AC 2007-1413: SENIOR PROJECT COURSE ENHANCEMENT

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Senior Project Course Sequence Enhancement

Abstract

Curriculum changes implemented to enhance the Mechanical Engineering Technology (MET) BS degree curriculum have brought about distinct differences in the methodology of teaching the Senior Design Project course sequence. The previous course sequence required a senior project course that spanned two semesters for the undergraduate student. The students sought out an advisor who offers a choice of senior project problem statements that most often require a team of 3 or 4 students to complete. The first semester of the senior project required the students to research the problem, submit weekly memos, midterm report of findings, and a final project proposal. After advisor input and approval the second semester concluded the project with the design documentation and often the manufacturing of a device to satisfy the design problem.

This course sequence is probably similar to many engineering or engineering technology degree programs which offer the students a capstone project simulating a workplace experience. There are inconsistencies in this experience, because each faculty advisor may have different level of expectations, amount of contact with the group, and degree of instruction of design principles. The change implemented at Michigan Technological University (Michigan Tech) is a course to replace the first semester of senior project called Product Design and Development (PDD).

As the prerequisite to the one semester Senior Project course the PDD course is required of senior students. The students are still required to seek out an advisor and team members. The difference is that the students attend a regularly scheduled lab/recitation course to guide them through the design process from problem identification through the final project presentation stage. Topics including total quality management methods, Quality Function Deployment, design selection matrix, material selection, analysis, robust design, design for “X”. Additional design process tools are taught in the context of the senior project, and students are able to apply the tools learned in lecture activities during the lab with their senior project group.

The pedagogical challenges, advantages, disadvantages, as well as student reaction to the senior project course sequence will be discussed in the paper. Actual examples of senior projects from 2006-07 semesters will be presented as examples to illustrate the outcomes of the recently redesigned curriculum sequence.

Introduction

At Michigan Tech, the School of Technology (SOT) is home to six Bachelor of Science Degree Programs; Computer Network and System Administration, Construction Management, Electrical Engineering Technology, Industrial Technology, Surveying Engineering, and Mechanical Engineering Technology (MET). The SOT is one-sixth the size of the College of Engineering in which the majority of the university’s approximately 5,500 undergraduate students are enrolled. The MET program is an ABET-accredited program and enrolls the most students of any SOT program—approximately 200 students. The SOT started offering Baccalaureate degrees in 1994 and recently stopped offering Associate's Degrees. This administrative decision was based partly on the desire to not compete with what community colleges do best; delivering well-qualified technicians to the workforce. Along with the elimination of the Associate degree option, the MET curriculum was redesigned based on extensive benchmarking of comparable university degree offerings, industry needs, and advisory input. Table 1 provides a summary of new courses added and highlights courses enhanced in the senior project course sequence.

Table 1 Courses Added to the Curriculum in 2005/2006
*** NOTE – Courses in italic/shaded are senior project course sequence enhancements**

Course Number and Title	Course Description	Impact on Program and Students
TE 1010 Technology Computer Applications	*An introduction to parametric modeling and will act as a foundation for additional studies in solid modeling*	*Foundation to parametric modeling. Skill set to be used in following courses.*
MET 2400 Practical Application in Parametric Modeling	*Expand student knowledge of computer modeling techniques, and introduce advanced assemblies and GD&T concepts. Investigate advanced concepts available to the designer.*	*Intermediate course critical to all program concentrations. Provides student with skill set not previously integrated into program*
MET3600 Applied Thermodynamics	Introduction to engineering thermodynamic principles. Topics include, work, heat and temperature, pure substances, closed and open systems, first and second laws of thermodynamics, power and refrigeration cycles.	Heat Transfer and Thermodynamics divided into two stand-alone courses. Both utilize state of the art thermo science lab.
MET4200 Design of Experiments	This course provides basic knowledge required to develop statistical experiments to improve quality of process and products. Taguchi experimental design techniques are used.	Changed from elective course to required, as a result of Industrial Advisory Board and positive feedback from employers of our graduates.
MET4300 Applied Heat Transfer	An introduction to heat transfer principles. The course covers conduction, convection and radiation heat transfer mechanisms. Practical applications include thermal insulation, heat sink and heat exchanger design.	Heat Transfer and thermodynamics divided into two stand alone courses. Both utilize state of the art thermo science lab.
MET4460 Product Design and Development	*A treatment of design and development issues such as design for manufacturing, prototyping, industrial design, and customer needs. Presents integrated methodologies that examine marketing, manufacturing, and cross-functional teams. Includes concurrent engineering and projects utilizing CAD systems.*	*This course is designed to precursor to the capstone experience utilizing the tools mastered during the students course work. Students organize a team, and meet with an advisor to review the preliminary design concepts, embodiment, and proposed detail documentation of design solution for their senior project.*
MET4550 Computer Aided Manufacturing	*Course designed to apply techniques used in parametric modeling and student design courses to produce machine code and manufacture components utilizing CAM methods.*	*Course added and deemed critical by employers, Industrial Advisory Board and Students. Course required for concentrations in Manufacturing and Computer-Aided Engineering*

