Design of An Industry-Tied and Team-Oriented Course for Mechanical Engineering Senior

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Abstract

Rapid and drastic changes in economic growth nowadays are creating higher demands for employability skills in the workforce and labor market is becoming more competitive. The employers have high expectations of fresh engineering graduates to perform in their organization as soon as they are hired, which necessitates the creation of new educational models for training undergraduate engineers. In order to better prepare engineering students to meet these demands, an industry-based and team-oriented design course, Mechanical Engineering System Design, was renovated and offered to Mechanical Engineering (ME) senior students at Mississippi State University.

In the renovated course, students work in teams to understand, model, solve, and interpret a variety of engineering problems provided from industry sponsors. The implementation of this course allows students to become the "most employable engineering graduates" by fully developing their experimental and computational skills in modeling, solving, and understanding real-world problems as well as their "soft skills" in teamwork, communication, and leadership.

Keywords

Curriculum renovation, industry sponsored project, group design, mechanical engineering system design, Mississippi State University

1. Introduction

Rapid and drastic changes in economic growth nowadays are creating higher demands for employable skills in the workforce, and additionally, the labor market is becoming more competitive. Employers have high expectations of fresh engineering graduates to perform in their organization as soon as they are hired, which necessitates the creation of new educational models for training undergraduate engineers. In order to better prepare mechanical engineering students to meet these demands, we renovated an existing course, Mechanical Engineering System Design (MSD), by implementing semester-long, industry-based and team-oriented design projects into the syllabus and adding several finite element analysis (FEA) laboratories.

In the renovated course, students are asked to work in teams to understand, model, solve, and interpret a variety of engineering projects provided and sponsored by industry companies. Those projects either focus on product/system design or process/structural/material analysis, depending on the requirements of our sponsors. FEA software package ANSYS is also included in the syllabus to show students fundamental operations of finite element modeling and analysis using different types of elements. The implementation of this course will allow students to become the "most employable engineering graduates" by fully developing their computational skills in modeling, solving, and understanding problems from different mechanical engineering disciplines as well as their “soft skills” such as teamwork, communication, project management and leadership. The outcomes of this project will also form a base for a distance course, which will be developed and offered after the completion of this renovation and reorganization effort.

2. Background

2.1 Current Status

The current economic challenges and globalization are forcing employers in the engineering sector to seek competent engineers. Nowadays, the employers have high expectations on fresh engineering graduates in two aspects. First, the employers are always looking for those graduates equipped with enough employability skills and abilities to perform in their organization as soon as they are hired[1]. Second, in the mechanical industry, employers require that their new engineers possess strong computational skills in CAD/CAE and FEA, and that they are able to fluently use engineering computer software packages such as ANSYS. Meanwhile, other skills and abilities in teamwork, communication, project management and leadership are highly wanted in modern engineering job fair.

However, there is a gap between expectation of engineering industries and our existing engineering education programs. In the mechanical engineering curriculum at Mississippi State University (MSU), we are offering a finite element analysis (FEA) class to our upper-division undergraduate students as an elective. Since it is only an elective, a lot of students who have not taken that course do not possess fundamental FEA skills, which are so critical in project design nowadays. Also, the current MSD course doesn’t include effective teamwork, communication, project management and leadership training. From feedback of our recent student advisory committee meeting results, senior exit review results, as well as alumni survey results, a well-rounded education is highly desired by our students, which includes the development of communication and humanistic social skills, and other capabilities which are necessary to function in a team environment in a global marketplace. Thus, in this project, we reorganized current MSD course into an applied lecture-laboratory course that closely ties to the industrial requirements, to prepare our engineering students to better meet the expectations of their future employers by overcoming aforementioned limitations.

