A New Special Topics Course in Mechanical Engineering: Invention Case Studies

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Abstract

A new special topics course has been developed for the mechanical engineering program at Mississippi State University. The course content is based on engineering case studies from three focus areas: inventions, ethics, and experiments. The primary objective of the course is to develop professional skills applicable to mechanical engineering practice. In addition to building mechanical design intuition and understanding of basic engineering concepts, the course builds soft skills in the areas of ethical reasoning, technical reading, group discussion, and public speaking. This paper will summarize the inventions focus area of this course and discuss plans to improve the course.

Keywords

Professional Skills, Course Development, Discussion Skills, Inventions

Introduction

Are most mechanical engineering graduates well prepared for a job in the industrial sector? Many would say that engineering curriculums focus too much on analytical skills while industry positions often require clear thinking on ill-defined problems, design intuition, professional skills, and the ability to keep learning. However, teaching these kinds of skills and character traits can be challenging. David Brooks[1] suggests that skills and character traits are learned by practice and by observing the examples of others. A new course has been developed to teach engineering professional skills to mechanical engineering students through a case study approach. Using case studies allows students to practice engineering skills, and to observe good examples to imitate. The learning objectives for students in the course are to:

1. Outline and understand challenging technical documents such as patents, journal articles, experiment reports, technical biographies, and ethical case studies
2. Communicate well in a group technical discussion
3. Explain development of central physicals laws related to mechanical engineering systems
4. Identify the key features in mechanical engineering designs
5. Perform trade studies for conceptual design
6. Perform a reverse engineering study to understand complex engineering designs
7. Apply basic principles for dealing with ethical situations in engineering

The course includes case studies in three major focus areas: inventions, ethics, and experiments. This paper will focus on the portion of the course focused on inventions. Then, a brief discussion of future improvements will be given.

Inventions Case Studies

The inventions focus area of the course is centered around two case studies: James Watt's steam engine and the development of axial piston pumps. Watt's steam engine is primarily studied using a biography, and the development of axial piston pumps is studied primarily through a series of patents. Before introducing these case studies, students are taught some skills to help them interact with the course materials.

Preparation for Inventions Case Studies

Because the reading assignments for this section are challenging to understand, several techniques for analyzing a difficult text are presented. Some example techniques include: marking puzzling words or sections, making an outline, summarizing, asking questions about the author's meaning and using context to answer these questions. During class, students are directed to practice these tools using a 2-page excerpt from the book, *Brave New World* by Huxley[3]. They read the passage and mark the difficult parts. Then, they work with a partner to make an outline, summarize the main point of the passage, and ask questions. Then, the group work is discussed in class.

Group discussion training is another technique that is used to prepare the students for understanding difficult reading assignments. The ability to have an effective discussion is also very beneficial to effective teamwork. Students are given guidelines for group discussions based on the Socratic seminar style discussions as recommended by Chowning[4]. To instill the proper environment a set of discussion norms are presented and explained to the students. The norms used for the course are listed below (adapted from Chowning[4]):

1. Listen carefully to each person's comments.
2. Build logically on other's comments.
3. Address others respectfully.
4. Base comments on text, not merely opinion.
5. Don't be afraid to speak, but be brief.

These norms are easy to understand but the habit of using them is difficult to acquire. Various methods of practice and coaching are used to reinforce these norms in the course. Before each discussion the students are encouraged to choose one of the 5 norms as an individual goal and as a group goal. The group goal provides a great focal point for the instructor to coach the students during the discussion. For example, if the group goal was item 4 in list, then the teacher could respond to an opinion by asking, "where do you see that in the text?" This kind of coaching helps students to stay focused on the group goal and to learn to stay on task. Further, at the end of the discussion the students are asked to discuss how they did on their personal goal and how the class did as a group.

