Teaching and Learning Experiences of Capstone Design Classes

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Extended Abstract

The author taught mechanical engineering design capstone classes three times during the year 2018. The teaching and learning experiences along with brief presentation of these projects assigned during Spring 2018, Fall 2018 and Winter 2019 terms will be discussed in this paper. Technical aspects and ideas behind all the projects undertaken by the group of students will be presented in this work. Course assessment and rubrics will also be discussed. Some of the challenges faced by both the instructor and for the students due to short time span available for this course will be discussed.

As a part of mechanical engineering senior elective courses and a senior capstone course, different projects were initially chosen by the students and approved by the instructor among the many chosen. The intention is to think innovatively to come up with several proposals and ideas for the project following the traditional but iterative engineering design process. The students are required to document the knowledge gained from previous courses they took such as mechanics of materials, manufacturing processes, mechanical design, and finite element analysis using CAE tools to develop conceptual design, final design, analysis, fabrication and testing activities of a mechanical system such as an example gooseneck trailer hitch. Likewise, they are to document the knowledge gaps needed to successfully design, build and test the device. In this paper, the experiences and assessment of these projects is discussed in detail along with presentation of two specific projects on trailer hitch designs. Detailed testing and measurement activities still needed to be completed.

With around 2,000 total undergraduate students who do mandatory co-op in 450+ different companies including the OEMs and their suppliers, UPS, and other health care manufacturers and providers, etc., the academic terms (Quarter system) keeps us very busy. Majority of co-op companies are in Michigan, Ohio and other surrounding states with a few in the Eastern, Southern and Western U.S. territories. Kettering is predominantly an undergraduate institution although graduate programs are available in Engineering and Business Departments. Mechanical engineering department is the largest with over 1,000 students total (> 50% of KU student population).

At our university, 5 different capstone courses are offered. These are in the main specialty areas such as Automotive, Bioengineering, CAD/CAM and Rapid Prototyping, Energy and Environment and Mechanical Systems. Some of these capstone classes are offered twice a year to cover the student population. Each capstone class size ranges from 14 to 25. With number of students of 3 to 4 per group, there are usually 4 to 6 groups in a capstone. The academic term lasts 11 weeks and so effectively the students must complete their capstone project in 10 weeks. Weekly progress of the students work is monitored by the instructor with occasional help from a senior lab technician who ensures that the design ideas are manufacturable. This person also helps in procuring new material and/or to give already available material within the department, and helps in fabrication and testing of the developed device. Limited budget of $250 per group is provided to fabricate a prototype. Students are provided the rubrics and assessment tools used for the final course grade. Some of these are listed below. The total number of points allotted for the course grade was 400.

Expectations and assessment tools used:

- Bring individual (own) ideas for capstone project that are original or improvement of existing designs for discussion in the class
- Brainstorm with your own project ideas and narrow them down to one or two ideas
- Form groups (combination of self-selected with justification and/or instructor selected)
- Brainstorm project ideas of other members of the group and together select two or three project ideas for instructor's input on their suitability
- Select one idea and justify the final project idea for its complexity, originality, etc.
- Project tasks should map in to CLOs listed on the syllabus
- Perform market analysis of the selected project idea
- Document the knowledge and gaps from pre-requisites
- Identify and document the engineering assumptions
- Do preliminary hand calculations
- Draw preliminary CAD drawings and do preliminary virtual simulations to validate the hand calculations
- Develop process chart outlining the different serial and iterative steps in the design process
- Refine the designs and analysis using math and CAE tools
- Develop BOM, fabrication and assembly
- Identify test procedure and physical testing
- Communicate the final designs via design reports and presentations (individual/group – weekly)

Although the above list of activities look long, each group and students within each group are clear about the expectations and course requirements. This ensures to some extent, that the workload is even and every member contributes to the quality and quantity of the project work, and just not engages only in a single activity such as report writing only.

Numerous papers are published in several educational and research conferences such as ASEE and ASME on teaching pedagogy of engineering design and design process. Typical capstone design course requirements are similar to ABET's Engineering Design principles [1]:

- Engineering design process, design stages
- Conceptual designs
- Teamwork, brainstorming, design synthesis
- Proposal writing, project planning, project management
- Engineering Ethics
- Product attributes, design criteria, engineering targets
- Identification of tasks with work load within the group
- Analysis techniques, alternative designs
- Virtual simulation of the final design
- BOM, bill of process, manufacturability, product variations, product quality
- Fabrication of the prototype
- Test procedure and measurement techniques
- Physical testing of the prototype
- Design reports and presentations (individual and group)

In a recent paper, the author presented few examples of senior undergraduate capstone design projects at a meeting [2].