"Extended Abstract - Industry-based Strategy for Teaching First Year Engineering Students"

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Abstract - **Most first year engineering courses are taught using a lecture-based curriculum. Some engineering courses are taught using a project-based model. Austin Community College has developed an industry-based approach to teaching the Introduction to Engineering course. The class model is based on developing students as functioning engineers before they exit college by emphasizing interpersonal skills, critical thinking, collaborative projects, and using standard engineering tools of today's industry. It is augmented with industry guest speakers and tours. The study hopes to compare traditional-based curriculum versus the industry-based curriculum as a means to enhance the overall student learning experience and preparation for an engineering career. A further goal is that the college retains engineering students by showing them what it is like to work as an engineer early in their college career rather than waiting until the senior year as in most engineering degree plans. A goal of the new curriculum is to train engineering students to act as practicing engineers so that they are more proficient engineers from the start of their career.**

Index Terms – Industry-based learning, cognitive development, first year engineering curriculum

INDUSTRY-BASED CURRICULUM STRATEGY

The class model is based on:

1. Industry norms in the engineering professions.
2. Project-based learning is incorporated into the class in the form of individual and small group team projects covering a variety of engineering disciplines.
3. Incorporating interpersonal skills through:
   - written and verbal communication in the form of formal business letters, technical reports, oral presentations, etc.
   - teamwork and collaboration in the form of technical projects while emphasizing project constraints
4. Industry guest speakers in two different engineering disciplines as guest speakers throughout the course.
5. Cognitive development in which critical-thinking skills are developed and applied to specific industry-based projects.
6. Students do not need higher-level math and science courses as a prerequisite to the first year engineering course.
7. Teaching an overview of software that is important to the current engineering practice such as Microsoft Word, Microsoft Excel, MathCAD, SolidWorks, etc.

INDUSTRY NORMS

Engineers are expected to be punctual, dress appropriately, communicate well, and solve seemingly impossible problems as a matter of routine. These industry norms are transcending global boundaries as well as the corporate office buildings of today.

Teaching how to work as an effective engineer by example instead of a lecture-based class is a main focus of the Introduction to Engineering course. Students learn the expectations of working as an engineer in industry at the start of their college career rather than after they graduate, where they are expected to act like a practicing engineer although they have not had the training to do so in most degree plans. As students learn the practice of engineering by doing, they are better prepared to enter an engineering career upon graduation.

PROJECT-BASED LEARNING

Most engineering degree plans focus on subject-specific courses throughout the first three years and later focus on design project classes during the last year of study. These senior design classes are meant to accumulate the knowledge from the previous three years into a practical design project that emphasizes teamwork and collaboration to solve a specific industry design problem. The idea of introducing the industry-based design project late in the degree plan is too late to teach and apply the skills that prospective engineers need to use while working in an engineering industry. Waiting until this late in the degree plan causes many students to abandon the idea of becoming an engineer. It is further supposed that many students who would make good engineers leave the practice before they finish their degree. Implementing an industry-based engineering course during the first year in engineering education can reduce the trend of capable students leaving before finishing a degree in engineering. Excellent, higher skilled engineers will also emerge from programs that teach "how to act like an engineer" rather than teaching "how to learn engineering subjects." This distinction is important and can be seen in the 2014 – 2015 ABET Criteria for Accrediting Engineering Programs [1] in which the student outcomes show learned outcomes emphasizing

communication, problem solving, multidisciplinary teamwork, and using modern engineering tools.

Boise State University has successfully implemented this concept into a first year engineering course with their FUSE: First Undergraduate Service learning Experience concept [2]. Student engineers work with members of the community to design, develop, and deliver a design that enables the client to become more independent with the tasks of daily living. The students receive training on how to be an engineer during the first year of their degree plan in a real-world project that helps members of the community.

INTERPERSONAL SKILLS

The stereo-typical idea of an engineer who has amazing math and computer skills but lacks interpersonal skills is abundant in the engineering profession. Engineering companies request that their engineers have skill sets that include communication skills as well as technical skills. The number one requested skill for engineers entering the workforce is communication skills [3], [4], [5]. ABET accreditation also requires communication skills as a student outcome for all engineering degree plans [1]. Effective communication involves both written and speaking skills as well as team collaboration skills. Teaching an engineering class that emphasizes communication skills during the first year of the degree plan will empower students with the proficiencies they need to successfully complete their engineering degree as well as become more successful engineers when they graduate and enter the engineering industry of their choice.

First year engineering classes that emphasize communication help prepare students for future project-based course work and the realities of working as a professional engineer. Assignments in the form of a business letter, executive summary, or formal technical report are examples in which to incorporate written communication into an engineering class. Similarly, technical reports, design project summaries, and project marketing summaries can easily be used to enhance oral communication skills.

WORKING WITH INDUSTRY

Students respond well to hearing from industry guest speakers rather than all lectures from a professor during a class. Bringing industry volunteers into the classroom reiterates the topics covered by the professor in a practical manner. Students also get to hear about specific career options within a given industry, working norms in the profession, education or professional licensure requirements for an industry, etc. Guest speakers also expose students to specific career options within a given industry, working norms in the profession, and education or professional licensure requirements for an industry among other things. A student's networking skills are also increased by using the industry guest speakers as a contact for a possible internship or job upon graduation. Tours of local manufacturing facilities with industry volunteers are another way to enhance student learning through a practical application of the topics discussed in the classroom. Showing real-world applications of engineering problems in the local community strengthen a student's knowledge and drive to learn more about the profession.