MET4580 Facilities Planning, Layout and Process Flow	This course works through the basics of site selection, plant layout, disaster control, energy conservation, & pollution abatement.	Course added to round out requirements for new Industrial Technology Degree
MET4590 Production Planning and Control	This course studies activities associated with both service sector and manufacturing activities required to forecast, schedule & determine functional requirements to produce a product or service.	Course added to round out requirements for new Industrial Technology Degree
MET 4600 Computer Aided Methods in Thermal Sciences	This course makes extensive use of modern computer based tools to solve problems in fluid mechanics, heat transfer and thermodynamics**.**	Course added and required for concentration in Computer-Aided Engineering
MET 4660 Applied Finite Element Analysis	Comprehensive use of both computer derived solutions and experimental validation of analytical and finite element solutions using methods such as strain gages, photoelasticity and brittle coatings.	Course added and required for concentration in Computer-Aided Engineering
MET4670 Senior Project	*Completion and evaluation of design projects using computer-aided engineering methods, physical models, and/or prototypes. Evaluation and design optimization methods for efficient and cost-effective designs. Oral/written report and comprehensive exam.*	*This course is designed to be a capstone experience utilizing the tools mastered during the students course work. Using design and build tools the student fabricates a concept and competes in a yearly university competition.*
MET 4780 Advanced Manufacturing Processes	*An introduction to advanced manufacturing processes, both traditional and nontraditional. Study of both theory and practice will be tied to laboratory experiments utilizing a spectrum of unique materials and methods.*	*Added to bolster the concentration in Manufacturing. Student is introduced to advanced methods utilized in a modern manufacturing facility.*
MET4900 Alternative Energy Systems	This course studies conventional and emerging energy sources. Conversion methods are discussed in terms of their long term viability, based on technical and political factors.	This course was added to build a concentration in Fluids & Power Systems
MET4999 Program Evaluation and Certification	*Course designed to review and evaluate the program objectives linked with industrial partners and accreditation body. Focus given to preparing the student to take CMfgT Exam*	*This course was added to provide an evaluation model for program continuous improvement.*

At Michigan Tech the present MET degree has three focus areas that students can choose electives during their junior and senior year which are: Manufacturing, Computer Aided Engineering (CAE), or Fluids and Power Systems. Courses in the curriculum which serves as prerequisites to Senior Project courses are ***Practical Applications in Parametric Modeling*** and ***Integrated Design and Manufacturing***, which focus on practical aspects of design and manufacturing incorporating CAD/CAM tools. These courses prepare students for the CAD and CAM skills necessary to model and manufacture parts required for production during the senior capstone experience. Table 2 illustrates the finalized MET curriculum program requirements with the manufacturing concentration.

Table 2 Finalized Curriculum
*** NOTE – Courses shaded are senior project course sequence enhancements**

