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The balance of theory, simulation and projects for mechanical component design course

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The balance of theory, simulation and projects for a mechanical component design course

Abstract
The trend in engineering education is swinging from an emphasis on theory to a balance between theory and applied design activities. Nowadays, the finite element analysis (FEA) is a common powerful engineering tool available for both engineers and engineering students. Because of its widespread use and industry expectations of entry level engineering capability, it should be integrated in the engineering education. When we recently modified & redesigned our teaching approach for the course "Design of Machine Elements", there were some discussions and arguments relative to effectively executing this course. Four different approaches: the theory-focused; the balance of theory, simulation and the projects; the simulated-focused, the project-focused for the course were discussed and explored. We believed that the balance of theory, simulation and projects for this course is the best approach and was implemented in the fall 2013. During the course, we explored and discussed the fundamental theories, then FEA simulation on components was used to complement and in some cases replace some complicated theoretical analysis. The course also included two design projects, one was individual and one was team based. This paper is intended to present the course content, the execution plan & summary and both student and faculty experiences when the balance of theory, simulation and projects was implemented in the course. Valuable information from students' survey will be presented and analyzed. According to the students' survey in our three classes, the majority of students strongly agreed with that the teaching approach "the balance of theory, simulation and project" was the best one for teaching the course "Design of Machine Elements".

1. Introduction

The trend in engineering education is swinging from an emphasis on theory to a balance between theory and applied design activities [1-4]. There are certainly some gaps or differences between the academic settings and the industrial settings for mechanical engineering programs. Years ago, the graduating students from engineering programs would expect a half-year or one-year training period provided by the companies in order to migrate them from academic settings to real industry settings. However, students are surprised that the migration period for them nowadays might be very short such as just a few weeks. The employers expect that students can immediately start working. One of the big gaps is the capability of conducting design projects. In order to facilitate the migration from students to entry level engineers, students should have chances to conduct as many design projects as possible during their education process.

For the course "Design of Machine Elements" (DME), many faculties covered theory and its applications in detail during class lectures and practiced these concepts in focused homework assignments, but students sometimes had difficulties implementing them in their design projects. One year, some students came to our offices for help during their capstone design project. In their project, they needed to design a power transmission by using gears and shafts. In the previous DME course in which the theoretical analysis through lectures was focused without any design project, we did discuss how to design a shaft, how to design a pair of gears and how to choose bearings. They did homework assignments very well on each of these tasks. But they did not know how to effectively start to conduct the power transmission design. The reason, we believed, was that the homework assignments for gear, shaft or bearing were close-ended problems. But the power transmission design in the project was an open-ended problem. This implied that there might have been some flaws in the previous DME course, which was 3-2-4 credit course, that is, 3 lecture-hours and 2 lab-hour per week. In previous DME course, the theory and its derivation were the focal points with the application of the theory in the close-ended homework assignments.

The DME course is one of many core technical courses for mechanical engineering programs. When we recently modified & redesigned our teaching approach for this course, there were some discussions and arguments about how to effectively present the course material. Four different approaches: (1) the theory-focused; (2) the balance of theory, simulation and project; (3) the simulated-focused, and (4) the project-focused approaches for the course were discussed and explored. We believed that a balance of theory, simulation and projects for this course would be the best approach and implemented it in the fall 2013. During the course, we explored and discussed the fundamental theories, applied FEA and other tools on components to help in the visualization of complicated theoretical analysis and application of theory through the execution of two design projects. This paper will present the course content, the execution plan & summary and both student and faculty experiences when attempted to balance theory, simulation and projects for the course. Valuable information from students' survey will be presented and analyzed in this paper.

2. Four teaching approaches for the DME course

The DME course in academic settings is considered the bridge course between the Strength of Materials course and the Capstone Design. The DME course is considered one of the core technical courses for our mechanical engineering program to achieve competency in mechanical design. In following sections, the relationship of the DME course to other mechanical design courses will be listed and explained first. Then the four different teaching approaches for the DME course will be described, discussed and compared. Finally, the reason for the choice implemented in our DME course will be explained.

