Integrating Design into the Entire Electrical Engineering Four-Year Experience

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Abstract

This paper shares the experiences from an undergraduate curriculum refinement involving integration of design contents in the entire four-year Electrical Engineering program. The implementation of the refinement can be described by four mottos: *start early, be persistent, open more fronts, and cap with a peak.* The integration of design at certain years, such as the freshmen year or in capstone senior level projects have been studied by many researchers. However, the refinement of EE curriculum with the integration of design component in all EE courses with emphasis on the overall design experience for capstone project is a transformative approach in EE undergraduate education. This paper presents the details of such integration throughout the adapted curriculum for all the courses. Such refinement may provide a national model for possible adaptation by other institutions around the nation.

The collected student survey data for the past five years (2013-2018) is presented to validate the effectiveness of the approach and the resulting students' satisfaction in comparison with their predecessors and with peers in other institutions.

Keywords: engineering education, curriculum design, electrical engineering, capstone design

1. Introduction

An alarm was sounded in 2010 by two influential government reports delivering the following two messages: a) Over 60% of US undergraduate STEM students drop out from their engineering programs [1], b) Many US engineering graduates feel unready for engineering practice and eventually leave the engineering field altogether [2]. The challenges posed to engineering education institutes were to find quick solutions how to recruit and retain engineering students and how to instill in all engineering graduates a sense of pride and a lifelong passion in being engineers.

The correlation between low retention of engineering majors and lack of lower division engineering coursework was well understood even two decades earlier than 2010. The Florida Atlantic University (FAU) freshmen-level Fundamentals of Engineering course, for instance, was developed in 1998, and around that time we believe that most engineering programs around the nation were experimenting with more or less the same issues. There were obvious goals for creating such a freshmen-level engineering presence: direct contact between engineering students and engineering faculty from Day One, introduction and exposure to the various engineering disciplines, and lot of interdisciplinary fun indoors and outdoors design activities. Yet, retention remained low.

It was pointed out that the weakest link of the engineering education experience may lie in the sophomore and junior years [3]. Much engineering design is done in the senior-level capstone design courses. However during the sophomore and junior years, a typical engineering curriculum is packed with courses that are heavy in theory but light in design and hands-on related activities.

Integrating design experience into engineering curricula has been a long standing ABET accreditation concern and an active research subject. A practice-based curriculum “theory meets practice” enhanced by students’ access to advanced manufacturing facilities was created by consortium of engineering colleges, national laboratories and premier US industries named Manufacturing Engineering Education Partnership (MEEP) [4]. A Northwestern University Institute for Design Engineering and Applications (IDEA) integrated multi-disciplinary design methodologies throughout the engineering curriculum, and created a design community to support technology innovations [5]. A multidisciplinary freshmen and sophomore levels design approach called “2D design challenge” was developed at Singapore University of Technology and Design [6]. During a designated term, all courses simultaneously attacked a common multidisciplinary design problem. Students’ perception of their ability to solve such problems was evaluated and assessed statistically. Connecting several Mechanical Engineering core courses, Thermodynamics, System Dynamics and Control, Fluid Mechanics with a common design project was attempted at Rowan University [7]. Each course was divided into multiple modules, each had its completion objectives and milestones. Long term Computer Engineering design projects were reported at [8] - [9]. The former involved the breaking down of traditional course boundaries, and their replacement with a progression of modules, in order to better explore diverse facets of System-On-Chip technology. The latter involved core courses curriculum alteration to assure that students can relate key digital circuit design principles to chips and circuits technologies.

Much has been done to enhance students’ design experience through capstone engineering projects. Promoting practical and real-world projects within capstone design has been an active research topic in engineering education. For instance, at the Colleges of Engineering and Education at San Diego State University a partnership was formed with an organization of sailors with disabilities [10] in order to develop engineering solutions to allow physically-challenged individuals to safely and independently participate in various aquatic recreational activities. Similar NSF-funded approach at FAU was reported in [11]. Systematic approach to the multi-disciplinary design process (see [12]) attempted to answer the questions of what the best way is to teach design and what types of design problems provide excellent learning opportunities.

Much research effort has been devoted to incorporating design into an entire engineering curriculum; see [13]. An interesting approach was reported in [14] involving the University of Wyoming Colleges of Engineering and Architecture, and cross-integration of design activities with an emphasis on capstone design courses covering major areas in architectural engineering. Integration of design contents of engineering core courses and engineering elective courses was studied at the University of Tennessee as reported in [15].