B.S. Mechanical Engineering Technology (Manufacturing)					
		Year #1 - Semester #1			**Year #1 - Semester #2**
			PH	1110	Physics I
UN	1001	(Gen. Ed.) Perspectives on Inquiry	PH	1100	Physics Lab I
MA	1032	Data Functions & Graphs	UN	1002	World Cultures (Gen. Ed.)
CH	1100	General Chemistry	MA	1140	Technical Calculus I
TE	1010	Technology Computer Methods	EET	1411	Electronic Divices
		Gen. Ed. Distribution			1/2 credit Co-Curricular (PE)
		Year #2 - Semester #3			**Year #2 - Semester #4**
UN	2001	Re-Visions I (Gen. Ed.)			
MET	2120	Statics and Strength of Materials	MET	1540	Materials Science
MA	2140	Technical Calculus II	UN	2002	Institutions
PH	1210	Physics II	MA	2720	Statistics
PH	1200	Physics Lab II	MET	2130	Dynamics
BA	2300	Accounting Principles I	MET	2400	Practical Applications in Parametric Modeling
		Year #3 - Semester #5			**Year #3 - Semester #6**
MET	3250	Fluid Mechanics			Gen. Ed. Distribution
MEEM	2500	Integrated Design and Manufacturing	MET	3600	Applied Thermodynamics
MET	3242	Machine Design I	EET	3131	Instrumentation
EC	3400	Econmic Decision Analysis	EET	3700	Electric Power, Machinery & PLC's
		Gen. Ed. Distribution	MET	3450	Machine Design II
		1/2 credit Co-Curricular (PE)			
		1/2 credit Co-Curricular (PE)			
		Year #4 - Semester #7			**Year #4 - Semester #8**
MET	4460	Product Design and Development	MET	4670	Senior Project
MET	4200	Design of Experiments	MET	4780	Advanced Manufacturing Process
MET	4400	Manufacturing Simulation	MET	4999	Program Evaluation/SME Certification
MET	4550	Computer Aided Manufacturing	MET	4500	Lean Manufacturing

As a capstone experience at Michigan Tech, senior year MET students from each of the focus areas are required to complete a team-based senior design project. Students progress through a two semester sequence starting with ***Product Design and***

Development (PDD) presenting integrated methodologies that examine marketing, manufacturing, and cross-functional teams including concurrent engineering and projects utilizing CAD systems, and ending with a ***Senior Project*** course including evaluation and design optimization methods for efficient and cost-effective designs requiring an oral/written report and comprehensive exam. In the capstone sequence the student teams first generate the design, optimize the design and document the design. Then, during the last semester the teams plan for production, manufacture and assemble components, and test their design using the skills acquired through the computer-aided engineering and manufacturing related courses taken in earlier semesters.The ***Program Evaluation/SME Certification*** course adds a much needed element to the degree adding to the program an overall assessment measurement of the effectiveness of the curriculum.

Enhancement Rational

The rationale for the curriculum enhancement has been communicated to Michigan Tech from our industrial partners. These companies approached higher education to say, "We need the super engineer—one that can **design, develop, *and* manufacture** using today's technology." The Society of Manufacturing Engineers (SME) supports their assertion (Society of Manufacturing Engineers, 2002) [4]. Also, the National Association of Manufacturers recently identified critical key competency gaps in graduating manufacturing engineers and technologists (Deloitte, National Association of Manufacturers and the Manufacturing Institute, 2005) [2]. These gaps indicate U.S. engineering technology graduates have a poor understanding of manufacturing processes and principles.

The curriculum enhancement started with an extensive benchmarking of similar BSMET programs around the nation. Site visits were conducted to 2-year College ATE centers around the United States, including the National Center for Manufacturing Education (NCME) located at Sinclair Community College and the Florida Advanced Technological Education (FL-ATE) Center at Hillsborough Community College. These visits have reinforced the strengths of what two-year college programs have to offer in Manufacturing Technology. Also, a site visit to the certified Haas Training Education Center at Rock Valley College was conducted to evaluate the CNC equipment and personnel qualifications that are necessary for a CAM laboratory.

