courses was satisfaction of the ABET requirements regarding design activities, specifically with “an ability to design a system, component, or process to meet desired needs” as well as to possess “an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice”. This was achieved through ongoing discussions and progress briefings with each of the teams as well as confirmed by the assessments of the design juries and the mechanical engineering advisory board members providing inputs to the student teams.

Conduct of the Capstone Design Courses

Matching the students’ interests turned out to be a harder task than originally thought to be. Every student had visions of working in their own field of interest which is unlikely to take place in most work environments. Yet, the authors know from long standing experiences that if the students are energized with the assignments close to their hearts they would invest the time necessary for the project and deliver better products. The majority of the students prefers and enjoy working on projects which involve competitions, i.e. Mini Baja, Human Power Vehicles and Human Powered Submarine, SAE Air Cargo, Drift Car, SAE Formula One car, ASME Super Mileage vehicle…The pace of these projects is dictated by the deadlines which each of the competition entails and are excellent examples of the pace encountered in industrial settings. While these projects entail excellent engineering challenges they are also good for the reputation of the program as well as for building and maintaining connections with the alumni. Yet, one of the authors of this paper prefers projects which have a more humanistic nature and are for the benefit of the society such as designing equipment for the handicapped, items that are usable in Kinesiology department of our university like The Stability Platform, New Surgical Devices, equipment that aids rehabilitation of the patient after surgery, design for the elderly and for eclectic projects for the local industry such as the aircraft winch, camera for inspection of various structures, re-design of wheelchairs, robotic painting devices…[10]. There are several additional interesting aspects of conducting the capstone design courses which include discussions of selected case studies from the ASEE Case Studies Committee Library which is currently at Rose-Hulman Institute of Technology in Terre Haute, Indiana, analysis of some more prominent failures encountered in the engineering practice along with demonstration of some of the movies illustrating these[11]. Safety concerns were emphasized during the conduct of both of the courses with numerous illustrations as to how failures occurred and how the prevention of these could have been achieved[9]. Human Factors and Safety concepts were discussed at length and examples of product liability cases brought to the students' attention in order to sensitize them to that paramount cannon of the ASME Engineering Codes of Ethics which is that "Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties" and that "Engineers shall recognized that the lives, safety, health and welfare of the general public are dependent upon engineering judgments, decisions and practices …" [4,8]. Different hazards in design must be recognized and dealt with in the optimal way i.e. kinematic, energy, electrical, chemical, material, environmental, ergonomic ones etc [5,7]. Also, it is important to recognize potential for misuse or abuse of products, particularly with regard to maintenance aspects. Ethical issues of the engineering practice are discusses with regard to the well known engineering cases[4]. Maintenance of weekly logbooks of progress, or lack thereof, was an integral part of the requirements for the course which had to be met. These were inspected by the course instructors and signed off on the weekly basis. The contents of these logbooks had to be scanned and presented with the final design project report along with the specifications of purchased off-the-shelf items. Fabrication of projects was done mostly at the facilities within the University with able assistance of our machine shop. Students have previously learned to utilize most of the machine tools within the shop and were doing a good amount of the machining themselves. Some of the fabrication was outsourced when necessary. The importance of avoiding obsolescence is being impressed throughout of the courses as is the need to pursue learning throughout one's career [6].

Funding of the projects

The California fiscal crises notwithstanding, the funds for the projects have for years originated as a result of the instructors' entrepreneurial efforts and activities. The bulk of the funds have been secured by submitting proposals to the CSUF student government's IRA – Instructionally Related Activities fund which has enthusiastically supported the project activities. The fund's resources hail from students' fees. Proposals for the funding of the projects undergo a rigorous scrutiny of a large committee consisting of students, faculty and administrators. The committee then allocates the funds to those projects it deems to be worthwhile. The support of the different project activities is a long standing tradition at the university and has contributed to numerous ambitious and sophisticated projects across the spectrum of different disciplines. Some mechanical engineering projects have been funded by the local industry for a variety of reasons: the projects are of the type that are not of an urgent nature and are on the proverbial "back burner" so that the time for completion is not of essence, the projects can be done over the two semester period which is the duration of the two capstone courses, the only costs of the projects are the components and fabrication as the students' and faculty labor come free. The industry funded projects serve as an excellent recruiting tool for new engineers where the company engineers interact with our students and can evaluate their prospective contribution and subsequently decide if they should be hired upon graduation. Also, it is a good public policy for companies to maintain active relationship with the biggest local University in Orange County. Interestingly enough, some projects were directly and completely funded by the students or their families. The rules for these rare projects were clearly laid out: if any funds whatsoever utilized in the projects come from the University the project remains property of the University. If the project is completely funded externally it belongs to the source of funding. However, the owners of the project must *a priori* agree in writing to let the University be able to loan the prototype for special occasions such as Open House Tours, ABET visits, Job Fairs etc with the appropriate time notice. Interesting situations arise from time to time with respect to the intellectual property associated with the projects as some have potential to generate income once a patent is issued. These have been handled on a case by case basis. In some circumstances the University has yielded the patent rights to the sponsor of the project while in other a sharing of future income has been negotiated. Pursuit of patent rights is an expensive process and has been in most cases left to the sponsor of the project yielding a larger share of potential future profits. Instructors have waived their rights to the benefits but retained the rights to be named on the patents, if granted. The intent of the department has from the inception of the projects been that the students are not expected to contribute to funding of any of the projects. In view of the cataclysmic changes taking place at this very time this approach may regrettably have to be changed? The projects originating from industry have been the result of the active Departmental Advisory Board as well as a result of the good relationship with the alumni of the program who cherished opportunities to be engaged and help their Alma Mater. During the conduct of the courses the students were encouraged and guided to seek support for their projects on their own. They were taught how to write granting proposals and seek out sponsors for their efforts. The support requested was in form of cash, components, discount on purchases, help with travel arrangements etc. The sponsors would, in turn, obtain favorable publicity as their logos would be posted on the project. Additionally, the students were encouraged to give presentations to chapters of the professional engineering societies and seek their support as well. The learning curve on fund raising was a steep one as very few students, if any, did ever anything similar but they rose to the occasion and were successful in their efforts.