At FAU the motivation to integrate engineering design throughout the four-year Electrical Engineering curriculum was amplified in part by recommendation from the Department's Industry Advisory Board (IAB) and by ABET accreditation reviewers. In the former the importance of engineering design to industry needs was emphasized. More specifically, it was pointed out that there is presently a shortage of entry-level engineers who are confident with analog circuit design, RF and mixed signals and systems and with embedded system design. It was further pointed out that recent growth in software systems and digital solutions must be balanced by hardware know-how. In a recent 2015 ABET visit, the evaluators commented that our curriculum could be greatly improved by providing students with engineering design experience at an earlier stage. Consequently, the EE Undergraduate Program Committee re-examined the EE curriculum and set to integrate engineering design into all levels of the curriculum, including both core and elective courses, as listed in Table 1. In addition, the department has since encouraged students to participate in both hardware and software design competitions both in and outside campus. For instance, at least one engineering design competition took place during FAU Engineering Week every year.

Table 1: List of Courses that Incorporate Design Components

Core Courses	Select EE Elective Courses
Fundamentals of Engineering	Electric Power Systems
Introduction to Logic Design	Intro to Embedded System Design
Introduction to Microprocessors	Photovoltaic Power Systems
C for Engineers	High Frequency Amplifier Design
Electronics I	Intro to Antennas
Electronics II	Electromagnetic Compatibility
Laboratory II	RF and Microwave Lab
Intro to Digital Signal Processing	Renewable Energy
Control Systems I	Biomedical Signal Processing
Engineering Design I	Robotic Applications
Engineering Design II	Digital Design

The idea of introducing engineering design in the freshman year is not new [16] - [18]. The importance of "being persistent" in integrating design to the entire engineering curricula has also been proposed by many researchers, such as [19]. What is emphasized in this paper is that these are all integrated parts of an overall design experience for engineering students.

In the remainder of this paper, let us share some of our experience in incorporating design components into our undergraduate electrical engineering curriculum. The overall effort can be summarized by the following four mottos: a) *start early*, 2) *be persistent*, 3) *open more fronts*, and

4) *cap with a peak*. One section of the paper is devoted to each of the mottos, describing experiences drawn from specific courses. The last section is devoted to analysis of students' satisfaction data.

"Starting early" with freshmen-level engineering and high-school-level pre-engineering activities is by now an almost universal axiom. As a distinction between design competitions that many of engineering students may have encountered in pre-engineering high school activities, the ones conducted in the freshmen level Fundamentals of Engineering FAU course focus on themes such as design tradeoffs, design modifications and adopt-but-adapt. This is described in Section 2.

In order to "be persistent" it is important to include engineering design in the sophomore and junior years. Certain Computer Science and Computer Engineering courses, taken by Electrical Engineers, that require a little less mathematical preparation, courses such as Introduction to Programming, Logic Design and Introduction to Microprocessors, are critical in filling the design gap during the sophomore and early junior years.

Design-rich Electrical Engineering courses, such as Electronics and Control Systems play a major design role during the junior year. Students become exposed to design concepts such as Simulation for design and circuit verification, how to systematically tweak the final design, "divide-and-conquer" as various sub-circuits are tuned, Monte Carlo and Worst Case Analysis, and many more. Design activities at the sophomore and junior years is the topic of Section 3.

"Opening more fronts" strategy is accomplished by introduction of design-oriented senior-level elective courses. The most important ones are courses which directly prepare the students to the quickly looming job market. The design experience that students receive in courses such as Antennas or Photovoltaic Power Systems is already at a level on par with industry. Such design experience, to be fully successful, must open internship doors for the senior students. This type of senior level design is discussed in Section 4.

Section 5 discusses in detail the roles played by the two-semester capstone senior design project courses – "capping with a peak" of design contents.

Longitudinal and comparative assessments, based on EBI survey data of graduating students, described in Section 6, show strong correlation between application of the above four mottos and students' satisfaction, learning perception and graduation. Our Electrical Engineering graduates in the last five years tended to be more satisfied with their design experience at FAU compared with their predecessors and compared with peers in other institutions.

2. Motto 1: Start Early - Design in the Fundamentals of Engineering course

"Starting Early" by introducing design concepts and engineering practice during the Freshmen Year, has been advocated by almost all engineering education programs. Typical papers are [16] - [18]. We chose to share several educational approaches pursued in the FAU three-credit Fundamentals of Engineering course.