2.2 Previous Work

Importance of developing students’ problem solving skills, career skills, and hands on ability through group design project has long been recognized by many educators. Considerable progresses have been made in bringing industry projects in to senior engineering courses through course development, program establishment, and formation of university-industry partnership. Todd et al.[2] developed a senior capstone design course entitled “Integrated Product and Process Design” at Brigham Young University. This course is centered on industrial design and manufacturing projects and involve both product and process design activities. Conn and Sharpe[3] described a year-long senior mechanical design course that was supported by an industrial sponsor, which gave students an experience which was as close as possible to the realities of how project engineering was practiced in an industrial organization. In that small class, all students were able to share in the wide range of experience that any development of a new device might encounter. Ruud and Deleveaux[4] designed and conducted a senior capstone course to address key skill deficiencies of the engineering graduate in parallel sections in Departments of Industrial, Mechanical, and Aerospace Engineering at Penn State. Dunn-Rankin et al.[5] proposed their solution of teaching students how to apply fundamental engineering principles to practical problems by forming the "Engineering Design in Industry" program in the Mechanical and Aerospace Engineering Department at the University of California, Irvine. Kumar[6] successfully introduced industry participation in the capstone course "Civil Engineering Design" in the Department of Civil Engineering at Southern Illinois University – Carbondale by assigning practicing engineers to serve as technical advisor on the projects and inviting them for open discussions with the students. Reichlmay[7] discussed how the Software Engineering Department at the Rochester Institute of Technology had provided students the opportunity to actively collaborate with industry by incorporating cooperative education, commercially sponsored senior capstone projects and the development of research partnerships. Liu substantially innovated the course structure for the design course "Structured Programming". Course evaluation results and students' feedback proved that the reorganized course effectively helped the students grasp fundamental software engineering concepts and develop their programming techniques[8]. Dr. Liu and coworkers also revitalized an obsolete boiler system and established a steam lab based on that system and used that lab for the thermal engineering system design class[9].

In the present work, a new model of exposing the students to a real industrial design environment is presented, which was achieved through renovating and reorganizing an existing course in the Department of Mechanical Engineering at MSU. ANSYS was chosen as the main instructional software package for this reorganized course because as a popular computer software package, it is being widely used by the automobile, aerospace, construction, military, manufacturing, and bioengineering industries. The author of this paper has 13-year experience in using ANSYS for various research projects from product development, structural analysis, dynamic impact analysis, thermal analysis, and fluid dynamics simulation[10-14].

3. Implementation Plan

3.1 Syllabus Renovation

Syllabus was renovated by adding industry sponsored projects and FEA classes. Two 75-minute sessions per week are devoted to lectures, computer labs, and project discussions. Overall 30 classes are offered during a 15-week semester. Among the 30 classes, three classes focus on fundamentals of mechanical design such as the design process, engineer ethics, geometric dimensions and tolerances, standards and codes; five classes are devoted to FEA and ANSYS including overview, truss, beam, plate, and solid elements; four classes are used for project discussions and industry tour; 16 courses are spent on design and analysis of mechanical components such as springs, gears, brakes, belts, etc.; and the remaining two courses are reserved for one midterm and final review.

As a design course, the most important tool for assessing students' success in this course is the group design project, which weighs 60% in the final score. Two tests were offered in the middle of the semester as well as the end of the semester and each test takes 10%. The remaining 20% of the final score comes from homework assignments and computer lab reports.

3.2 Group design project

In fall of 2014, four projects were assigned to student groups. Those projects were designed based on real engineering industry problems and sponsored by our long term industrial partners such as PACCAR, Airbus Helicopter Inc., and SAI. In the PACCAR projects, the students were required to design and validate automatic cleaning systems to clean and collect debris, residual metal swarf, and engine oil from its conveyor lines. In the Airbus Helicopter project, the students were asked to provide effective solutions to remove the heat buildup within the engine area by performing an in-depth review and analysis in terms of the manufacturing process, structure design, and material selection. SAI, however, needs us to design a lifting assistant to move car seats from an assembly line to a conveyor line.

The students worked on those projects as groups and each group was assigned one project. A group typically includes four students and the group members can take the role of project leader or coordinator in turn during the semester. In particular, the industry sponsors were heavily involved into this design course to help our students and make sure that they are following the right direction. A effective communication and coordination between the students and the industry collaborators were achieved through following activities: (1) each industry company offered a free tour for the students who worked on its project at the beginning of the semester; (2) midterm phone conferences or project demonstrations were organized for the industry customers to exchange questions and concerns with our students; (3) the industry customers attended final demonstrations and provide their comments which were critical in the project grading; (4) frequent email conversations were held among the instructor and students and the industry customers to share data, questions, concerns, and updates frequently. From above measures, a “real” working environment was provided for the students to face and solve real-world problems. The design project was graded based on a design proposal, an oral presentation, a final report, and peer evaluation forms.