2.1 The relationship of the DME course to other mechanical design courses

Every course in the program is to provide students' knowledge and skills for their capability of conducting mechanical and thermal design. The courses directly related with mechanical design in our program are listed in the Table 1.

In the freshmen year, students learn how to create models and drawings from MECH130-Engineering Graphics and learn the generic 5-phase design process of any general design project [5] from the course MECH165-Mechanical Engineering Design. Through these courses, students develop some basic skills such as 3D modeling & drawing and a general process flow for a design project. But they still don't know how to actually conduct mechanical design because they don't know how to quantitatively judge whether a component is safe or not.

In the sophomore year, students learn how to determine loading on a component from the MECH252-Engineering Statics and how to calculate stress and strain on idealized geometries under typical idealized loading from MECH302-Mechanics of Materials. The basics of mechanical material behaviors are provided by using the typical stress-strain curves during MECH302- Mechanics of Materials. Through focused homework assignments they learn how to quantitatively judge whether an idealized component is safe under simple loading scenarios. MECH317-Mechanical Design and Analysis is a faculty-guided-project course. Students learn dimension & tolerance and design interface analysis between mated components through a guided-reverse-engineering project and then a redesigning an existing device in an open-ended project.

Table 1- list of courses directly related to mechanical design

The years of the program	**Courses**
Freshmen year	MECH130-Engineering Graphics MECH165-Mechanical Engineering Design
Sophomore year	MECH252-Engineering Statics MECH302 - Mechanics of Materials MECH317-Mechanical Design and Analysis
Junior year	MECH420 - Design of Machine Elements MECH573-Engineering Dynamics MECH496-Material Science
Senior year	MECH610-Mechanical Vibrations MECH625 - Simulation Based Design MECH650- Mechanical Capstone Project

In the junior year, students will learn how to design and choose typical machine elements such as bolts & nuts, shaft, gear, bearing and etc. from the course MECH420- design of machine elements (DME) which will be described in detail in this paper. Details of material behavior is covered in MECH496-Material Science and MECH573-Engineering Dynamics provides coverage of the mechanics of motion and generation of acceleration based forces.

In senior year, students will learn how to determine component vibration for dynamic deflection and dynamic loading during MECH610-mechanical vibration and how to numerically simulate the behavior of components and assemblies along with interpreting the results during MECH625 - Simulation Based Design. The MECH625-Simulation Based Design is mainly focused on implementation of FEA in mechanical design. Students will conduct a self-selected-and-faculty-approved design project through the MECH650- Mechanical Capstone Project. The projects selected are based on real needs under real constraints similar to real industrial constraints such as funding, time and available resource labor hours.

From the mechanical design threads described above, the course MECH420-design of machine elements (DME) is one of the core courses for mechanical design. This course is one of the bridges between the mechanics of materials and the capstone because it is focused on typical mechanical elements. In following section, we will explore how we propose to effectively execute this course in order to facilitate student's transition from learning mechanical design concepts to conducting open-ended mechanical design projects.

2.2 Discussions on the four teaching approaches for the DME course

MECH420 - Design of Machine Elements (DME) is a 4-0-4 credit course. Every week, there are two 2-hour lectures without any lab hours. The DME course is a required course for the program. When we recently redesigned this course, we identified three key aspects for delivering the course materials, which are theory, simulation and design project and then identified four potential teaching approaches. After a few discussions, we identified four possible methods of teaching this course. One viewpoint was that the course should be concentrated on theoretical derivation and analysis of different combined loading scenarios so that students had solid understanding of stress & strain calculations for machine element design. Another viewpoint was that the theory, simulation and projects are all essential and should be all included. This is an integrated approach, that is, the balance of theory, simulation and project. Another perspective was that industrial engineers rarely run the complicated theoretical hand calculations for real component design, but use numerical simulation tools such as Finite Element Analysis (FEA) to ensure design integrity. An increasing number of educators were suggesting that students could learn and explore the theories and skills independently through the execution of design projects as the student progressed through the design process guided by faculty serving as a consultant to answer questions and to provide advice.

