The Benefits of a Final Applied Design Project that Comprehensively Integrates Course Material Content & Concepts

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Abstract

The objective of this paper is to explore the benefits of a final applied engineering design project, which serves to comprehensively integrate the content and concepts of a senior-level course. By integrating course content and concepts through an applied project, the benefits of a typical multi-semester capstone design project are translated to a single course. For this, an upper-level mechanics-track course that is being offered to seniors in the Manufacturing and Mechanical Engineering Technology (MMET) program at Texas A&M University was chosen. The course, titled "Mechanical Design Applications-II" involved the application of the principles of design to mechanical power transmission elements. The final assigned project was to complete the design of all the individual elements constituting the power transmission system that was intended to deliver power between two machines, and to put them together (with certain requirements and constraints). Periodic guidance was offered to the students on a need-basis for this open-ended project. On completion, it was observed that this interactive activity was very well received by the students, and that it clearly exhibited many short-term and long-term benefits in the form of concept and content clarity, problem-based learning, metacognition, and higher-order thinking skills.

Introduction

The benefits of a multi-semester and multi-disciplinary capstone project especially in the context of engineering undergraduate degrees, in terms of student learning is well documented[1-4]. This paper serves to explore such benefits from the standpoint of a one-semester mechanical engineering design course[5-8] in the context of integrating the course material content and concepts. The exercise of capstone design is thus adapted for an applied design project within an upper-level mechanical engineering design course offered to seniors.

Course Details

The course that was chosen was an upper-level mechanics-track course that is being offered to seniors in the Manufacturing and Mechanical Engineering Technology (MMET) program at Texas A&M University. This course, titled "Mechanical Design Applications-II" involved the application of the principles of design to mechanical power transmission elements such as transmission shafts, gears, belts, chains, bearings, brakes, clutches, etc., and the use of technical software packages for efficient iterative design and analysis. The major learning outcomes included enabling the students to apply the concepts, procedures, and data to be able to select, size, design and analyze machine elements for power transmission and other mechanical systems. Note that this course is the last one among a line of mechanics-track courses such as Statics and Dynamics, Strength of Materials, and Materials Design, and that it is a one-semester, three credit course that was typically taken by seniors during their last year.

Project Details

The final applied project that was assigned during this course involved completing the design of all the individual elements constituting a power transmission system that was intended to deliver power from a driver to a driven machine, and to assemble them together while satisfying certain design requirements and confining to certain constraints. In this case, the task specifically was to transmit a certain amount of power from a gasoline-engine (driver) to an air compressor that was used for driving air hammers (driven machine) at a specified power and rotational speed combination. This input gasoline-engine was coupled through a clutch to a gear-set to increase the output torque. The output shaft was then used to drive the crank of a piston compressor which needed to provide the required output power through a keyed coupling. The shafts were supported in the gearbox housing by suitable bearings. As a starting point, a preliminary design sketch/guide[9] of the above details was provided to the students.

Note that though the preliminary design guide depicted a pair of gears as the main power transmission elements, the students were free to choose any machine component if they provided proper justification for the decision. Thus, the major component design tasks of the project involved designing the shafts, the meshing element pair such as gears, belts, chains, etc., appropriately locking these components both axially and radially on the shafts, bearings to hold them in the housing, the housing dimensions, appropriate couplings, the clutch, and any other power transmission elements that are required to satisfactorily deliver power from the engine to the compressor. The students were required to take into account the effects due to material fatigue, stress concentrations, etc. Further, details of the expected duty cycle, the range of temperatures experienced during operation, and the torque-time plot of the output shaft were provided to the students as part of the project statement.

The students had the last one-third of the semester to complete this design project as their final take home exam, and it accounted for about one-third of their grade points. A final project report was required of each student with the following main deliverables:

- Executive summary
- Details and calculations of component design, assembly, and material selection
- Confirming calculations using spreadsheet aids

- CAD drafting of shaft designs
- Final assembly drawing
- Confirm design calculations using a mechanical design software
- Costing estimate
- List of anticipated and encountered issues during the design process

Guidance

Both formal and informal guidance was provided to the students during the course of the semester for successfully completing this design project. In addition to the final project report that was required at the end of the semester, a short preliminary report was required of the student as well – this two-page report was required to include a conceptual sketch of the gearbox housing and its contents showing all the intended power transmission elements that were to be designed, as well as an outline of the procedure and sequence in which the constituent elements would be designed. Further, a copious amount of informal guidance was provided as well on a need basis through one-on-one interactions.