Prominent among the goals of the course is the engineering design experience. The course includes multiple team competition projects that vary from semester to semester: Projects such as a construction of a mousetrap car, construction of a solar water distillation device, and more as seems fit by different instructors. Many such projects initially derive from popular pre-college pre-engineering hands-on activities, as can be evidenced by the many web links devoted to the above sample subjects. For instance, most mousetrap car high-school level competitions involve either maximum distance or maximum speed design objectives, and for each type of a construction task there is a vast selection of available web-based audio visual resources guiding every step of the construction. At the college-level however, several design concepts can be introduced in order to make such projects more challenging.

One is that of **design tradeoffs**. The Mousetrap Car Competition may feature multiple equally weighted events – for instance, in one the goal may be to achieve maximum travel distance, and in the other we pair the cars to play a round robin (or elimination) tournament of tug-of-war. No design modifications were allowed between the two events. The two goals totally oppose one another and the students need to think how to compromise the design in order to succeed reasonably well in both events. Figure 1 features the surprise winner of both events in the Fall 2014 course. The design featured a combination of a fishing rod, long spool release and an unusually heavy car body weight.

Another design concept created by the unusual competition rules is that of **adopt but adapt**. It is no longer sufficient to merely adopt a design process provided on the internet. Multiple approaches have to be adopted and adapted to fit into the tradeoff competition theme.

The Solar Distiller project introduces the students to an important global/societal problem of Earth atmosphere greenhouse effect and to the growing problem of dwindling water resources. Students learn to interpret embedded sensory information (in this case a thermometer) as active part of the trial and error design process.

Figure 1: The overall winner of the mousetrap competition, which surprisingly won both events despite the radically opposing event objectives.

Other graded course activities attempted to plant the seeds of what can be viewed as Systems Approach to Engineering. One such example is that of **production planning** using the EXCEL Solver Optimization tool. To many it may seem premature to teach students, most of whom have not yet finished their calculus courses, about optimization. We noted however that by getting a glimpse of what business executives often have to do on a daily basis, may provide the freshmen students with a sense of purpose, especially for the on-going math courses that they take.

Another design concept is that **Simulations are indispensable design tools**. In the course the students were introduced to two common simulation software tools – a) Matlab/Simulink to experience hands-on the simulation of simple systems such as a rotating pendulum, and b) Orcad Lite PSPICE, to work hands on with simple circuit such as charging of a capacitor.

3. Motto 2: Be Persistent - Design Contents in Middle-Year ECE Courses

As is well documented (see [3]), early days engineering curriculum based on having the freshmen and sophomore years to be full of mathematics and other sciences background, was a disaster by creating severe retention problems. Important as it is that new-coming engineering students interact with engineering professors from the first semester, it is equally important to continue that interaction in almost every single semester that follows. Some of this interaction may unavoidably involve electrical engineering courses that are mostly analysis and contain almost no design, such as the first Circuits courses. We argue however that the more design we persistently have the students do the more positive the interaction become. Sophomore level design-rich courses are the Computer Engineering service courses of Logic Design and Introduction to Microprocessors. Both require only an introductory Computer Programming course (such as Introduction to C) as prerequisite and both do not have excessive math prerequisites.

Many junior level electrical engineering basic courses (such as Circuits 2, Electronics 1, Electromagnetic Fields and Waves and Linear Systems) are analysis-rich but typically have very small design contents. This is balanced by having the junior level electrical engineering students pursue electrical engineering lab courses (such as Lab 1 and Lab 2, as we call it at FAU). Other late junior year EE core courses, such as Control Systems 1, Introduction to DSP and Communication Systems have of course significant design contents. In this section, we elaborate on two courses Introduction to Microprocessors (Sophomore or Early-Junior year) and Electronics 2 (Junior year).

3.1 Introduction to Microprocessors

Students in this course learn to program microcontrollers with both Assembly and C languages. The course topics include architectures of microprocessors and microcontrollers, digital inputs and outputs, timers, polling and interrupts, mixed signal systems, and communications. Traditionally, students were asked to complete a number of programming assignments and complete several laboratory experiments. In order to improve students' design skills, the course now features a comprehensive design project involving both digital and analog inputs and outputs. A sample project is shown in Table 2. In a Fall 2014 class exit survey 94% of the students thought that the project was a good idea and that they learned a lot from it.