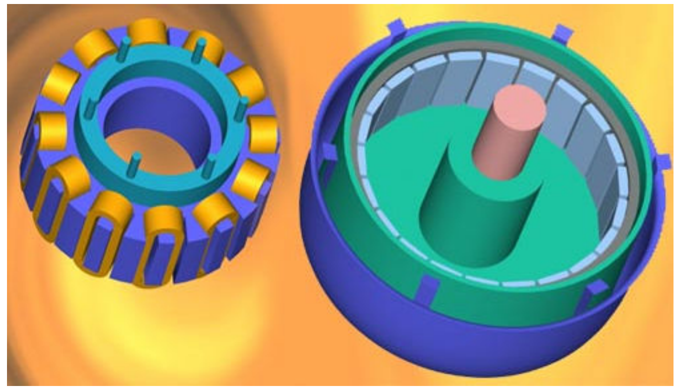
Super Engineer to Design and Develop

In order for MET students to "design" they must possess certain prerequisite skills in today's technologically advanced world. One key skill is the ability to create parametric 3D models that can be utilized throughout the design process from conceptualization through to the detail drawing stage. Software companies such as UGS (developer of Unigraphics NX) and Dassault Systemes, (developer of CATIA) are integrating computer aided design, engineering and manufacturing capabilities into one product solution. In this new technology, instead of a traditional drawing, a single solid model geometry file is the master component that drives product design. This "Master Model" concept promotes collaboration between engineers, technicians, and production workers. As identified in the Manufacturing Engineering publication (Waurzyniak, Patrick, 2003) [6], in recent years CAD/CAM developers have continued to add more functionality aimed at machining solid models, high speed machining, automatic feature recognition, tool path verification/simulation, and estimating job costs. Students are introduced to these advanced CAD, CAE and CAM products through an introductory course in ***Technology Computer Methods***, intermediate course called ***Practical Applications in Parametric Modeling***, and a ***Computer Aided Manufacturing*** course. These courses prepare students with the computer skills to carry out the laboratory requirements in the capstone senior project sequence.

The PDD class has the following goals; to provide the engineering student with a broad realistic understanding of the design process, stress the importance of the connection between design and manufacturing, and provide an awareness of the accelerated influence of computers in design. In this course students choose their design project presented by a faculty adviser. The following is an example from the 2006-07 fall/winter semester:

"Off the grid" Property Irrigation System (one or more students)

Design and fabricate an irrigation pumping drip system for installation in remote areas of property where a water source is available, but could be sparse due to dry weather patterns. The system must run without access to conventional electrical power. This is a modification to an existing design where 2 Solar panels (3 amp & 1.5 amp) are presently being used to charge 12 volt batteries to run submersible pumps to feed water from a small stream up in elevation to additional pump stations to distribute water to planting beds. The modification on the existing design must add functionality in the rate of flow, shut off regulation, self regulating valves and monitoring devices, and most importantly be manufactured using readily available materials and at a low cost. The design will require a step-by-step procedure for manufacture, maintenance and safety for possible distribution as a "do-it-yourself" kit for area landowners.



During the fall semester the project was initiated by defining the problem, gathering information, generating concepts, creating product architecture, configuring the design, applying parametric principles and finally detailing the design. During the Senior Project course a student team will finalize the design by fabricating and testing a wind powered generator.

Super Engineer to Manufacture

The previous MET curriculum included a machining course, which is no longer part of the curriculum. During the curriculum revision process, the machining course was dropped because the intention of the MET program was not to provide skilled machinists—instead, the goal was to provide engineering technologists skilled in hi-tech machining and manufacturing evaluation capabilities. Additionally, with the degree program growing in size it became increasingly difficult to offer an intensive hands-on introductory laboratory class to 50 new students every year. With the elimination of the machining course, manual lathes and milling machines were also removed.

So, without a manual machining course, the challenge in the curriculum design was how to create experiences for students to learn manufacturing processes and principles. The ***Advanced Manufacturing Processes*** and the ***Computer Aided Manufacturing*** (***CAM)*** courses utilizing CNC capable mill and lathe machines were added to fill this gap. This CNC laboratory (presently under development), combined with the new course curriculum also allow Senior Project students to complete the manufacturing portion of their designs. In the past, MET senior projects were outsourced outside the college for manufacture, which does not support the experiential learning approach sought after in this curriculum enhancement project—an approach that has been shown to enhance student learning (Albanese, M. A. and Mitchell, S., 1993) [1].

Product Design and Development (PDD) Pedagogy

The ***PDD course*** is a 14 week 3 credit one semester course consisting of 2 hours per week recitation and 2 hours per week in lab. The course progresses through the design process as related through the Engineering Design textbook, (Dieter, 2000) [3]. In the recitation students solve problems individually and as a group. Course materials outlining the chapter information are provided to the student via the WebCT online course management system in the form of Power Point slides, reference web sites, and examples to problems. The lab section is provided for students to work as a group on their senior weekly progress. Progress on the senior project is monitored by weekly memos and scheduled group meetings with their faculty advisor. These meetings are outside of regularly scheduled class time and are vital to the success of the project to ensure that the original intention of the project is maintained. The students in PDD reach the course goals through practice and application problems related to the following competencies:

- **Identify the steps required in the design process, and adopting team behavior and tools objectives.**

Here students formulate their senior project team, choose a senior project and advisor, choose team roles, and study the steps required in the design process. Usually teams consist of 3-4 students to optimize the time on task for the work to be completed during the semester. Students complete a peer evaluation of each team member at the completion of the semester to encourage all students to participate equally.