Throughout the duration of this design project, the significance of the non-existence of a perfect design, as well as the non-existence of a single right answer was emphasized. Further, there were a number of instances where the students had to make important design assumptions and decisions (while providing justifications) that significantly impacted the rest of the design. This open-ended nature of the design project highlighted the iterative nature of the mechanical design process as well as forced students to find or assume missing information.

Samples of Student Work

Two representative samples of the assembly drawings that were required from the students as part of their final project report are shown below in Figure 1 and Figure 2. Note that though Computed Aided Design (CAD) drawings of the input and output shafts were required as part of the final report, for the assembly drawings, students were given the choice of drafting it by hand or with the aid of any CAD software, while providing ample information regardless of the method used.

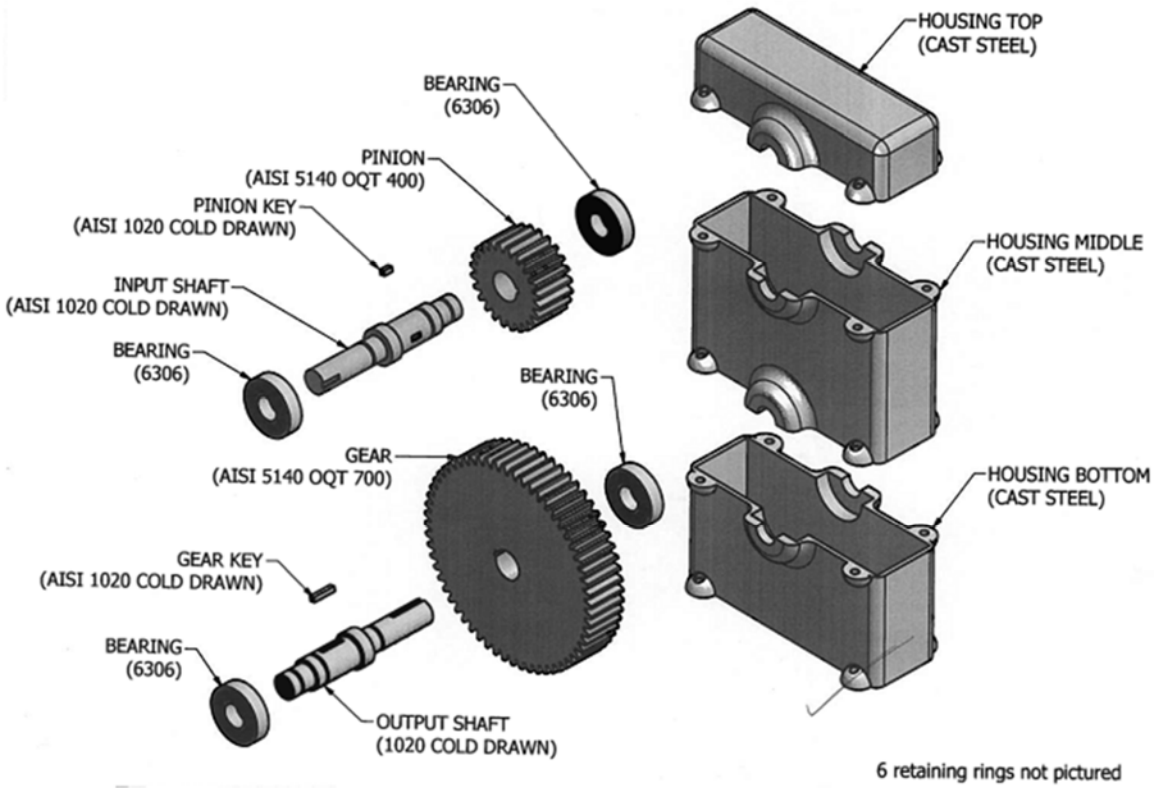

Figure 1: Sample #1 of the assembly drawing drafted by a student[10].