Inventions Case Study 1: James Watt's Steam Engine

The first inventions case study is centered on James Watt's steam engine inventions. James Watt is one of the most central figures in mechanical engineering history. His first steam engine invention (patented in 1769) is considered by many to be the main catalyst of the industrial revolution. Technologies based on his design form a central part of mechanical engineering today. Using readings from a biography by James Muirhead[2], this case study focuses on the circumstances and characteristics that led James Watt to this great achievement. Muirhead's biography is primarily an organization of contemporary accounts from Watt's colleagues as well as from Watt himself. The fact that it is an older publication makes it difficult to read, but these accounts from Watt's contemporaries hold more weight than modern biographies. Watt is an admirable character, and his industriousness and passion for learning are inspiring in these first-hand accounts. Several portions of the biography of about 10-15 pages are assigned to the students for outside of class reading. The students are required to create an outline, summary (or unity), and a list of questions as part of the reading assignment. Figure 1 shows an example of student work for one reading assignment.

1. Watts account on his experience.
   a. Describes his initial acquaintance with steam engines.
   b. Discusses his initial ideas for improvements and noted areas for such.
   c. Discusses his observations of water boiling in vacuum.
2. Watts account on his creation
   a. Discovers the benefits of a condenser.
   b. Determined ways to prevent losses by sealing the cylinder.
   c. Ascertained the specifications necessary for the communication of the two vessels as well as making them work efficiently. (valve cocks, pipe diameter, pump etc.)
3. Harts account on Watts.
   a. Discusses difference between different methods employed in the design of the steam engine.
   b. Discusses Watts specific difference relating to his design.
   c. Advocates that Watt's did not conceal his invention, and that it was his own.

Unity: This is an account from Watts intended to describe his experiences and his invention as his intellectual property furthermore supplemented by Harts account advocating Watt's authenticity.

1. What does Watt's mean by "Non ea nostra voco."?

2. Does Black's credibility suffer because of his insinuation of experiments per p. 72?

3. Why didn't Watt's benefit from all of his improvements, instead allowing some free to his loss?

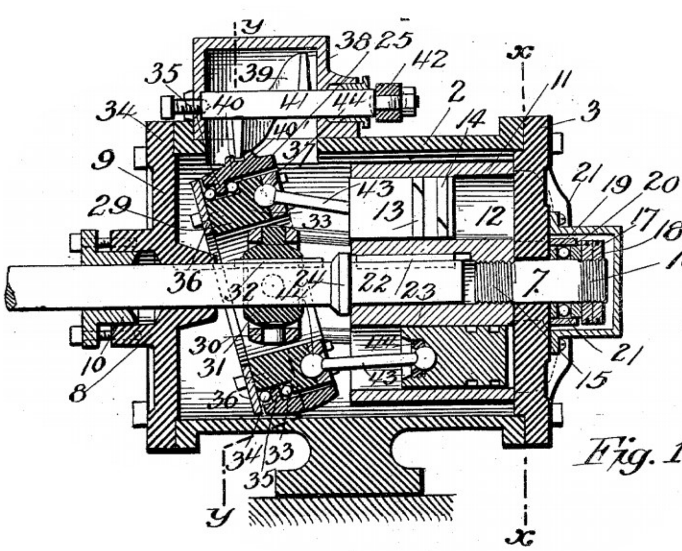
4. Why did Watt's desire to create improve and patent this invention?

Figure 1. An example of student outline, summary, and questions for a reading assignment

After each reading assignment, a class discussion is held. In the first offering of this course these discussions included about 15 students and lasted 45 minutes to an hour. These discussions follow the Socratic seminar style discussed previously. The vision of the Socratic seminar is a group discussion where everyone is seeking to understand a difficult text together. The students are seated facing each other in a circle and are encouraged to do most of the talking, while the instructor acts as a facilitator. The instructor opens these discussions with a question about the central meaning of the text, such as "Why does Watt deserve exclusive ownership of this invention?" Then, students would take turns answering and responding to each other. The instructor would take notes and redirect or prompt the discussion as necessary. After about 30-40 minutes of discussing this main question, the discussion would shift to applications outside the text. Finally, the discussion was ended with the reflection questions mentioned above. The goal of these discussions is for the students to understand the merit of Watt's invention and the personal and intellectual challenges that he had to overcome.