Use of Modern Design Tools

It is difficult to envision contemporary design without a comprehensive utilization of modern computational tools. Student teams were provided with numerous software packages acquired by the either the university or the mechanical engineering department such as AutoCAD, Fluent, MathCad, MathLab, Project Management software, Solid Works, ProE, Cosmos, Ansys etc[3]. Additionally, most projects required usage of specialized software which was purchased, if affordable, to support the design activities at the appropriate technical level of sophistication. The Air Cargo project utilized NASA Airfoil design software and Simufoil, the Mini Baja utilized software for modeling of the suspension of the vehicle and shock and vibration behavior of the frame. Every effort is made during the conduct of this (and other) courses that the word processing, spreadsheets, Cad/Drafting, project management, internet communications and web browsing are in the inventory of the skills of our graduates. The car related projects represent ideal settings to learn object related programming as software allows modeling of various physical components of the car: its engine, transmission, differential, tires, steer mechanism, suspension etc. Students were able to design a car within the constraints provided. Many of the other projects also lend themselves to computational modeling of components and systems.

Communication Skills

Engineers are to be employed in a wide variety of business functions, for example: Technical marketing, product research and design, plant operations, fabrication and their ability to successfully perform in these functions demands that they be good communicators both in writing and in oral presentations. During the capstone design courses teams were mandated to regularly deliver progress reports by using Power Point presentations. The resistance to this requirement was palpable, particularly from students with the foreign background, but after some time passed the students were able to deliver good briefings and to choreograph their presentations. The instructors encouraged questions and answers engagements which resulted in interesting discussions involving the entire student body of the class. Ultimately, at the end of each semester, the teams gave final presentations to the instructors and the design jury specially constituted for this purpose. The members of the design jury challenged the teams with the questions related to the alternatives considered when doing the arriving to a particular decision. Another interesting aspect of communication was the interaction with suppliers. The contact had to be made with different manufacturers and information was sought regarding to specific components performance as well as the cost of these. Students had to research the companies producing the said components, obtain the technical specifications and data and ultimately select the optimum one for their application with the appropriate cost for it[1]. Members of the Mechanical Engineering Advisory Board interacted with the teams on several occasions and provided much of valued constructive critiques. Members of the Board have also reviewed the final reports of the teams for both semesters and offered their comments and suggestions for improvements. Efforts were made to ascertain the proper level of literacy in the reports with respect to grammar, syntax, spelling, vocabulary to make them achieve the desired high standard. Since a large number of students were foreign born this required a special effort on behalf of the instructors.

Information Gathering

Every team had to evaluate the current state of the art of the know-how of the project it was working on. That required extensive information gathering both by conventional means in library searches and by contemporary methods via search engines, patent searches, visits to the industry and interviews with engineers knowledgeable with the product. Of immense help were the briefings of the reference librarians of the California State University, Fullerton. They met with each team separately and helped them identify the sources which would be helpful in their work; the published works of the persons engaged in the like efforts and have obtained, via interlibrary loans, documents pertinent to the individual searches. Their contributions to the effort cannot be adequately recognized as their knowledge and skills in the searches significantly abbreviated the students' efforts and lead them directly to the most appropriate sources and taught them to avail themselves of these powerful contemporary tools.

Conclusions

Universities and educators are working together to identify requisite engineering skills and abilities for the entry level engineers and to facilitate their transition from the graduating senior to an engineering professional who carries his or her own weight in the industry[12]. There is no better opportunity to do so than in the capstone design projects courses such as the ones discussed in this paper. The constantly evolving industrial practice demands that a constant vigil and attention be given to determining which evolving skills are to be required of current graduates and where and when are these to be introduced and practiced. The successful projects in the ME 414 and ME 419 courses proved to be valuable to the graduates of the CSUF mechanical engineering program as their portfolios of the final design projects were convincing documents about their competency in the profession, written and oral communication skills, leadership abilities and indeed most helpful during the interview process for steady employment.

Appendix

Examples of projects accomplished in the ME 414 and ME 419 Capstone Design courses at CSU Fullerton

SAE Mini Baja
Drift Car
SAE Formula One Vehicle
Human Powered Vehicle
Human Powered Submarine
ASME Super Mileage Vehicle
SAE Air Cargo Plane Design
Bowling Machine for Handicapped Persons
Frisbee Thrower for Handicapped Persons
Landsailer Design
Rehabilitation Device for People after Hand/Finger Surgery
Tool to Assist Surgeon during Surgery and Reduce Hemorrhage
Ankle Testing Device for Kinesiology

Balance Response Platform for Stability Assessment for Kinesiology
Rehabilitation Device after Knee Surgery
Lift for Placing and Extracting of a Handicapped Person to the Pool
Robotic Painting Device
Conversion of an Internal Combustion Automobile into an Electric Vehicle
Hovercraft Vehicle Design
Platform for Mounting Inspection Cameras
Thermal Management Unit
Solar Hot Dog Cooker
Automatic Shish Kebab Machine
Rickshaw Design
Sterling Engine
Movable Mirror Focusing Solar Collector

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Biographies

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