Table 2: Sample Final Project for Introduction to Microprocessors

This project is a combination of the tasks given in Units 7 and 8 assignments as well as what you have learned in Labs 5 and 6. Connect an LM34 to your microcontroller using the scheme given in Lab 6 (you may change the pin though). Connect a 7-segment display to the pins of your choice (using what you have learned in Lab 5). The 7-segment display is used to display the temperature value measured by the LM34 in binary (^{0}F). Connect an LED to mimic a fan. Connect a switch to the microcontroller too. Write a program in C which achieves the following tasks:

1. Initially the 7-segment digits are all off and the switch is at the off position. The system is in a low power mode (mode 3).
2. When the switch is turned to the on position, the system leaves the low power mode. This step needs to be done using a Port I/O interrupt. For the first 10s, your first and last initials are shown in the 7-segment display.
3. In the active mode, every 0.1 second, the program does an A/D conversion.
4. Every second, an average value of the temperature samples is calculated.
5. The digital value corresponding to the average temperature is displayed on the 7-segment display once the average temperature is calculated. It is assumed that you have calibrated the system in completing the Unit 8 assignment.
6. When the average temperature reading is at a level corresponding to 77 ^{0}F or above but below 90 ^{0}F, a PWM signal (duty cycle = 0.2) is sent to the LED. Test your circuit using your hand to change temperature to above 77 ^{0}F. Observe if the system output is correct (the LED is dim).
7. When the average temperature reading is at a level equal to or above 90 ^{0}F, a PWM signal (duty cycle = 0.9) is sent to the LED. Test your circuit using a heating tool to change temperature to above 90 ^{0}F. Observe if the system output is correct (the LED is bright).
8. When the temperature reading is back to below 90 ^{0}F and then below 77 ^{0}F, the PWM signal changes and then stops. Again observe the corresponding outputs.

Instructions: You need to record test results with a video for each step given above, submit your pin-configurations and code with a Wordpad file, and demonstrate the project using a video link. You MUST demonstrate each step of the project.

3.2 Electronics 2

Design activities during the Late-Junior/Early-Senior period aim in part at preparing students to their senior level lab activities and capstone senior design projects. The sequence of electronic circuits courses, and in particular the second course EEE 4361 Electronics 2 plays a major role in advancing the student a step closer to being confident electrical engineers.

Using an electronics circuit simulator (such as PSPICE or ADS, depending on the instructor's preference) the students have to go far beyond mere circuit verification. Need to use simulations as an active design tool. Students learn how to **tweak their final design** in order to better meet the specifications, how to **"divide and conquer"** a multi-transistor amplifier into sub-circuits that can be tuned separately, and how to run **Monte Carlo Analysis and Worst Case Simulations** to see the impact of parameter variations. They further learn the importance of **buffers** in the design, how any **redesign process** requires a set of **familiarization experiments**, the importance of creating a **cost function** for **comparing quantitatively competing design optionss to a baseline benchmark**, and that nothing comes for free – there are always design **tradeoffs**.

4. Motto 3: Open More Fronts - Design Contents in Elective Courses

Many of the senior-level elective courses begin to cover industry-grade analysis software tools and industry-level design skills that directly translate to the students' resumes with the aim of enhancing students' chances of finding internship positions and consequently engineering jobs. This is one of the fronts that opens up at the FAU EE program. Another front is that of possibly pursuing graduate studies in EE. The better students may enroll in an accelerated BS to MS program, allowing up to three of their senior level elective courses to apply to their MS degree program as well. A third front that is open to the top 5% students is that of the Innovative Leadership Honors Program (ILHP) involving personal guidance by members of the College of Engineering and Computer Science Industry Advisory Board and opportunities for an undergraduate research. Let us elaborate on two design-rich senior level elective courses.

4.1 Electromagnetic Compatibility (EMC)

Most modern digital electronic devices operate with large clock speeds. Hence such devices have to be compliant with the Federal Communication Commissions (FCC); see Title 47 [20]. Students learn the nature of EMC as well as Electromagnetic Interference (EMI). The focus of the course is on the EMC/EMI sources of conducted, radiated and coupling mechanisms and on how to **mitigate the impact** of such effects.

The students are exposed to FCC, European and US Military standards. Hence, they become aware that any device which just operates and functions merely as designed still cannot be marketed in the US without passing **FCC compliances**. EMI mechanisms are introduced theoretically first and then hands-on through team projects. For conducted emissions, a simple line filter or a high frequency capacitor can be incorporated in the product as a remedy. Shielding and Grounding are the approaches to combat the radiated mechanisms. With teams' choices of online free Printed Circuit Board (PCB) layout software and the capability of the PCB fabrication in house, the PCB design is limited to either single or two sided PCB. The university has a good relationship with a neighboring accredited EMC lab, as shown in Figure 2.