Inventions Case Study II: The Development of Axial Piston Pumps

A second major segment in the inventions portion of the course is a study of axial piston pumps, an important technology in the hydraulics industry. In this section students read and discuss patents and dissect a modern axial piston pump. Like historic biographies, patents can also be difficult to read, but the methods involved are a little different. The first skill that students are taught for reading patents is to create a feature list with explanations of the function of each feature. Students create a feature list for the first axial piston pump patent[5] as a homework assignment. These pumps are quite complex and offer a rich variety of mechanical engineering design insight. An image from the 1893 patent is shown in Figure 2 along with portion of a feature list developed in the class. The feature lists generated in the individual homework assignments are discussed in class, and the class, then, works together to create an improved feature list. Students also create an outline of the device operation. These skills are, then, applied in a project in which students read modern patents on axial piston pumps.



#	Feature Name	Feature Description/Purpose
10	Stuffing box	- in drive head - purpose is to prevent leakage around the shaft
11	Drum	aka cylinder block
12	Barrels/cylinders	aka piston bores ideally there are 6
13	Pistons/plungers	one fits inside each barrel
14	Metal packing rings	purpose to seal piston to barrel interface
17	Shaft locking nut	Used to adjust axial position of the drum with respect to the head
18	Shaft locking nut	Used to adjust axial position of the drum with respect to the head

Figure 2. Image from 1893 pump patent[5] and a portion of feature list developed in the class

Students learn more about axial piston pumps through dissecting a commercially available aerospace hydraulic pump donated by Eaton Aerospace. Figure 3 shows this pump partially disassembled. Students are tasked to create a detailed bill of materials, a list of questions, and a rough description of the pump function. Students are, then, tasked with figuring out the answers to their questions and trying to figure out the reason for various design decisions.

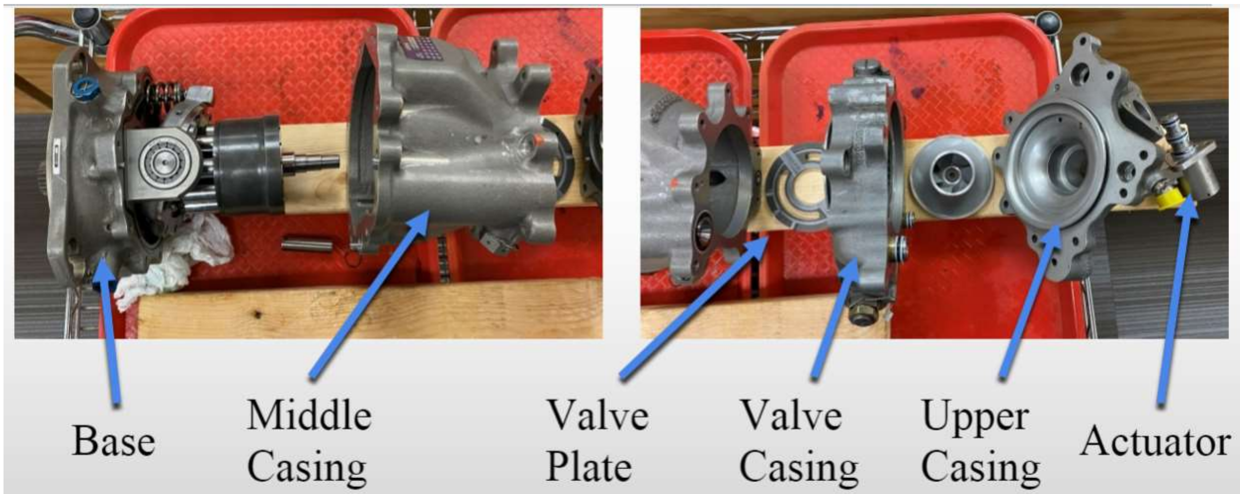


Figure 3. Image from student presentation of dissected modern axial piston pump.

Discussion and Improvements

The section on inventions was very successful in the first offering of this course. Students who began the course with little ability to read difficult texts showed great improvement in making quality outlines, summarizing the work, and asking questions that addressed the core of the author's meaning. The quality of classroom discussions improved tremendously. Students respected the discussion norms and were highly engaged in discussion. Many students commented on enjoying and being challenged by the course. Also, many students shared that Watt's story was an inspiration. The section on hydraulic pumps was also successful. However, both portions of the invention section of the course could have benefit from more time. Students need more time to develop the skills of reading, discussion, and cataloguing features. Further, skills could be added with case studies on conceptual design brainstorming and evaluation, and reliability assessments.

References

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