The four different teaching approaches will be descried, analyzed and compared briefly in following sections. Finally, the reasons for our choice and implementation will be explained in detail.

A: The theory-focused approach

The theory-focused approach means that theoretical analysis / derivation and calculation on typical simplified components under typical loadings are mainly emphasized. In the course, homework assignment for simplified components under typical loading conditions are used to practice the theory. There are no open-ended design projects.

This is a traditional approach [6, 7] for teaching the DME course. The justification for this approach was that mechanical design is based on design theory, so students must have solid understanding theoretical calculation of the stress/strain. The pros and Cons for this traditional approach are as follows:

Pros: students have strong/solid theory about how to calculate stress/strain on several typical and idealized shapes under different loading conditions; the approach is suitable for the course without any lab.

Cons: real components might be very complicated so that it could not be idealized as one of the theoretical models; theoretical hand calculation might be very difficult for some real component and; the approach is without an open-ended design project.

We thought this could be one of possible approaches mainly because we did not have any lab hours and were afraid to overburden students. This was the approach we used in previous semesters and we knew that this approach had some flaws as described in the introduction. Actually, most of the time, this course was taught by the theory-focused method with some focused design projects as described in the textbooks [8, 9].

B: The balance of theory, simulation and project

The balance of theory, simulation and project means that theoretical analysis, numerical simulations and projects are inseparable for the course. The fundamental theory and theoretical analysis are discussed in the course; the FEA simulation is used to analyze complicated components under complicated loading conditions; and the design projects are used to implement the fundamental theories with the theoretical calculations using various computer software such as: SolidWorks Simulation (FEA), EXCEL and EES (Engineering Equation Solver).

The justifications of this approach are that (1) the theory and theoretical analysis is the base and foundation for mechanical component design; (2) the numerical simulation using FEA analysis is numerical versions of the fundamental theories; and (3) conducting a design project is the implementation of the fundamental theories with the use of industry available software tools. The Pros and Cons of this approach are as follows:

Pros: This is a balance of teaching theory, simulation and projects for the course; Students still obtain a comprehensive understanding the fundamentals of design theory; students also start to use FEA for stress and strain analysis of complex components; students can gain more valuable experiences in conducting open-ended design projects.

Cons: Students might be overburdened due to the lack of lab hours; students might "abuse" FEA for the mechanical component design and might misinterpret some simulation results. This approach was implemented in the course. We will explain the details of implantation in the section subtitle E: "the choice we implemented".

C: The simulation-focused approach

The simulation-focused approach means that the FEA numerical simulation is mainly emphasized with minimal theoretical analysis and calculation. The homework assignments and projects are used to practice the use of FEA software.

The justification for this approach is that industrial engineers rarely run the complicated theoretical calculations or conduct derivations, but use the numerical simulation for real component designs because FEA analysis is a common engineering tool [10, 11, 12] available for both engineers and engineering students. The Pros and Cons of this approach are as follows:

Pros: students can use FEA to simulate the stress and strain on complicated components; students can have more experiences with FEA which is one of most powerful engineering tools for mechanical design.

Cons: Some machine element design such as bolts & nuts, gears, bearing and etc. are not designed through FEA, but chosen according to procedures with vast amount of cumulated table

& figures; students might not have strong theoretical understanding about machine element design.

We did not use this approach for the course because some mechanical components including the standard or semi-standard components are designed and determined by the corresponding procedures with cumulated sets of tables & curves. Furthermore, there will be one FEA focused simulation-based design course in their senior year as shown in the table 1.