Local experienced EMC engineers and PCB design engineers are routinely invited to share their experience and design techniques with the class. This exposes students to **real world situations**.

Figure 2: An Accredited EMC Lab at the FAU Research Park

4.2 Photovoltaic Systems Engineering

The Photovoltaics (PV) course is structured to give students background in solar system design for standalone and grid-tie options. The textbook for the class "Photovoltaic Systems Engineering" was written by an FAU EE emeritus professor. He still maintains tight contact with the department and does frequent guest lecture appearances during the course. The book prescribes steps on how to design small and large PV systems.

The course features team projects with realistic scenarios. The students select solar panels, inverters, appliances, wires, circuit breakers, and deep cycle batteries in which the **specifications** are obtained from the web. Each team has different components and different manufacturers to fulfill the **project constraints**. Two technical reports detailed not only the components but the reasons of choosing those devices. The **cost analysis** and the **return on investment** based on a local energy rates are included in the report.

Since the electrical installation of solar systems must comply with **National Electrical Code** (NEC), the textbook is unable to catch up with the code changes. Another topic which was not included in the textbook but is important to any system installation is to secure a **building permit**. An effective way to get up-to-date codes and information on how to secure the building permit is to invite the company lead design engineer to present the relevant code changes as well as steps to obtain the permits. Fortunately, there are local solar companies in town that often volunteer to share their expertise with the younger generation of engineers. Students can also gain **firsthand experience** through several organized field trips to solar project installations. At the end, students who complete the class should be able to design small to medium solar systems, starting from the beginning until the permit being pulled off. These students are ready to join the solar workforce.

5. Motto 4: Capping with a Peak - the Capstone Design Course Sequence

The capstone design course sequence offered at our department consists of two 3-credit courses: Engineering Design I and Engineering Design II, which are taken jointly by Electrical and Computer Engineering Students.

Engineering Design I covers technical topics such as Interfacing Microcontrollers, Sensors and Actuators, PCB Design, and 3D Printing, as well as non-technical topics that include Innovation and Creativity, Brainstorming, Design Principles, Patents and Intellectual Property, and Oral and Written Communication Skills. The latter topics directly contribute to the engineering program educational outcomes specified by ABET.

Engineering Design I starts with a 6-week mini-project, which prepares students to work with a **multi-disciplinary team,** to complete a specified task using **available resources**. The objective of the exercise is to train the students to practice concepts such as **constraints**, **time management**, **team spirit**, **planning and execution**, among others. An example of a completed project is a "singing ball" which is passed around from hand to hand in a "musical chairs" style until it randomly stops playing music. The person who is caught with the ball is "penalized" to either sing or act in front of the group. Another example is a "lost-and-found" system, which embodies a set of tracking devices that can be used to sound an alarm in order to locate missing items throughout a house. To promote **innovation and creativity**, a competition is conducted as part of the class where students vote on the winning project.

The main focus of Engineering Design I is that of developing a proposal for the main design project. At the beginning of the semester students are asked to engage, for example, with local industry, healthcare professionals, and elderly and ailing people in order to **identify needs** that may be addressed in the senior design. To encourage students to identify real-world issues in assistive technology and to promote **social awareness**, a related assignment is given at the beginning of the semester (Table 3). A number of **brainstorming** sessions are then held to encourage students first to **explore** and then to **narrow down** the topics. Project pre-proposals submitted by the students are reviewed by the instructor against the set of criteria presented in Table 4. Proposals that pass the initial scrutiny are selected for further development [11]. Throughout the semester every team is required to make presentations in order to update the faculty on the progress of their proposals. A final formal oral presentation and a written project proposal are required at the end of the semester. The proposal must contain the **problem statement**, the **rationale** of the project, **market survey**, **alternate designs** and **decision** using a **design matrix**, design details (hardware, software, interfacing, and challenges), **implementation plan** including **deliverables**, **Gantt** and **personnel charts**, and a **budget**. The teams implement their project through the succeeding semester (in Engineering Design II).

Table 3: A Sample Assignment that Promotes Social Awareness

Assignment 1

Propose a design project to help people with disabilities in the following areas:

- Students who have learning disabilities
- Persons who have severe physical or mental disabilities
- Elderly who suffer Alzheimer's and other illnesses

You need to interview with caretakers to get first-hand information on what are needed, what are available in the market, and what you are proposing to do. Provide references for the ideas and devices that you think are worth mentioning.

