A *CORNERSTONE* FRESHMAN DESIGN EXPERIENCE

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Abstract
In 1997 a major overhaul of the introductory experience to Mechanical Engineering at Florida Tech was initiated. The purpose of this overhaul was to develop an experience that would serve to: (1) prepare students for the ME curriculum, (2) motivate students to complete their studies, (3) provide students with academic success skills, and (4) introduce students to the engineering profession. The format chosen to realize this goal is a yearlong sequence of two courses that freshman take entitled Introduction to Mechanical Engineering I (MAE1022 Fall, 2 credits) and II (MAE1023 Spring, 1 credit). This sequence is a project-motivated experience inspired by traditional capstone design courses. In the fall students are taught basic academic success skills such as time management, study skills, working in study groups, self-motivation, and goal setting. Next, a major team-based design project is assigned. This is immediately followed by an introduction to basic design theory and methodology including brainstorming techniques. Students then learn the skills they need in order to complete the design: computer-aided design via Pro/ENGINEER, basic machine shop skills, generating dimensioned production drawings, project management including timelines and Gantt charts, project budgeting, and documentation. The major assignment in the fall course is the design proposal that each team prepares. In the spring course student teams complete their designs, fabricate functioning devices, and demonstrate these devices to the campus community.

Introduction
The reconstructing of the Introduction to Mechanical Engineering experience at Florida Tech was motivated by a recognition that more could and should be done for our students. It was decided early on that a traditional introductory course that provides an overview of ME technical subject areas was not desirable. Such an overview approach does not serve the needs of the freshmen students nor does it prepare them for their future course work. These technical topics are most effectively covered in detail in the traditional engineering sciences courses (e.g. statics, fluids, thermo). Instead, a thorough

review of the state of the art in pedagogy [1-23] identified some basic themes that would be adhered to in formulating a new Introduction to Mechanical Engineering experience. These themes are evident in the following citations that had a profound influence on the outcome of this effort:

- ***"Lead the participants from a relatively dependent status to as independent a status as their competency warrants" (NSF Research Experiences for Undergraduates Site Program 03-577).***
- ***Marshall Lih, then Director of NSF's Division of Engineering Education and Centers, wrote in ASEE Prism [7] "engineering schools should help students develop the following leadership traits- knowledge, know-how, judgment, and character" and "that engineering curricular should be eclectic and integrative".***
- ***In 1997, the Deputy Director of NSF Joe Bordogna in "Next-Generation Engineering: Innovation through Integration" [2] stated "Participating in the entire concurrent process of realizing a new product through integration of seemingly disparate skills is an educational imperative."***
- ***"Sink or Swim" is on its way out and we are in the process of a shift from that paradigm to one of "student development." Engineering colleges all across the nation are revising their freshman year curricula with the primary goal of enhancing student success. R. B. Landis, "Studying Engineering: A Road Map to a Rewarding Career" [21].***
- ***NSF Sponsored Chautauqua Short Course by Prof. Landis (May 1998). Goal: "To develop and document an Introduction to Engineering course designed to enhance student success by addressing five primary themes: community building; professional development; academic success strategies; personal development; and orientation to the university and the engineering program."***

These themes have lead to the development of a curriculum that is based upon providing a foundation ***cornerstone*** design experience to first year students. This cornerstone experience lays the foundation for the engineering sciences and the capstone design experience of mechanical engineering students. The course objectives are to produce students that: (1) are motivated to pursue their chosen educational and professional goals (2) have a working knowledge of who an engineer is (3) have an appreciation of the various engineering disciplines (4) have a working knowledge of the engineering design process (5) can plan and manage design project teams (6) can prepare a written engineering project proposal (7) can prepare and present an oral and written engineering project report (8) understand the concept of features based solid models (9) can conceptualize, create, and build simple 3D geometries with a focus on mechanical parts and assemblies (10) have a working knowledge of and ability to perform basic machine tool manufacturing operations (e.g. drilling, milling, turning, finishing) and (12) have an understanding of the relationship between detailed drawings and manufacturing processes. ***The course is structured as a project motivated learning experience modeled after traditional capstone design courses***. Students are assigned to teams, write project proposals, generate design concepts, perform analyses, generate detailed production drawings, attend design reviews, and manufacture functioning physical prototypes. Currently, the project is the ASME Student Design Contest. Moreover, throughout the experience focus is placed upon the success of the whole student. As the process gets underway students recognize the need for learning design theory, computer-aided design, machine shop skills, project & time management, technical writing, etc. As the students recognize these needs they are taught to them in a "just-in-time" fashion. Efforts are made to integrate the course schedule with the capstone design schedule such that interactions between the first and senior year students are maximized.; e.g. design reviews, machine shop access, project presentations These interactions facilitate knowledge transfer from seniors to freshman and the youthful energy of the freshman serves to motivate the seniors. The remaining sections of this document present the implementation details of each of the courses as well as the relationship and effect this new sequence has had upon the remainder of the ME curriculum at Florida Tech.