D: The project-focused approach

The project-focused approach means that the project is the focus of the course and the faculty are used as a consultant for answering students' questions during the completion of the design project. The common lectures and development of theory are minimized.

The justifications for this approach are that (1) students could learn, understand and master more knowledge and skills by doing the project as the faculty drove students through the design process and (2) students have learned the generic design procedure and the mechanics of material. The pros and Cons of this approach are followings.

Pros: Good students can learn, understand and master more knowledge and skills for mechanical element design through conducting design project;

Cons: Student might not have solid theoretical understanding because design project might just use portions of design theory; students might be overburdened by learning and exploring machine element design by themselves; Faculty might be overburdened because of the need to explain same concepts and to solve same issues to individual again and again.

We did not use this approach for the course because this is the course that bridges the mechanics of materials and the Capstone design. We still needed some lectures to discuss and explain theory and the corresponding procedures with cumulated sets of tables & curves for the mechanical element design. The project-based approach was the approach we used for the capstone design project.

2.3 The choice implemented for the DME course in fall 2013

A balanced approach in the delivery of theory, simulation and both individual plus team based projects was the approach implemented in the fall 2013. We chose this approach for our course because it was an integrated approach with theory, modern FEA simulation tool and open-ended projects. We believe that theoretical analysis, numerical simulations and projects are coherently related and inseparable for a mechanical component design course but must be balanced through careful presentation of theory, homework assignments, and numerical simulation and design projects. The theory and theoretical analysis is the foundation for mechanical component design. Simulation tools such as Finite element analysis (FEA) are a wonderful engineering tool, they are widely used in industry and they are numerical versions of the fundamental theories capable of being applied to complex geometries. Conducting a modern industry relevant design project is the implementation of the fundamental theories with the numerical simulation tools to achieve a given specification based on a perceived need. So we believed that the balanced approach of providing theory, simulation and projects together should provide a better learning environment. Several textbooks [13, 14 and 15] include a chapter for FEA and a chapter for a project.

3. Execution summary and explanation

In fall 2013, the MECH420 - Design of Machine Elements (DME) course was delivered with two two-hour lectures per week with zero lab hours and maximum 19 students per section of the class. The textbook used for this course was "Shigley's mechanical engineering design" [14]. We attempted to provide a balance of theory, simulation and projects to teach the course. The execution summary and plan we carried out in fall 2013 are listed in the table 2. Some explanation about lectures and projects are included.

Table 2 the execution summary and plan for MECH420-design of machine elements, fall 2013

Week	Lecture topics	Design projects
1~3	**Part I: Fundamentals** • Mechanical engineering design process • Materials • Introduction to the minor design project • Load & stress analysis • Deflection & stiffness • FEA simulation on components	Minor design project (individual): Design check on a scissor jack. The main tasks of this minor project were: • To implement what they had learned in statics to find maximum loading conditions for the jack; • To run the theoretical calculation on the link bar, bolts and the power-thread rod; • To run FEA analysis on the complex top plate and the simple link bar; • To make the mechanical drawings; • To communicate the findings in a technical report.
4-6	**Part II: Failure theories** • Failure resulting from static loading • Fatigue failure resulting from variable loading	
6	**Part III: Design of mechanical elements** • Screws, fasteners, and design of nonpermanent joint	
7	**Mid-term exam**	
7-13	**Part III: Design of mechanical elements** • Introduction to the major design project • Gears system • Spur gears • Shaft, shaft components and FEA simulation • Rolling-contact bearings • Power transmission	Major design project (team based): Design single-stage spur gearbox. The main tasks of the major design project were: • Free body diagrams and overall loading • theoretic calculation on spur gear; • Shaft layout; • Shaft design with theoretical calculation for shaft dimensions • Shaft fatigue analysis • FEA analysis for deflection and natural frequency of the shafts • theoretical calculation for bearing selection, life, loading, etc.; • 3D modeling and drawing • Group presentation • Final technical report
14	**Final exam**	