The format for this essay is strictly required:

- Title and name
- Who have you contacted? Give name and contact information of the person(s).
- Give a statement on the objective of the design, and followed by a description on
- Write a section on what is available on the market.
- Write a section summarizes the functionalities of your design with only verbal descriptions. You may itemize these functionalities.
- References

In Engineering Design II, each team completes the project proposed in Engineering Design I. There are three semester **milestones**, each reached after approximately five weeks. At every milestone, each team delivers a presentation to the entire class to demonstrate its progress to date, emphasizing the challenges and potential bottlenecks encountered. As a guideline, the first milestone sets a deadline for finalizing design **iterations** of both **synthesis** and **analysis**, and for components and other material to be acquired. At the second milestone, every group must demonstrate a working **prototype**, and identify any remaining issues, including **barriers** for the completion of the project. At the last milestone, every project must be completed including a project report, which **documents** all implementation details, including **testing** and **evaluation** results and discussion of future improvements. At this time, all design projects are **demonstrated** to the public, including the IAB and other invited industry observers. Projects are evaluated based mainly on the following three categories: **Creativity**, **Challenge** and **Completeness** ("3Cs").

Questions to help the instructors evaluate students' projects are detailed in Table 5. Such a questionnaire evolved over many years based on input from students, faculty and employers.

Table 4: Evaluation Questions for the Project Selection

- Is the design a result of consultation with someone who will actually use the product?
- Is the design suited to the users' diverse social and physical environments?
- Does the design reflect the technology innovations in the field?
- Is the analytical component of the design sound?
- Is the design inexpensive to produce, purchase and maintain?
- Is the design easy to use?
- Is the design effective?
- Will the eventual product be affordable?

Sample Project 1: A Robotic Hand

A team of students developed a multifunctional robotic hand that mimics movements of a human hand. The data from the human hand is wirelessly transmitted to the robotic hand from anywhere in the world. The design attains the agility of fine motor control to the robotic hand. The hand can be controlled by the patient's small movements. The robotic hand can be useful in such applications such as prosthetic hands, the handling of hazardous materials and surgical implementations. The challenge of this project in terms of implementation was in the integration of mechanical components, electrical components and software, bringing together different competencies. The robotic hand (shown in Figure 3a) was successfully demonstrated with input transmitted via the Internet.

Sample Project 2: An Ankle-Assisted Therapy Device

An Ankle Recovery Device was developed to provide the necessary rehabilitation for an injured ankle. This device consisted of a boot equipped with pressure sensors strapped onto a platform which allowed vertical and horizontal movements for the ankle (Figure 3b). It was controlled by a mobile device which had pre-programmed exercises with varying levels of intensity in order to follow up with the healing progress of the ankle, as well as custom exercises prescribed medically.

Table 5: Criteria for Students' Design (each criterion statement starts with the word "Student")

Understanding of professional and ethical responsibility

- Is familiar with professional aspects of their discipline
- Is familiar with and shows regard for professional and ethical considerations
- Seeks information from sources outside of classes
- Shows understanding of the need for continuing education and professional development

Working knowledge of fundamentals, engineering tools, and experimental methodologies

- Knows and is able to apply math, science, and engineering fundamentals
- Knows and is able to apply experimental and design methodologies relevant to the discipline
- Makes appropriate use of modern engineering and analytical tools

Understanding of the social, economic, and political contexts in which engineers must function

- Shows understanding and consideration of the impact of engineering solutions on society
- Shows understanding of economic, environmental, sustainability, social and political aspects of engineering work