- **Adhere to the requirements of project need identification and problem definition, and perform gathering information tasks.**

At this stage the students have selected their senior project, but they need to become more familiar with the needs and customer requirements. Lab sessions include a trip to the library and extensive searches for technical papers and internet sources related to their topic. Classroom problems are presented relating to creating a Product Design Specification, a Quality Function Deployment (House of Quality) analysis to determine the level of importance of customer requirements.

- **Be sensitive to embodiment design theories.**

Senior project groups had come to a consensus as to the general concept for their design, and now sketches and general dimensions were presented. In the lab section the solid modeling software was used to create parametric models that could be used throughout the design sequence able to changed and updated when necessary. In recitation the students studied poor examples of designs and proposed solutions to designs that they found to be cumbersome to manufacture or assemble. This discussion lead to an assignment to produce a "Design for X" analysis related to their design encompassing design for manufacturability, assembly, and the environment.

- **Apply concept generation and evaluation principles.**

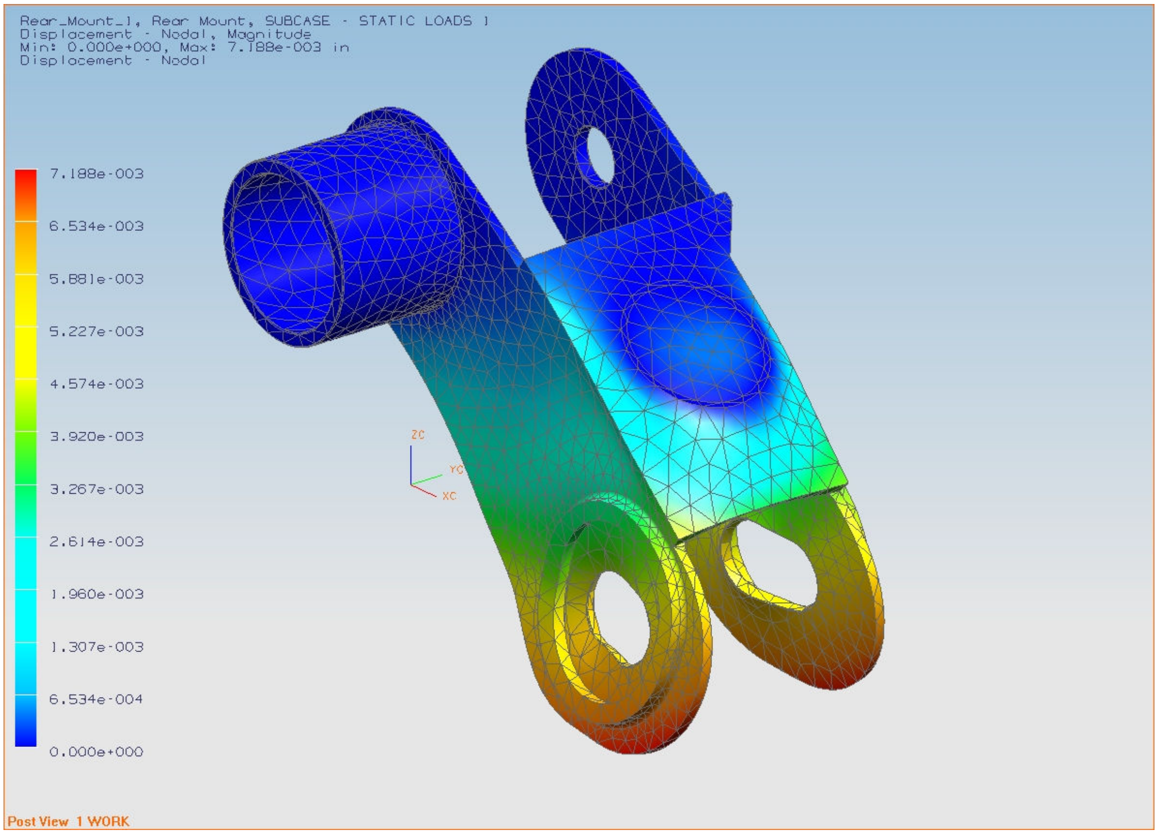
Some classroom activities used to assist students in learning to generate new concepts in design included breaking down commonplace products, (i.e. Stapler, clock, flashlight) into their component parts and creating physical and functional decomposition diagrams. This opened the students' minds to think in terms of function rather than physical parts related to their designs. Morphological charts and Pugh's concept selection were used to generate, compare, and evaluate design concepts. Table 3 is an example of a Morphological chart used to generate concepts for the irrigation system project.