Intro to ME I: The Fall

The format of this two-credit course is that there is a common lecture of 50 minutes each week and lab sections (limited to 16 students) that meet on Tuesdays & Thursdays for 75 minutes each. First we discuss the Wednesday common lectures. The first 6 weeks are spent covering the first five Chapters of the Landis text [21]. The topics include: academic success skills, study skills, an introduction to the engineering profession, an overview of the engineering disciplines, time management, self-awareness and enlightenment, and ethics and professionalism. The next four weeks are devoted to an introduction to engineering graphics with a focus upon sketching techniques, orthographic views, 3-D projections, and dimensioning and tolerancing via [22]. The subsequent week's lecture is devoted to the presentation of the major course design project. The remaining four weeks provide an introduction to design theory and methodology utilizing [20].

In the fall the semiweekly lab sessions are lead by graduate student teaching assistants as well as campus technicians. The first week is devoted to acclimating the students to the many varied campus' computing resources. The next week is for assuring student competency in word processing and spreadsheet applications for technical report writing. For the following six week period the lab sections are split in half- with half of the students going to the student machine shop to be trained on basic machine shop measuring (e.g. calipers and micrometers) and tool operations (e.g. mill and lathe) and the other half of the students remaining in the computer lab to learn Pro/E. After three weeks the groups exchange locations. Next the sections resume meeting as a whole in the computer lab for three additional weeks of computer-aided drafting and training. Upon completion of these six weeks students are capable of generating solid models, assemblies, dimensioned production drawing, and are able to manufacture piece parts. Next, two weeks are devoted to learning MatLab; basic engineering computations, plotting, and writing functions and scripts are covered. The semester ends with the students working on teams to complete a two-week measuring, drawing, and manufacturing exercise in which small teams of 2 or 3 students are assigned a small mechanical assembly of 4-6 parts to reproduce. They must then measure each of the parts, generate cad models and dimensioned shop drawings for each, and must manufacture all of the parts.

Intro to ME II: The Spring

The format of this one-credit course is a weekly common lab session of 3 hours duration. The first lab session is devoted to providing feedback on the design proposals that were submitted at the end of the fall semester. The remaining weeks of the semester are devoted to assisting the student teams with their projects. This assistance takes many forms: common lecture style sessions to the entire class, meetings with whole project teams, and meeting with individual team members. Throughout the semester the progress of each team is monitored closely via- the team website where weekly progress reports are posted, weekly time cards submitted by each team member which detail all effort devoted to the project, and two formal design reviews. Approximately four weeks before the end of the semester the teams make design project presentations of their designs to the class. These presentations are formal and a working demonstration of the design is required. The semester ends with completion of the design project and submission of a formal written design report.

The Design Project

Since 1997, when the revision of the introductory mechanical engineering experience began, the design project has been the ASME Student Design Contest (www.asme.org/students/Competitions/designcontest/index.html) or a project based on the contest. The competitive nature of the ASME contest serves well to motivate the students and also serves to introduce them to their professional organization- ASME International. The few times the exact contest has not been used are when, in the author's opinion, the contest's level of difficulty was inappropriate for the freshmen students. In these cases a simplified version of the contest was created. In the middle of the fall semester students are assigned to project teams of 4-6 members. Students are assigned to teams to maximize diversity among team participants. The measures of diversity used include: academic strength, gender, ethnicity, machine shop experience, cad experience, as well as personality types as all students in the course take the Keirsey Temperament Sorter II (www.advisorteam.com/temperament_sorter). The fall project assignments are: to select a team leader, to conduct formal brainstorming sessions and generate design concepts, to undergo a formal design review, and prepare a formal written design proposal.