3.1 The execution summary of the lectures

The lectures could divided into three distinguished parts: the fundamentals; the failure theories and the design of mechanical components. The execution summary for each topics are following:

Part I - the fundamentals includes topics:

- The general design process, which is the typical 5-phase design process [5]. This topic was discussed in detail in the MECH165-Mechanical Engineering Design course in their freshmen year and we concisely reviewed the 5-phase design process for consistency. We felt consistency in vocabulary is the very important for the students.
- Materials lectures focused on a review of material behavior from MECH302 - Mechanics of Materials course in their sophomore year. The stress-strain curves of typical steels were only briefly reviewed.
- The minor project, the design check on a scissor jack, was introduced early to give a context for the development of theories to be used in the project. In the weeks1 to 6, we devoted approximately one half-hour every week to explain /to answer questions from students. The purpose of this was to ensure the pace of students' project progress. The design project will be explained in details in section 3.2 of this paper.
- Traditional load and stress analysis with stress transformations and the combined stress of components under several loading were presented in detail along with dedicated homework. We also discussed the superposition principle about the combined stress and we demonstrated some examples. In reality, engineers rarely run the theoretical hand calculations of the stress /strain on complex components under complicated loading. We utilized SolidWorks Simulation (a commercial FEA software) to run and display the stresses of the complex components. Verification was stressed by finding a portion of the complex shape where a simple hand calculation could verify the FEA results and confirm proper application of the boundary conditions.
- The deflection and singularity functions we introduced briefly as applied in beam deflection calculations, and to understand the superposition principle about deflection. Again the use of commercial FEA tools to analyze and to display the deflection /strain of components with hand calculations to verify correct boundary conditions were correctly applied.
- FEA simulation on components, included several examples conducted with students in class to determine stress and strain under different restraints and loading conditions. Tutorials and self-study examples were assigned for students as homework. During lectures it was stressed that FEA is the numerical version of the stress/ strain theories. If restraint and loading conditions are properly defined, the numerical simulation results are then reliable. The purposes of introducing FEA analysis on component design verification is mainly to show that FEA simulation is a powerful engineering tool for stress/strain analysis and is widely used by engineers in industry. We only discussed FEA simulation on components rather than assemblies, which will be explored in a later course MECH625 - Simulation Based Design. Component level FEA simulations were required for some homework assignments and for the two design projects.

Part II- Failure theory and Part III- Design of mechanical elements, are new topics for students, which are not covered in any previous course. Because failure theory and element design theory are not developed in other classes, it was one of the main reasons the course committee felt that the project-focused and the simulation-focused approaches might not be viable options for teaching the DME course.

The Part II- Failure theories includes topics:

- The failure theory under static loadings were developed in detail for brittle materials and the ductile materials along with classroom example problems. We spent approximately one week on static loading failure theory.
- Fatigue theory, required two weeks to be devoted to this topic. Fatigue theory is very complicated and can easily consume the whole semester. But since this was the DME course for undergraduate students, so we focused on the fatigue mechanism, fatigue testing, S-N curve and the simplified S-N curve, with fatigue theory under single level of cyclic stress or loading. We assigned the homework to students through implementing failure theories in specific close-end problems. Students were required to extend these concepts in their open-ended design projects.

The Part III: The design of mechanical elements included the following topics:

- Typical machine elements including: bolts, shaft and key systems, gearing theories, spur gear, and bearings. It was well known that the design of typical machine elements were not the simple application of the stress/ strain theory discussed in the mechanics of materials but rather the application of design procedures. The design procedures included the interpretation of related tables and curves as part of design techniques and skills. We spent approximately 5 weeks on the various components. For each of these typical machine elements, we discussed the key failure modes, design equations and the design procedures and then went through examples with students. These examples were under similar context to the major design project which provided guidance for students to implement these design procedures in their major design project.
- Power transmission design was the topic for major project: design of a single-stage spur gearbox. This required the application of the typical machine elements highlighted in the course. Since these components were linked together in a gearbox, students were required to systematically approach each component design and address the interaction with other components. We believed that these were the main differences between simple homework assignments for each component and the integrated design project. The major design project will be explained in detail in section 3.2.

