Problems and Solutions in Internationalizing Capstone Design

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Abstract

ABET is authoritative in US. However, engineers who graduate from an ABET accredited curriculum may not meet expectations in a global environment such as working in an Asian country. Through discussion with collaborating faculty members in 2-year and 4-year US colleges, and in two Asian universities, this paper first attempts to recognize the strengths and differences of engineering curriculums in different countries in teaching capstone design. It is found that a typical US 4-year engineering curriculum trains engineers in a more broad-base, applied science direction, and its Asian counter part focuses more on specialized and pragmatic training. Analyzing the differences and learning from each other's strengths in an effort to internationalize the teaching of capstone design, it is hoped that students trained in different countries will be more adaptable to a global working environment.

Introduction

The main purpose of this paper is to improve teaching of mechanical engineering in higher education, and to train future engineers that are more competitive and adaptable to global working environment. The approach is through discussion and communication, to recognize the current and different practice in different institutions, to identify the strength and desirable practice, and to develop commonly used tools and materials for better and more effective teaching.

It seems reasonable to start the discussion from the educational objectives of engineering curriculum. In preparation for an upcoming ABET review, the following are the educational objectives established by University of Missouri-Columbia, which should be representative for US engineering schools:

1. Students are able to apply the analytical, experimental, and computational techniques to solve engineering problems associated with the design and manufacture of devices, machines and systems;
2. Students are able to synthesize and analyze integrated thermal/fluid and mechanical systems;
3. Students are able to communicate effectively and work collaboratively on multidisciplinary teams;
4. Students contribute to society and the profession through professional activities, and understand the impact of engineering solutions on a diverse and global society and their

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professional and ethical responsibility;
5. Students are able to engage in life-long learning necessary to advance professionally through continuing education and training;
6. Students can succeed in graduate studies in mechanical engineering or a related field if pursued.

Some of these objectives may be emphasized to different degrees depending on the program, for example, the importance in an undergraduate program to prepare its undergraduate students for graduate study. However, all of these qualities are obviously desirable for graduating student engineers to have. The authors will first examine current practices that may be helpful or problematic for achieving these educational objectives. Potential solutions will be presented with each identified problem.

In this paper, differences and similarities in the capstone design courses in different three countries, the United States, China and Korea, are studied and compared. The main consideration is not because capstone design courses have more similarity, or easier to internationalize. It is because capstone design courses can serve as "check points," or calibration tools for different undergraduate curricula.

The authors realize that even when a commonly agreeable set of goals is established, changes will take time. Therefore, this paper does not provide definitive solutions to many questions raised, but merely points to the direction of future effort. Like a previous paper [1], the topics discussed in this paper are just starting points for more future collaboration.

Broader or More Specific Knowledge

With the shift from a "planned economy" to a market economy, more graduating student engineers in China will not be guaranteed a job and assigned to a post. Chinese engineering schools need to offer more broad based programs to produce more versatile engineers because of the jobs available are more varied. Faculty members trained in Russia in late 40's and through out 50's are now retired and replaced by faculty trained in the western world, especially the United States. It seems changes in Chinese engineering schools can be done most easily by simply copying from the best undergraduate curriculum offered in the US. However, after careful examination of the current practices in a few US and Chinese engineering schools, the authors would not recommend such a direct copying. The changes and deletions are not necessary all in the Chinese engineering curricula. There are also valuable course contents current Chinese engineering curricula that are worth preserving, and are valuable to be learned by the US schools. For example, *Metal Cutting Principle and Cutting Tools Design* used to be a typical and standard course offered in the manufacturing major for Mechanical Engineering department of all Chinese engineering schools. Now the division of narrowly focused majors has been eliminated in many engineering schools. Students in mechanical engineering will not have subdivisions for majors or specialties. The cutting tools design course has been eliminated from many curricula. The content of this course is condensed into one or more chapters in a more general course of *Manufacturing Processes*, This is necessary because broader training adds new subjects and the total credit hours in any undergraduate curriculum are limited. An opposite example is the material contained in another typical Chinese course, *Tolerance and*

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Metrology. In our opinion, this subject material should not only be retained but also introduced to US 4-year technology based, or even engineering curriculum. Qualitatively speaking, lacking specific and specialized knowledge can greatly limit the ability of graduating engineers to do quality and in-depth design work. Limited materials related to tolerance and metrology are taught in US engineering schools, most likely in a single manufacturing course. The deficiency is made up by offering professional courses by engineering societies. This is evident, for example, SME, ASME, and SAE all offer *Geometric Dimensioning and Tolerancing*, which is part of the content of the standard Chinese machine design and manufacturing curricula.

Adding new materials to already crowded US engineering curriculum could be a problem. Similar problems appear in Chinese engineering curriculum with the addition of advanced materials, such as FEA, optimization, and mechanism simulation materials to undergraduate curriculum. The authors suggest the development of computer tools to alleviate this problem. A possible approach is to "compartmentalize" the knowledge by developing units of teaching material with associated computer programs. This approach, to some extent, actually has been adopted by some engineering schools. Finite element analysis, for example, can be taught as a unit in the capstone design with an available software package. It can be a whole semester elective course for undergraduates. However, it is probably not possible to cramp FEA, optimization, GD&T, and more specialized subject materials into a one-semester, required Capstone Design course. The development of web-based tools, which includes database functioning as expert knowledge to be retrieved, has been discussed in detail in a previous paper [1]. Our effort is to develop and share this type of compartmentalized teaching materials that can be selectively used in Capstone Design.