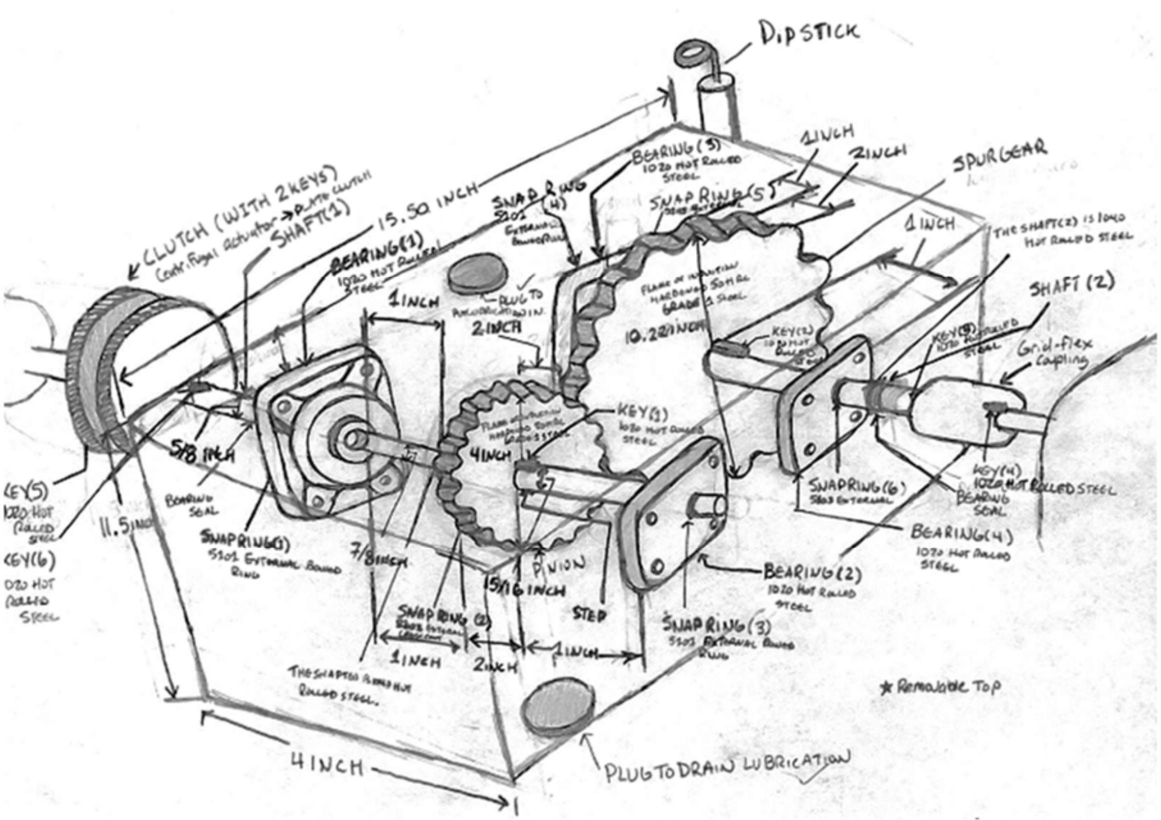

Figure 2: Sample #2 of the assembly drawing drafted by another student[11].

Reception

In general, this project exercise was very well received by the students who willingly took ownership of their designs. Besides exhibiting excitement and enthusiasm, the number of relevant questions and office visits increased significantly. Further, a number of students went to the extent of incorporating out-of-the-box ideas and adaptations to their designs – a clear sign that they embraced the activity positively and wanted to provide a personal touch to their design projects. The reception to this design project was measured in the following manner:

- Informal verbal and written (email) feedback from the students, who voluntarily got in touch with me to remark how rewarding the experience had been,
- Student comments from the official end-of-semester instructor and course reviews that explicitly emphasized their positive experience with the project (samples follow), and
- A significant number of students contacting me the following semester, wanting their graded final reports back so as to retain it for their records, thus clearly showing that they were proud of their work.

A sampling of the student comments from the official end-of-semester instructor and course reviews that exhibit their approval of the project activity follows:

- "The fact that we get to do a major project with everything that we learn and cover in class. It is rewarding to know that we learned all of the material"
- "Bringing all of the things we learned and applying them to the final project"
- "I feel I will use what I learned for my job"
- "Applicable to real life situation"
- "Interesting and relevant coursework, provides a good wrap-up for the 376/363/463 course progression"
- "I love how this class is structured"
- "The design aspects are in depth and show application of all we have learned"

Benefits and Applications

Altogether, this final design project activity was a positive experience for both the students and the instructor, and further, it exhibited a number of short-term and long-term benefits.