4. Evaluation Method and Results

Two evaluation tools were employed to collect feedback from the students regarding the course and project effectiveness. One of them is the regular student evaluation form issued from the Provost’s Office for each class taught at MSU. In addition to that, a separate evaluation form was designed based on a published improvement-focused evaluation model, which had been revised to be used for evaluating engineering design courses that include group project work[15]. As shown in Table 1, four sets of evaluation research questions would guide both summative and formative evaluation. Those questions examine effectiveness of the renovated course in terms of student learning (awareness, knowledge, understanding, and skills), course validity (meeting industry needs), interest or engagement, and attitude. Although these questions are primarily summative in nature, they will also be assessed during formative evaluation to monitor and improve the course renovation process. All students who took the course in the fall of 2014 participated in the evaluation. The results listed in Table 1 reflect that this course was well organized and the design projects improved student interests in engineering system design. Overall course effectiveness and potential of meeting industry needs from this course were also confirmed by the students. The students highlighted the course project experience on their resumes and we have one student accepted an offer from a leading oil industry company in Houston with a starting salary of $100,000!

Table 1. Evaluation questions and student feedbacks

Evaluation Questions	1 = unsatisfactory; 5 = excellent					Overall scores
	1	**2**	**3**	**4**	**5**	
1. (Formative & Summative) Course effectiveness: Meeting industry needs. How well does the course meet industry needs?		1	3	7	13	4.33/5
2. (Formative & Summative) Course effectiveness: Student learning (awareness, knowledge, understanding, and skills). To what extent do the materials result in improved student learning? How do users perceive the effectiveness of the course on learning? What course components contribute to or interfere with learning?			3	8	13	4.42/5
3. (Formative & Summative) Course effectiveness: Interest. To what extent does the course result in improved student interest in engineering system design? What program components contribute to or interfere with improving interest?	1		1	6	16	4.5/5
4. (Summative). Project dissemination. How well is the course disseminated? (publications and presentations, course offering in different schools, online course development)	The renovated course will be shared within engineering education society through a journal article and a conference presentation					

Positive feedbacks and compliments were also received from the industrial sponsors at the end of the semester. Project outcomes along with the encouraging evaluation results have stimulated passions in industry on continue to participate in this class. PACCAR and Airbus Helicopters plan to allocate additional resources out of their budget to continue to support this class and in the next semester, new projects will also be provided by FedEx Express, Stark Aerospace Inc., and other local companies.

5. Significance

The presented work of creating such an industry-tied, lecture-laboratory, and team-oriented learning strategy has its importance in four areas in engineering education. At first, this work answers an increasing demand for an industry-tied and team-oriented teaching and learning model. Secondly, the renovated syllabus emphasizes the value of hands-on experience and computational skills besides the lecture component. Thirdly, the renovated course will address the industry needs for young engineers with strong practical skills and also helps to provide solutions to their current technical issues. Both students and industry partners will benefit from this course. Last but not least, this renovated course can be easily converted to an online course and even transported to a large number of institutions because of the well available facilities required by this course and its explicit implementation steps.

6. Conclusions

An industry-tied and team-oriented mechanical engineering system design course was prepared and offered to senior students at MSU. This course features semester-long group design projects funded by industry sponsors and those projects provide students hands-on experience in working as a group to solve for real-world problems, from which a set of soft skills such as communication, team work, project management and leadership can be developed. In addition, computational labs were added into the curriculum to show the students how to use ANSYS to solve for FEA problems. The renovated course can be easily modified to an online course and even implemented to the curriculum of other institutions. Positive feedbacks have been received from both industry and students and a complete assessment of this renovated course will be available as soon as the course evaluation is completed. Based on the current progress, the author plans to continue to reorganize this course by adding some process improvements techniques such as six sigma and lean into it to better prepare our future engineers and engineering leaders.

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