Table 3 Morphological chart

FUNCTION	CONCEPTS		
Prevent clogging of pumps	screen filter around pumps	cover pumps completely	
Prevent clogging of tubing	more powerful pumps	tighter seals and screened output	
Prevent backflow into well	backflow valves		
Utilize all of pump's capacity	only operates with full well	dig deeper well	find new well location
Prevent overflow when water abundant	alarm when full	automatic shutdown	overflow reservoir
Automate	timer valves/float valves/windmill	windmill charges battery/rest is manual	windmill/central control box
Easily maintained	lightweight/easy to teardown	weatherproof/leave up in the winter	
Charge batteries	more solar panels	use windmill to charge extra batteries	
Repel mosquitoes from reservoir	screen over reservoir	cover completely	
Provides correct voltage	automatic voltage reduction	more powerful pumps	

- **Apply modeling and simulation techniques.**

Now that 3D models were created the students were able to begin creating parametric assemblies of mechanisms that were required for their designs to be analyzed for kinematics and dynamic related properties. If the design consisted of structural members under load simulation software was utilized to calculate finite element analysis (FEA) related to components. Other projects required students to analyze weight, thermal, and/or fluids calculations.



- **Determine material selection and materials in the design, and analyze materials processing in design.**

In recitation, textbook problems related to the physical, mechanical, electrical, thermal, chemical, and fabrication properties of materials were discussed. Web sites were used to assist in determining the types of materials that would best suit the design requirements in the student projects. Solid models were modified based on the production process decision made for each component of the designs to illustrate tubular bends as apposed to welded joint construction for example.

- Sub-frame Materials
  - 5’ 1.00” x 0.035 4130 steel tube x $2.52 per foot = $12.60
  - 8’ 1.25” x 0.049 4130 steel tube x $3.48 per foot = $27.84
  - 6’ 1.25” x 1.25” x .065 mild steel square tube x $1.85 per foot = $11.10
  - 9” x 12” x .125” steel plate x $24.30 ea. = $24.30
  - 9” x 12” x .070” steel plate x $17.00 ea. = $17.00
  - 9” x 12” x .048” steel plate x $13.60 ea. = $13.60

- **Utilize engineering statistics in the design process, calculate risk, reliability and safety in a design, and integrate robustness and quality in the design process.**

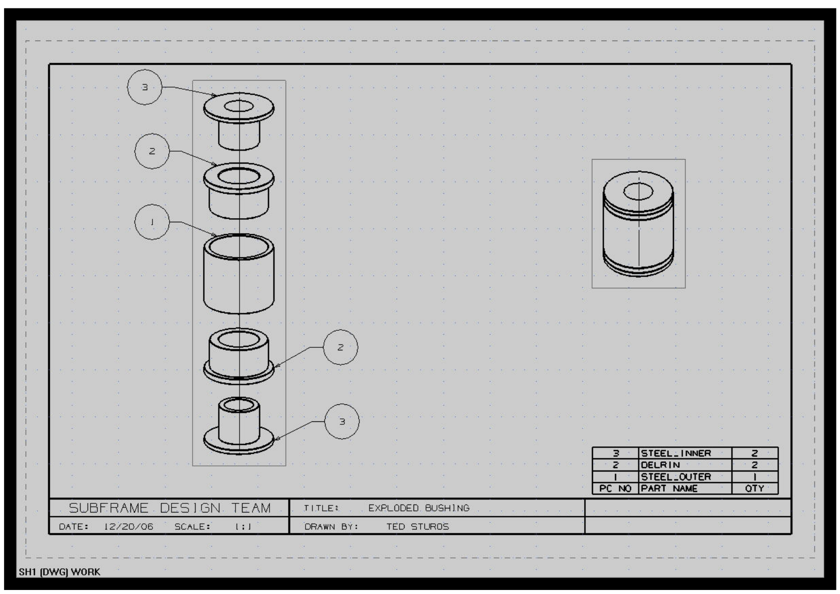
Statistics are the working tool for engineers, which students are required to study in a prerequisite course. This section requires students to calculate statistics related to data collected during analysis and testing. Also, a Failure Modes and Effects Analysis (FMEA) is performed by each student team to aid in the design of their product to plan for possible failures due to user or part malfunctions.