At the beginning of the spring semester the heavily commented design proposals are returned to the project teams. Teams are provided a nominal budget of $30 from the Dept. that they allowed to supplement with another $30 via donations- students are not allowed to fund their own projects. Teams may solicit an unlimited amount of material donations to their projects. Team members are told of the requirements for the completion of their projects: to create and maintain a team website that has weekly progress reports posted, each team member must submit a formal time sheet that has been signed electronically by their team leader stating *who, what, when, where,* and *why* for all of their project efforts for the week, a formal oral design project presentation is required from the team near the end of the semester as well as a formal design project report. Grading is based as follows: websites (10%), progress reports & timesheets (15%), oral design presentation (25%), written design report (25%), and performance of the design (25%). The performance grade is objective and is solely based upon the team's score per the ASME Student Design Contest scoring formula- the top team receiving a perfect score. A heavy emphasis is placed throughout on project management, budgeting, and production drawings. No physical hardware (e.g. raw materials or piece parts) may be purchased until completed production drawings for all piece parts to be manufactured have been completed.

Integration of Design Across the Curriculum

This curriculum greatly facilitates the integration of meaningful design experiences across the curriculum in that it produces sophomore year students that have the basic skills and experiences necessary to manage and execute design project teams. These skills are easily drawn upon in other engineering courses with minimal effort required of the faculty. At Florida Tech these required design courses include: *Solids Modeling and 3D Mechanical Design Principles* in the sophomore year, *Design Methodologies and Practice* in the junior year, and *Mechanical Engineering Design I & II (capstone design)* in the senior year. Moreover, design experiences are now facilitated in courses that are more traditionally "engineering science" courses such as: *Statics, Dynamics* and *Thermodynamics* in the sophomore year.

Demonstrated Reduction to Practice

This curriculum has been taught at Florida Tech since 1997 and results have exceeded expectations. ***Student retention from the freshman year to the sophomore year has risen from a low of 82% to a high of 97%***. This success further motivated and facilitated the integration of design throughout our curriculum. For example, two additional new required design courses were created and adopted: *Solids Modeling & 3D Mechanical Design Principles* in the sophomore year and *Computer-Aided Engineering* in the junior year. These courses have also been very successful in furthering our efforts to have meaningful design experiences throughout our curriculum.

The first author has taught these courses exclusively since 1997 except for the 2002-2003 academic year when he was on sabbatical leave and the third author taught both courses. Enrolment data for the course is shown in the table below. This data reflects students that received a letter grade in the course- save the most recent data (Spring 2004) that is based solely upon official enrolment in the course.

Academic Year	Intro I (Fall)	Intro II (Spring)
1997-1998	39	35
1998-1999	53	46
1999-2000	30	26
2000-2001	32	29
2001-2002	41	36
2002-2003	46	48
2003-2004	64	58

Meeting the Changing Needs of the Engineering Profession

It is widely accepted that today's engineering student must have a meaningful design experience as part of their formal education. Traditionally, this need has been met with a single capstone design experience. However, the engineering education community (ABET Criteria 2000) has concluded that an isolated capstone design experience fails to provide such an experience. **How can you have a meaningful capstone design experience when no foundation cornerstone has been laid?** By providing first year students with an introductory cornerstone design experience a proper foundation is being laid and the students are well prepared and motivated to learn the engineering sciences and design. Furthermore, once they reach capstone design the students benefit from the strong foundation provided to them in their cornerstone design experience.

Adaptability in an Affordable & Effective Manner

This cornerstone curriculum can easily be implemented in an affordable and effective manner in that it leverages existing and ongoing efforts in each program's capstone design experience. By utilizing the resources already available at their institution for capstone design, educators can implement this curriculum without having to overcome significant administrative or logistical challenges. Hence, the potential for widespread adoption of this curriculum is very high.

Closing Remarks

In revising the Introduction to Mechanical Engineering experience at Florida Tech we have created a two semester long sequence that is structured as a project motivated learning experience modeled after traditional capstone design courses. The new sequence has proven to be a success at Florida Tech and our hope is that similar experiences can be created at other institutions. It is important to note that the success of the course would not have been possible without the support of the entire mechanical engineering faculty and the administration of the College of Engineering. Moreover, implementing this freshman experience has required the coordination of several campus resources including- technicians, computer labs, the Mechanical & Aerospace Engineering Department's (MAE) support staff, and the student machine shop. However, it is important to note the costs involved in providing this experience are minimal. Finally, we believe that freshman must be provided with a meaningful design experience so that they are well prepared for a curriculum that has design integrated throughout. And, we believe that a cornerstone design experience is an effective means of achieving this goal.

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