COGNITIVE DEVELOPMENT

When learners are aware of their ability to understand and control their own cognitive processes, their metacognitive (or simply put knowing about knowing) skills increase. These skills are vital to successful engineering practices of professional engineers. Raymond Anthony Dixon presents that there are differences in the use of mental representations between professional and student engineers [6]. Increasing a student's awareness and understanding of their metacognitive skills yields engineers that are better equipped to solve difficult engineering problems in a more effective and efficient manner [7].

Increasing a student's critical thinking skills is paramount to becoming a good engineer. First year engineering courses should encourage students to analyze and look at the world around them as never before. For example, analyzing the design of a typical ball-point pen is an exercise few students have ever done. Analyzing design features, marketing features, costs, materials selection, program timeline, recyclability, and packaging of a ball-point pen enables a student to enhance their critical thinking skills.

MATH AND SCIENCE PREREQUISITES

Engineering students do not need to have completed Calculus or Physics as prerequisites to a first year engineering course in order to learn and implement important skills such as teamwork, good time management, and the critical thinking skills needed to successfully design a product or assembly. David Scott studied this concept in a National Science Foundation funded project to restructure the engineering undergraduate curriculum at Northern Arizona University [8]. The idea of working together as a collaborative team while meeting the project requirements is a skill that will enable engineers to be productive members of an increasingly global engineering industry in today's society as well as in the future. Building on a solid foundation of industry-based learning can actually help a student in their specific technical classes. The technical details will be developed throughout the engineering degree plan, but emphasizing the industry-based learning experience while gaining the technical skills needed will yield better engineers that are ready for a career in the industry of their choice.

There are many types of project-based activities a first year engineering student can perform without

completing Calculus or Physics courses. Team-based design projects such as designing and building structures such as a marshmallow and spaghetti tower, a drinking straw egg enclosure, or a toothpick bridge showcase Civil and Mechanical Engineering. Projects such as designing a Lego Mindstorms robot to perform tasks emphasize Mechanical, Industrial, Electrical, and Mechatronics Engineering. Using CAD software to design a simple part like a metal gasket or computer case can be applied to all engineering disciplines. Learning to effectively use the common engineering tools of the industry while working in a design team enables the students to get a more complete perspective of a practicing engineer. Skills learned in team design projects such as forces, materials selection, teamwork, project management, and the engineering design cycle are applicable skills to any engineering industry.

ENGINEERING SOFTWARE

Long gone are the ideas that tools such as a calculator and a slide rule will suffice in the engineering profession. With the increased computing power and software tools available to engineers today, students must be trained in the use of these tools in order to effectively enter the engineering workforce. Office software such as Microsoft Word, Microsoft Excel, Microsoft Project, Apple Pages, and Apple Keynote is used practically daily in the engineering profession. Mathematics software, such as MathCAD, MATLAB, and Mathematica, is used to model, analyze, and calculate complex engineering equations. Computer Aided Design (CAD) software, examples of which include NX, SolidWorks, AutoCAD, Inventor, Catia, and ProE, use personal computers and work stations to generate three-dimensional data for the analysis, design, and manufacture of engineering projects.

Students must be versed on office, mathematical, and CAD software in order to be effective professional engineers. Expanding a student's tool set to include engineering software is just as important as teaching a mechanical engineer heat transfer and thermodynamics.

COURSE OUTCOMES

The outcomes of the course will be measured by:

1. Having the students take a pre-test and a post-test in the course.
2. Comparing student evaluations in the industry-based Introduction to Engineering course versus the traditional lecture-based course.
3. Conducting a student survey to evaluate the effectiveness of the course and suggestions for improvement.
4. Conducting an industry survey for input of which skills are needed to successfully enter the engineering workforce. Pair the skills provided with the learning outcomes of the course.

SUMMARY

Just as an engineer is a life-long learner, an engineering curriculum can undergo a life-long refinement in order to effectively train the engineers of tomorrow. In order to train engineering students today, an industry-based strategy for teaching first year engineering students should serve as the basis of an engineering curriculum. A focus of an industry-based curriculum emphasizes engineering norms, tools, interpersonal skills, critical thinking, and project-based learning while teaching students to act like engineers starting in their first year of an engineering degree plan. This focus, in turn, should increase the retention of engineering students and add to the number of qualified engineers entering the profession. These engineering students, by having a better engineering education that prepares for the engineering industry from the first engineering class, will become better prepared to solve the world's problems for future generations.

ACKNOWLEDGMENT

It is a pleasure to acknowledge Sarah O'Pella and Tracey Vickery for their discussions and insight.

REFERENCES

[1] http://www.abet.org/eac-criteria-2014-2015/

[2] http://coen.boisestate.edu/fuse

[3] Butcher, David, "5 Must-Have Soft Skills for Engineers' Career Success", *ThomasNet News*, March 18, 2013.

[4] "An A.S.M.E. Research Study The State of Mechanical Engineering: Today and Beyond", 2011, pp 18-19.

[5] Reddy, B. B., Gopi, M. M., and Aneel, Y., "Having Effective Communication Skills are Indispensable for the Successful Career of Engineering Students", IOSR Journal Of Humanities And Social Science (IOSR-JHSS), Volume 11, Issue 4, May - June 2013, pp 20-22.

[6] Dixon, Raymond Anthony, "Experts and Novices: Differences in Their Use of Mental Representation and Metacognition in Engineering Design", Dissertation, University of Illinois at Urbana-Champaign, 2010.

[7] Lawanto, O., "Students' metacognition during an engineering design project", *Performance Improvement Quarterly*, 23, 2010, pp 117–136.

[8] David P. Scott et. al., Systemic Thread-Based Adaptation of an Electrical Engineering Curriculum, NSF Project No. 0343297, Contract period 09/01/2003 – 08/31/2005, work performed at Northern Arizona University.