3.2 The execution summary of the design projects

MECH420 - Design of Machine Elements (DME) is about mechanical design, so we felt there must be open-ended design projects to address design compliance with an overall specification or system constraint. In fall 2013, we implemented two design projects for this course as shown in the table 2 the first was faculty guided and the second was open-ended. Since our DME course has no lab hours, approximately one-hour out of total 4 lecture hours every week was devoted for the support of design projects or homework exercises. During this one hour, the activities were mainly question & answers or discussions related to application of theory in the design projects. The execution summary of the minor and major design project are following.

The minor design project: design check on a scissor jack

In the first half of the semester, the lectures on the fundamentals of component loading and the application of failure theories. The minor design project chosen was a simple, but a real practical device, a scissor jack. The 3D model of the scissor jack was provided to students and a schematic is shown in figure 1. Students were required to provide an individual report but could work on this in a self-formed study group. The design specifications such as the rated loading, the minimum factor of safety and the performance envelope dimension (maximum raising height) were provided in the minor design project assignment. The main tasks of this minor project are listed in the table 2. This project served as a warm-up project and let students to go through the mechanical design process on a simple faculty led example before the open-ended project.

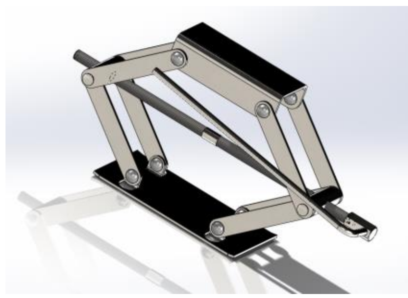

Figure 1 the isometric view of the scissor jack model

Major design project: single-stage spur gearbox

At the beginning of the second half of semester, we introduced the major design project, design of a single-stage spur gearbox based. One isometric view of a simple single-stage-spur gearbox is shown in figure 2. The students were asked to form a design team with 3 to 4 team members. Since we did not have lab hours for this course, teams were required to identify a minimum of two-hours of meeting times outside of class per week. The design team members were required to sign a team contract agreement among them. The team contract is shown in figure 3 which also serves as a vehicle to reinforce understanding of team duties and responsibilities.

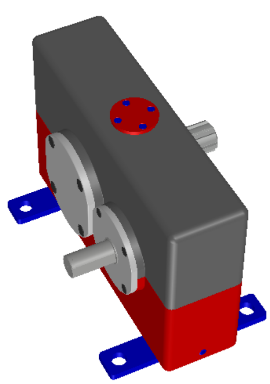

Figure 2 the isometric view of a single-stage spur gearbox model

Team Contract for the major project
Course: MECH420-Design of Machine elements
Department of Mechanical Engineering and Technology
Wentworth Institute of Technology

As a member of project team #____, I agree that coordinated teamwork is essential for successfully completing assigned projects. I understand my individual performance will affect the success of the entire project. I also understand that all members of successful teams need to exhibit the following behaviors during the execution of the project:

1. Fulfills duties of team role
   a. Attend all team meetings
   b. Actively participate in team meetings
   c. Be prepared to present work assigned from previous meeting
2. Researches and gathers pertinent information
3. Listens to other teammates
4. Shares work evenly
5. ***Submit meeting minutes and weekly report by the project manager***
6. Regularly scheduled meetings will meet (at least total two hours per week):
   a. Time/Day: Place:
   b. Time/Day: Place:

Additional Requirements Identified By Team Consensus:

7. ______________________________
8. ______________________________

Printed Team Member Name	Signature	Date:
1.		
2.		
3.		
Project manager:		

Figure 3 the team contract for the major design project

The lecture content for the second half of the semester focused on typical machine elements, such as bolts, shafts, gears and bearings. We found that homework assignments on each individual element done in the past was not the most effective method for helping students implement a cohesive design. The faculty committee decided that the best way to facilitate students to learn machine element design was to place these elements inside a design project. In reality, these machine elements are chosen and integrated according to the specified functions or performance. Homework assignments were developed with two goals, practice developing solutions to simple closed-ended problems and applying the process to their open-ended project.