- **Determine economic decision making factors, evaluate the cost of a design, and debate legal and ethical issues in a design.**

Students in recitation solve cost analysis problems related to industry situations involving determination of the cost of materials, manufacture, and production of a product to determine a suggested selling price. Also, students are challenged with scenarios involving calculating costs incurred during manufacturing to determine what type of tooling, cutting tools and/or processes to use in designs. During the lab the teams also prepared a budget for their senior design projects and placed orders for material and stock items.

- **Create detail documentation of a design.**

Included in the prerequisites for this course is a complete understanding of parametric modeling software capable of generating associative drafting layouts of components and assembly drawings. During the recitation, students were challenged with calculating hole and shaft fit tolerance calculations, interpretation of geometric tolerance callouts, and calculating assembly tolerance stack-up calculations. Preliminary assembly and detail drawings required for the manufacture of the senior projects were created in the lab session.



- **Communicate a design to colleagues.**

Students were presented a review of using presentation software, communicating a design concept orally to a group, and creating a written technical report. During the final week of the course, the student teams each presented a Power Point presentation and submitted a report of their findings along with a set of preliminary drawings of their designs.

Results

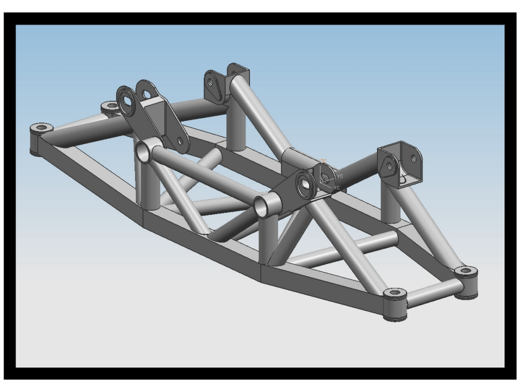
The PDD course was evaluated based upon student participation in classroom discussion/problem solving, individual solutions to design problems, timeliness and quality of senior project team tasks counting towards 50% of their grade. The remaining 50% of the student's grade was determined by exams, the group presentation, and project report. Thirty students were enrolled in the 2006-07 fall semester PDD course, which consisted of about 8 separate senior project teams.

The PDD students were surveyed for their course satisfaction, and perception of the course content. Formative evaluation results obtained via an informal student satisfaction survey resulted in very positive feedback. Students felt very prepared to participate in the second part of their senior project sequence even though some students indicated that not all team members participated equally in the project tasks. The University student course evaluation survey during the Fall 2006 semester yielded an average overall score of 4.6 on a scale of 5 being highly satisfied..

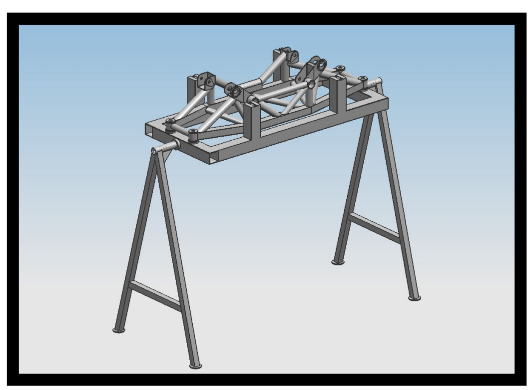
Senior Project Course

The senior project students are assigned to advisors as part of their professional faculty obligation, and not counted towards faculty load. Advising senior project students is advantageous for the faculty to facilitate research opportunities, technical publications, and professional presentations. Two projects presented during the 2006-07 fall semester were the irrigation system mentioned earlier in this article and a rally car rear sub-frame design project. The rally car rear sub-frame was a redesign of the factory installed original equipment manufacturer (OEM) part made by Subaru Corporation. The design of the sub-frame was made more robust handle the loads on the mounting points sustained during of-road rally racing. The student team designed, analyzed, and manufactured the sub-frame design also requiring the design and build of welding and machining fixtures for production. Some of the results from the project are shown in the following figures and tables.