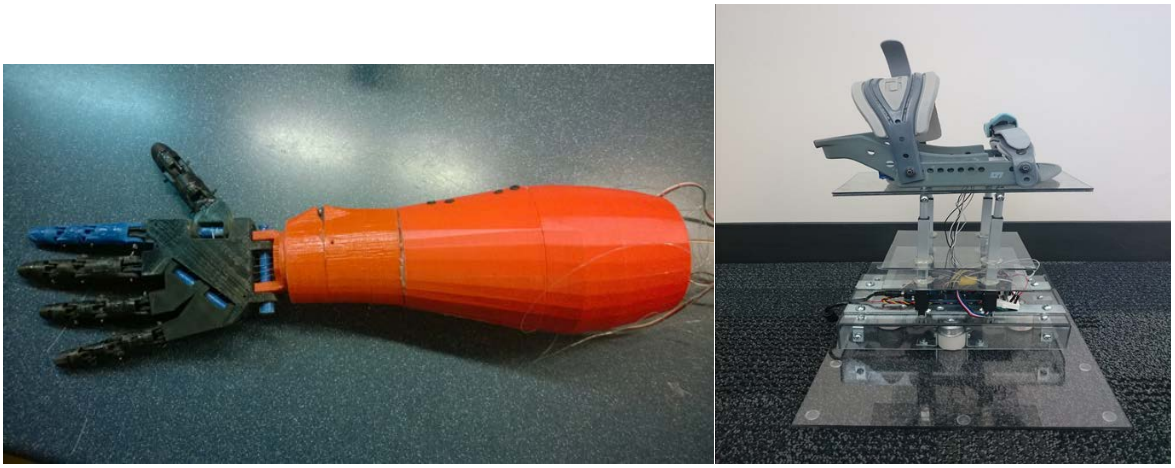

Figure 3: Senior design projects: a) a Robotic Hand, b) Ankle-assisted Therapy device

6. Assessment Method and Results

The degree of success of the methodology presented in this paper was assessed using the Education Benchmarking Inc (EBI) Exit Surveys of graduating students. According to the EBI website [21], the survey questions are highly correlated with the ABET Student Outcomes. The assessment provides data for most engineering colleges in the United States comparatively and longitudinally.

The FAU College of Engineering and Computer Science conducts annually program-level EBI assessments. All graduating undergraduate engineering and computer science students are asked to fill out questionnaires that are provided by EBI online, and rate each undergraduate engineering program. The data is analyzed statistically. There were several benchmark comparison groups: “Select Six” (which included six institutions – Louisiana State, Syracuse, Alabama, UC Riverside, Houston and Toledo), “Carnegie Institutes” (which included 13 institutions (Auburn, Dartmouth, Marquette, Michigan Tech, Mississippi State, Old Dominion, Alabama, Stevens, Texas San Antonio, Dayton and Toledo) and “All Institutions” (46 in number).

Table 6 shows the latest available scores, on a scale of 2.0-7.0. It is clear that the FAU BSEE program does well relatively (compared to the other peer groups). Similar relative information is conveyed by earlier years EBI surveys.

Table 6: Comparison of EBI Scores (2017-2018)

Factor	FAU BSEE	All Institutions
Factor 1: Quality of Instruction	5.26	4.96
Factor 2: Satisfaction: Aspects of Courses	5.38	5.12
Factor 3: Satisfaction: Breadth of Curriculum	4.18	3.93
Factor 4: Satisfaction: Co-Curricular Activities	5.32	5.00
Factor 5: Satisfaction: Classmates	5.36	5.35
Factor 6: Satisfaction: Career Services	4.61	4.63
Factor 7: Satisfaction: Laboratories	5.51	4.97
Factor 8: Satisfaction: Advisor	5.85	5.49
Factor 9: Satisfaction: Facilities	5.62	5.13
Factor 10: Learning: Engineering: System Design and Problem Solving	5.93	5.73
Factor 11: Learning: Engineering: Impact of Engineering Solutions	6.02	5.61
Factor 12: Learning: Engineering: Use of Tools	6.14	5.85
Factor 13: Learning: Engineering: Apply Knowledge and Identify Problems	5.98	5.85
Factor 25: Overall Satisfaction	5.69	5.40
Factor 26: Overall Learning	5.87	5.36
Factor 27: Overall Program Effectiveness	5.74	5.31

For the EBI survey factors a longitudinal analysis performance growth patterns are observed in the Design-related factors 10-13, as seen in Figure 4.

The time of onset of the growth patterns shown in Figure 4 correlates well with the time of deliberate initiation of the "design throughout the four years" strategy.