The choice of major design project was to design a single-stage spur gearbox. The reasons for the single-stage spur gearbox were: (1) Gearbox contain the desired typical machine elements such as shafts, keys, bearings, gears, bolts, welding and a case that were discussed in the second half of semester during the lectures; and (2) The workload was appropriate for this course since the course had no lab hours.

The design specification provided each team the following constraints: delivered output power; rated input speed; rated life; overall reliability; a different required gear ratio and rated power for each team. Each design team would be required to present progress in design reviews and a final project presentation along with the written report. The main tasks for the major design project were listed in the table 2.

4. The students' survey and the result analysis

During fall semester of 2013, we interacted with students through office hours, class discussion and meeting with the design teams for collecting valuable student input regarding how to effectively carry out the MECH420 - Design of Machine Elements course. The majority of students supported our approach and told us that doing a major design project with a team helped them to have better understanding of DME theories. Some of students also expressed that they really liked the way we carried out the course, but projects consumed them a lot of time. At the end of course, we distributed a student survey in 3 of the course sections with total 57 students. Of the 57 students, we received 51 responses. The following section provides the survey questions and results.

The results of survey question 1 "A design project should be required for the design of machine elements course" is shown in the figure 4. The 80 percent of students strongly agreed that the design project should be required for the course. A total 98 percent of students strongly agreed and agreed that the project should be required. Only one student disagreed, but the reason for the choice was that two projects were too much and one project would be fine.

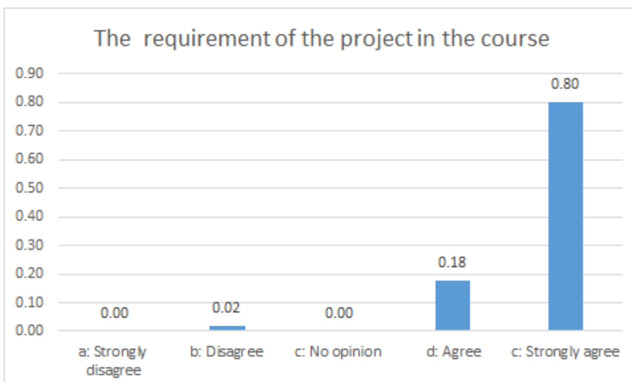

Figure 4 the survey results about the requirement of projects

For survey question 2, they were asked to explain their choice for the question 1. Two student's comments are listed here: (1) "This course needs a project to tie together everything we learn into something practical, something we can apply the knowledge we gained"; and (2) "The project allow us to directly apply classroom knowledge to a real world application while reinforces our understanding of the lecture materials". Other student comments regarding the requirement of project can be summarized as follows: (1) can implement what they learn; (2) have better understanding what they learn, (3) help them for future job and (4) help to build leadership and communication skills in a team environment.

The results of the survey question 3, "Introduction to Finite Element Analysis with industry relevant software should be a required component of the design of machine elements course" is shown in the figure 5. The 69 percent of students strongly agreed that the introduction of the FEA simulation should be a required item for the DME course. A total 96 percent of students strongly agreed and agreed that the introduction of the FEA simulation should be a required component for the DME course. One student disagreed and one showed no opinion. The reasons given were that they could not really understand the working principle of FEA and the FEA software (SolidWorks Simulation) might not be the software used in future. These doubts were reasonable because the purpose of introducing FEA just to show students that FEA simulation is another practical way for conducting stress/ strain analysis. In their senior year, students will systematically study the FEA simulation in MECH625 - Simulation Based Design.