On evaluating the immediate benefits, it was evident that this project activity served to assemble and tie together all of the major course material, so as to provide concept structure from the context of designing a mechanical power transmission system. Further, the open-ended nature of the problem, and flexibility in the designs and final solutions, provided a unique learning experience for the students in terms of having to hunt for missing information and then having to make associated major project decisions. It was interesting to note that the freedom that the students had to explore and adapt, through it seemed like a favorable scenario, was in fact a little "scary" for the students. Thus, this design exercise seems to have helped to incorporate some level of accountability and forceful decision-making by an undergraduate student who is typically given very clear guidelines and boundaries for completing a task all though out his/her curriculum. Further, by having to find and select actual standard machine components from local suppliers and other vendors, the students were able to obtain a fair idea of component costing and selection as well. Being from the Manufacturing and Mechanical Engineering Technology (MMET) program, the upper-level students found this design project exercise to be very relevant to their intended (and ongoing) careers. The use of dedicated design software and other design, calculation, and drafting aids also served to make sure that the students kept abreast with currently available technologies as well.

On evaluating the long-term benefits of this design project exercise, the predominant and most evident benefit seemed to be that structured knowledge seemed to help students gain mastery over the subject, and retain the concepts better. Thus, this project helped to effectively tie together all of the major course content, and hence enabled the students to synthesize and apply these concepts towards solving a large design problem. Such problem-based learning introduced and emphasized to the students, the iterative nature of the mechanical design process as well as the iterative nature of general problem-solving and design. Further, operating in an environment where all of the necessary technical information is not readily available, and where a number of conflicting requirements need to be satisfied within stated constraints, gave the students a taste of real-life design scenarios. In all, by the end of the design exercise, the students were able to recognize that they indeed had learned the course content and understood the major concepts, thereby generating a state of metacognition[12] that is beneficial in terms of learning and confidence. Finally, this project activity is thought to have invoked and advanced the higher-order thinking skills (from Bloom's taxonomy[13]) of the students as they had to understand, synthesize, and apply technical concepts so as to create a power transmission system with certain requirements and within certain constraints to successfully complete the design project.

Thus, in the past before the incorporation of the final project activity, this upper-level course predominantly involved the discrete design of individual mechanical power transmission components. Currently, with the advent of the final design project activity, the students are able to complete the design of mechanical power transmission components, assemble them to attain a working and optimized design, as well as address and solve the associated challenges that arise as part of the integration process. In the future, teams will be formed that will brainstorm, design and prototype interchangeable component sets, manage data sets and collaborate over the network, and complete a final working assembly. The assignment evolution is shown in Figure 3.

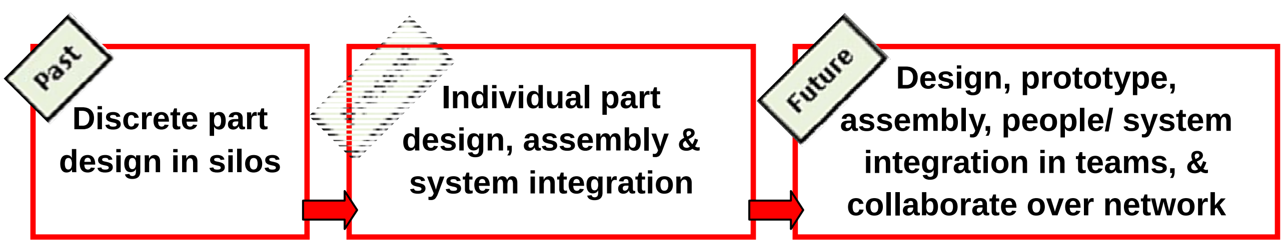

Figure 3: Course objective and activity evolution over time.

Summary and Conclusions

This paper served to explore the benefits of a final applied design project in the context of integrating the content and concepts of a senior-level mechanical engineering design course. By translating the benefits of a multi-semester capstone project into a single course, the students were able to synthesize and apply the learned concepts for creating and solving a large design problem. In addition to receiving a very positive response from the students, many short-term and long-term benefits were realized in the form of concept and content clarity, problem-based learning, metacognition, and higher-order thinking skills. Such an experience that solidifies the need of life-long learning for career sustainability, thus invokes the question whether we as educators need to provide an applied project or activity at the end of every course for a more thorough and rewarding learning experience for our students.

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