Process or System Approach to Design

An interesting observation arises from two different approaches to teach capstone design in Asian countries and in the US, respectively. In the most popular US capstone design textbooks [2, 3, 4], *a process-based approach* is used to teach capstone design and general mechanical design. A commonly used design process description is summarized as the following:

1. Recognition of the need for the design;
2. Collecting information on the state of the art for such a design. Information from similar and competing products, which can be a previous design, is very important;
3. Establishing a set of measurable and quantitative design objectives, using *Quality Function Deployment*;
4. Conceptual design and selection of concept for detailed design;
5. Detailed design and analysis, which can include production of professional quality design drawings, kinematic and dynamic analysis, optimization, cost analysis, etc.;
6. Communicating the design results, which include written and oral presentation of the design report.

Not just in Chinese engineering schools, but also in other Asian engineering schools, *a system-based approach* is often taught and practiced. Is system-based approach for teaching mechanical design acceptable for US undergraduate students? As an experiment, the first author started a new course, *Modular Tool Design* [5], a few years ago at University of Missouri-

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Columbia. The course material is organized in the following subsystem design units:

1. Mechanical system design, this includes machine structure design, jig and fixture design, spindle design. This unit also includes materials in manufacturing process planning and metrology to make up the deficiency in training in these subjects. However, students are assumed to have taken the course of process-based approach to capstone design.
2. Hydraulic system design, this unit includes the review of fundamental laws of fluid mechanics, properties of hydraulic oil and commonly used system components, typical circuits performing different functions used in previously designed modular machine tools.

3. Electrical system design, this unit presents different electrical control system that can be used in a modular system design. Specifically, traditional relay logic control, TTL and VLSI chip based logic controller, PLC and general purpose CNC controllers with application examples are presented.

Students who have taken this course welcome such a totally different approach. In a typical mechanical engineering curriculum in Asian countries, teachers and students spend much longer time in studying sub system design. For example, *Machine Element Design* course will contain a week long project to design a speed reducer in great detail. A jig design project will be included in a *Manufacturing technology* course which not only teaches detailed step by step process planning but also special tool design for the established process. When the students and faculty come to the capstone design, it is more an integration process to pull together and integrate the well studied and by-then familiar typical mechanical systems, such as speed reducers, mechanisms (e.g., 4-bar, Geneva mechanism), shafts, motion transmission elements.

On a more profound level, these two approaches represented the *deductive approach* and *inductive approach* to learning and teaching. From the Macmillan dictionary, the deductive approach goes from the rule to the example. The inductive approach goes from the example to the rule. The process approach to capstone design is closely associated with deductive learning which is based on the hypothesis that all mechanical design can be viewed and practiced as a process. A potential problem associated with this approach is that students do not have enough examples (design experience) to support and verify this hypothesis. They may simply refuse to use the tools developed for the process. System approach is not perfect either. If either of these approaches is perfect, then there will be no co-existence of inductive and deductive reasoning and learning. Clearly identifying these two different approaches can be very helpful in learning mechanical design, and in producing a design quickly and efficiently. Therefore, it seems the best solution to the different approaches is to know their differences, to use them appropriately and alternatively in different design projects, and in different stages of the same design.

With or Without a Prototype Construction

To construct or not to construct a prototype in the capstone design course is also a major difference in practice. This difference exists among US engineering schools. The following are some pros and cons for manufacturing a prototype from the student design:

1. Students can better appreciate their design and the details in their design. Students also feel

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great satisfaction to see their design come to life.

2. Making the prototype requires too much time and resources (machinist assistance, limitation of machine shop conditions, and funding). Also, students may not have enough time to see the finished prototype within one semester. According to a recent survey, few engineering curricula have two semester capstone design [6].

3. Students should not be limited to the manufacturing capability of the school's machine shop. They should be able to design devices much more complicated than those that can be produced by themselves or with the assistance from the staff technicians of their school.

However, in some schools in Korea and Taiwan, for example, a prototype is required. The school and students both contribute to the funding of the prototype. At the University of Missouri-Columbia, the prototyping part in capstone design is optional. Design teams obtain funding from companies suggesting and sponsoring the design project. Departments also contribute to some projects to some extent. It is reasonable to assume, without time and funding constraints, producing a prototype based on the design is desirable. The problem reduces to how to encourage the prototyping with limited resources. The second author of this paper teaches in a 2-year, technology-based curriculum. The first two authors suggest organizing collaboration of students in the 4-year engineering curriculum and the 2-year technology curriculum to produce a prototype. This has been proven possible and beneficial based on limited design cases.

Conclusion

By observing current practices in different engineering schools in different countries, specifically University of Missouri-Columbia representing a 4-year US engineering curriculum, Fuzhou University representing a Chinese 4-year engineering curriculum, Seoul National University of Technology representing a Korean 4-year technology based curriculum, and Linn State College at Mexico, Missouri, representing a 2-year technology curriculum, the authors identified the strengths of different curriculum in different countries. The most important conclusion is that faculty members can learn much from colleagues in other parts of the world. For the common goal of improving teaching in a global environment, there are opportunities for collaboration and learning from each other.

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Biography

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