Sub-Frame



Sub-Frame & Welding Fixture



Pugh's Concept Selection Matrix

Criterion	Concept 1	Concept 2	Concept 3	Concept 4	OEM Sub frame
Manufacturing Cost	-	-	-	-	
Manufacturability	-	-	-	-	
Easier to Install	+	+	S	+	
Easier to service	+	+	+	+	
Easier of Repair	S	-	-	S	D
Easier to adjust alignment	+	+	+	+	A
Unibody to sub-frame movement	+	+	+	+	T
Structure stiffness	+	+	+	+	U
Appearance	+	+	+	+	M
Weight	S	S	S	S	
Fatigue resistance	S	-	-	-	
Wear resistance	S	-	-	S	
Sum +	6	6	5	6	
Sum -	2	5	5	2	
Sum S	4	1	2	4	

Concept 1 Round 4130 tube frame with delrin mounting bushings
Concept 2 Round 6061 T tube frame with delrin mounting bushings
Concept 3 6061 T6 aluminum plate frame with delrin mounting bushings
Concept 4 Box 4130 tube frame with delrin mounting bushings

Discussion - Advantages and Disadvantages

The PDD and Senior Design course sequence presented many advantages over the traditional two semester long senior project course, but there are some disadvantages not to ignore. Research tells us those learning activities which recreate work situations foster better transfer of learning (Swanson & Holton, 1999) [5]. The plain advantage of the sequence is that students are mentored and instructed in design process steps at the same time as applying these skills to a real project. Many times capstone curriculum projects rely heavily on the prerequisite material from earlier courses that students may have stored in short term memory and have since forgotten, because they did not have an opportunity at the time to apply, evaluate or synthesize that information. This design allows the student application of the information during the lab session while working on senior project tasks. The faculty member for the PDD course is in constant communication with the design teams, which is advantageous in keeping track of student progress. One of the problems with the two semester senior project sequence was that it was too loosely supervised and students tended to procrastinate until the last few weeks in the semester.

The PDD course like most new courses has some disadvantages or challenges that need to be overcome in the future. The amount of information and complexity of tasks to be accomplished in 14 weeks of a 3 credit course is very intense. The students were rushed from one week to the next and at times were unable to meet required deadlines. There was at least one group where not all students divided the work evenly, and the other team members complained about having to do extra tasks to make up for their lack of participation. The courses have been changing over the past two years and not all students in the senior project course had the same prerequisite courses. So as a result, some students were not able to operate the CAD and CAE software necessary to document and analyze the 3D models. The software in the School of Technology was changed from IDEAS to Unigraphics NX within the past two years so students were required to transition their modeling skills.

Conclusions and Recommendations

The consistency in the development of the senior design tasks leading to the manufacturing and testing phase overwhelmingly outweighs the disadvantages in the curriculum sequence. The successful results from the 2006-07 PDD and Senior Design courses speak for themselves to illustrate the advantage of guiding students through the design process in an experiential learning atmosphere.

In the future it would be an improvement if advisors met on more of a regular basis with their groups during the PDD course, because it is very difficult as the faculty member for the PDD course to oversee up to 8 groups of students. Also, it would be helpful to have a portion of the student grade determined by the individual advisors based on their senior project groups' memos and meeting participation to encourage students to attend the regular advisor meetings. The Senior Project class is in need of a standardized set of instructions for students to follow as they progress through the manufacture and testing phase of their project. Presently, the requirements for senior project course are determined by the advisor, which vary depending on the project. This leads to an inconsistency of student outcomes.

The preparation of students for the senior project sequence has been optimized by the changes taken place in the curriculum. Specifically, the inclusion of courses in CAD, CAE and CAM have made it possible for students to design, develop and now manufacture their designs, which previously were outsourced to machine shops. In the future an increased emphasis on project management scheduling software may assist in keeping student groups on schedule to complete necessary tasks. Also, efforts are in the works for updating the CNC and material fabrication capabilities and equipment at the Michigan Tech School of Technology labs, which is necessary for the senior project sequence success.

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