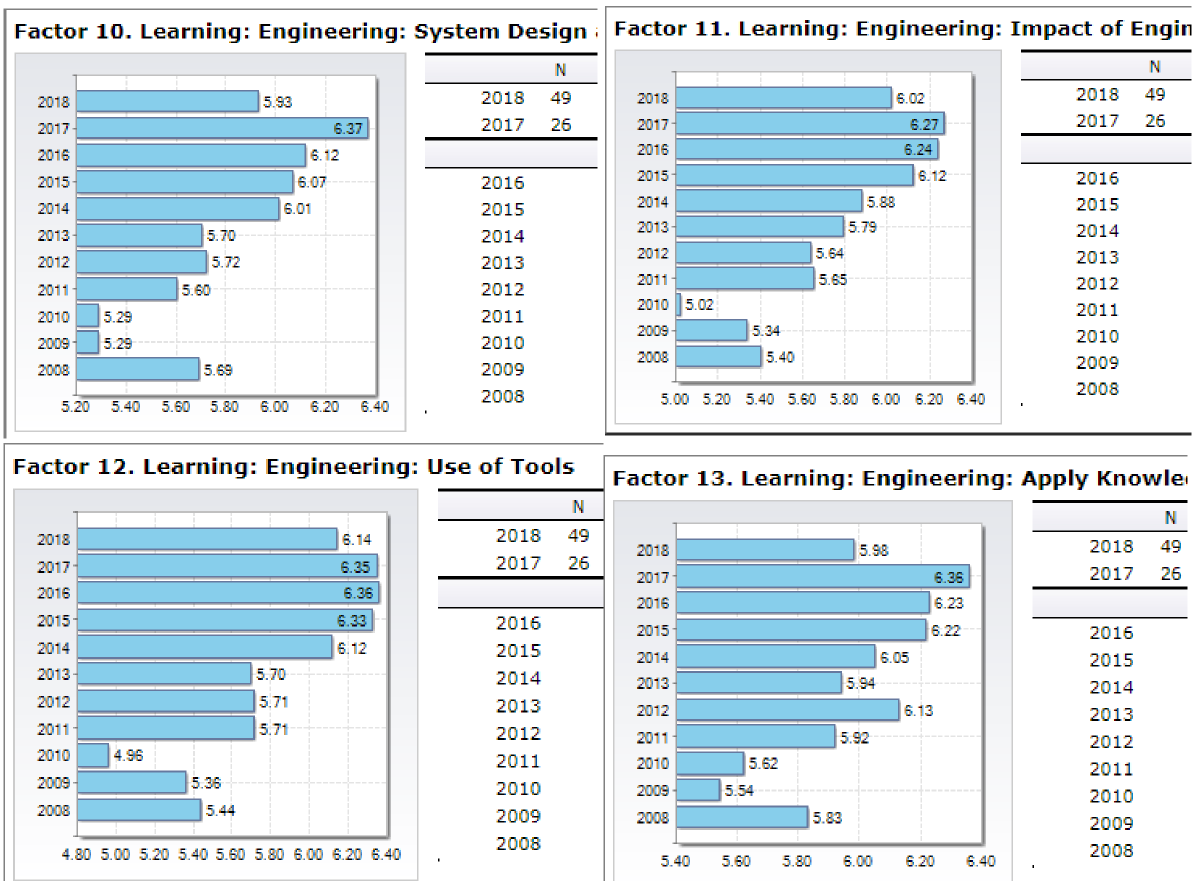

Figure 4: FAU BSEE longitudinal scores in Design-related EBI factors.

There are two possible reasons for the 2017-2018 consistent downwards turn in Figure 4, related to a possible violation of our own third motto about design practices featured in senior level elective courses.

Implementation of industry-like design activities in advanced senior-level courses are often the initiative of individual faculty who teach such specialty courses. It is not easy to train other faculty to become sufficiently familiar with such design activities. Thus whenever such faculty happen to leave the university it may create an elective courses void that may last a long time. In the case of the FAU BSEE program several courses (such as EMI/EMC and Photovoltaic Power Systems mentioned earlier in the paper) have not been offered in 2017-2018.

Another growing trend at the FAU BSEE program is the dramatic rise in the number of EE majors who decide to pursue a Minor in Computer Science. It was discovered two years ago that at FAU, with a proper choice of math electives and technical electives, EE students are able to meet the requirements for a minor in CS without taking any extra credits. A majority of EE student opt to do so in order to open more fronts on the job market. This has been resulting in a sharp decline in the enrollment to many senior level EE advanced electives.

The best that engineering programs must do in order to retain their precious design-oriented advanced elective courses knowledge is to record and preserve an archive of such courses, and to use it to train other faculty who may be capable and interested in picking up these courses.

7. Conclusion

It appears that every motto stated in this paper is critical for a successful engineering program. A direct benefit of integrating design components into middle-year courses is to prepare students to perform better in their capstone projects. For instance, students who do a comprehensive project in Introduction to Microprocessors course, which involves sensors and actuators, are better prepared to tackle more complex design projects in their senior year. A long-term effect of such an effort is to graduate students who not only are equipped with deep knowledge of their field of study but who also are exposed to an array of technological advances.

It is important, however to point out that the mottos advocated here are in no way intended to cover every aspect of a successful engineering education. For one, researchers have long discovered that students need to have solid science background, especially mathematics in order to be successful in engineering schools. Student need to be provided with opportunities to work with engineering practitioners either through internships or in research laboratories. Another important measure to improve engineering education is to help students from under-represented groups to succeed both in school and in employment.

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