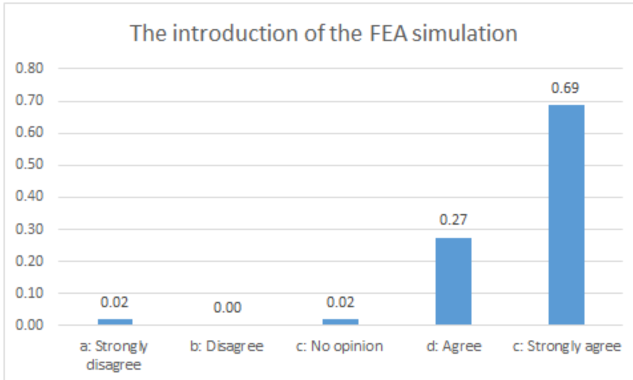

Figure 5 the survey results about the introduction of the FEA simulation tool

Question 4 of the survey asked: “Explain your choice for introduction to FEA”, two representative student comments are: (1) “If it is used in the industry, we should knew how to use it”; and (2) “With the intricacies of many engineering designs, performing hand calculation are extremely difficult, or nearly impossible for many cases. Being fully aware and having a better understanding of FEA software would allow me to analyze and design component more effectively”. Other students’ comments regarding the introduction of FEA simulation in the course had similar theme: “It is used in the industry so we should know how to use it.” It is true that DME courses should equip our students with the required tools for their future career.

The results of survey question 5 which asked students to, “Rate the 4 teaching approaches” resulted in 91% selecting the balanced approach as their first choice. Based on the scores obtained from the survey, the majority of students agreed that the balance of the theory, simulation and project was the best approach for teaching the course. An interesting observation came to light in that students did not have a clear second preference among the theory-focused approach, the simulation-based approach or the project only based approach.

5. Discussions and Conclusions

Undergraduate engineering education continues to be a balancing act between theory and practical applications. Alone neither is an effective teaching method but require a blend of both to ensure preparing students to pursue either advanced degrees or professional practice upon graduation of a four year program. Advances in industry simulation tools all too often allows one to forget how important a foundation in the fundamentals is to ensuring correct setup and interpretation of the results of simulation based design of machine components. We believe that theoretical analysis, numerical simulations and projects are coherently related and inseparable for a DME course but must be balanced through careful presentation of theory, homework assignments, numerical simulation and projects. The theory and theoretical analysis is the foundation for mechanical component design. Simulation tools such as FEA are merely a numerical version of the fundamental theories. Conducting a modern, industry relevant design project is the implementation of the fundamental theories with the numerical simulation tools to achieve a given specification based on a perceived need. Therefore, we believed that the integrated approach, that is, the blending of theory, simulation and project work should be the approach for teaching most design related courses.

During fall semester of 2013, we feel we were successful in implementing a balanced presentation of the theory, simulation and project based work in the Design of Machine Elements course, with a majority students supporting this approach. The following summarize the end of semester student surveys:

- The 80 percent of students strongly agreed that the design project should be required for the course. 98 percent of students strongly agreed or agreed that the project should be required.
- The main reasons cited by students to support the projects in the course were that projects allowed them to implement what they learned; the implementation of knowledge gained in the projects helped them to have better understanding of what they learned, and projects would help them for future jobs and helped to builds leadership and communication skills.
- The 69 percent of students strongly agreed that the introduction of the FEA simulation should be a required item for the course. 96 percent of students strongly agreed or agreed that the introduction of the FEA simulation should be a required item for the course.
- The main reason for supporting the introduction of FEA in the course is simply that "It is used in the industry, we should know how to use it."
- The 91 percent of students agreed that the faculty's efforts were successful in providing an optimization of the theory, simulation and project and it was the best approach for teaching the course.

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