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Integrating the Entrepreneurial Mindset into a Thermal-Fluid Sciences Course

Nancy J. Moore PhD, North Carolina State University

The author is a Teaching Associate Professor at North Carolina State University in the Mechanical and Aerospace Engineering Department. She teaches undergraduate courses in the thermal-fluid sciences and is the course coordinator for Thermal-Fluid Sciences. Her pedagogical research supports her teaching methods and philosophy.

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Abstract

At North Carolina State University, the undergraduate thermodynamics course has been modified to include both fluid mechanics and heat transfer topics. As the first course in the thermal-fluids curriculum, it is critical that students are introduced to these subjects in a relatable way that inspires their curiosity in the concepts and in future courses. This re-design of the course has been an opportunity to focus on student-driven learning that sparks intrinsic motivation for students going forward in the curriculum.

The current study is a work-in-progress to determine the impact of this curriculum change. This paper explains how aspects of entrepreneurial minded learning have been used to create assignments with real-world applications that link thermodynamics, fluid mechanics, and heat transfer. With their work, students demonstrated curiosity in the capabilities of each subject and solved problems that connected the subjects. The students' work and feedback show that the assignments improved their understanding of these subjects. Insight is also provided regarding lessons learned by the instructor.

Introduction

The Mechanical and Aerospace Engineering (MAE) Department at North Carolina State University strives to meet the needs of students in both majors while providing service courses to other engineering disciplines. Recently, concerns were raised that students were not sufficiently prepared for some later courses in the aerospace engineering curriculum or some laboratory courses in the mechanical engineering curriculum. The department determined that students would be better served if they were introduced to concepts of thermodynamics, fluid mechanics, and heat transfer in an introductory thermal-fluids course.

The "Thermodynamics I" course was changed to "Thermal-Fluid Sciences" and remained a sophomore level course for MAE students. Approximately twenty percent of the course was modified to focus on fluids and heat transfer topics. For mechanical engineering students, this course is followed by "Fluid Mechanics", "Heat Transfer Fundamentals", and "Thermodynamics II". For aerospace engineering students, the course is preceded by "Aerodynamics I" where some fluids concepts are introduced. These students do not take a heat transfer course or another thermodynamics course.

The challenge with modifying a thermodynamics course to include both fluid mechanics and heat transfer is ensuring that students understand the connections between these subjects and the differences. A series of assignments were created to allow students with opportunities to connect the concepts in the course and develop curiosity about applications in the broader world. Curiosity and connection are two elements of the entrepreneurial mindset.

Entrepreneurial minded learning (EML) is intended to develop engineering students into engineers who can find and develop opportunity, overcome obstacles, and make an impact. The point is to help students develop the mindset and skills to create value in society and is not limited to commercial endeavors [1], [2]. Educators have been finding ways of integrating EML into their courses such as online discussions [3] and e-modules [4] that do not require class time. The new assignments were created to encourage students to become more curious about the broader world and hopefully retain knowledge for future courses, and they were all completed outside of class [5].

This research is the first part of a planned longitudinal study to determine the effects of this course modification. Surveys and reflective statements are often used by researchers to understand student learning. Analysis of reflective narratives is discussed in Badenhorst, et al. [6] and Ilin [7]. For the first part of this research students were tasked with reflecting on their own learning and surveyed on their comprehension after completing the course. The instructor plans to survey students as they move through the curriculum to determine how the course and the assignments helped them connect with other courses and create value.

Course Assignments

To encourage students to connect the thermal-fluids concepts, four assignments were created that required students to individually think beyond the equations learned in class. Their summaries are as follows:

> Assignment 1: Locate and explain your home's water heater using concepts from class.
>
> Assignment 2: Design and perform an experiment with melting ice to estimate the thermal conductivity of a container.
>
> Assignment 3: Locate and explain a thermodynamic cycle you use regularly.
>
> Assignment 4: Reconsider your water heater conceptually and reflect on what you have learned.

The first assignment was given during the second week of the semester. This followed an introductory module in which concepts such as thermodynamic systems, internal and external flow, and modes of heat transfer were explained. Some students struggled with including these concepts in their description of the water heater. They focused more on the design, materials, and construction. Thus, they were given an option of resubmitting their work based on feedback of their conceptual description. In order to accommodate all students, the instructor received information from the university housing department that students could use for the assignment in case they could not gain access to their building's water heater.

For the second assignment, students measured how long it would take for ice to melt in a container to determine the thermal conductivity of the container. This required connecting concepts and equations from thermodynamics and heat transfer. Students were told to make reasonable assumptions for their designed experiment and that no materials needed to be purchased. They also had to compare their experimental result to tabulated data and discuss limitations in their experiment. This assignment led to discussions with students about how assumptions are determined to be reasonable.

The third assignment required students to choose a thermodynamic cycle that they used on a regular basis. They had to take a selfie with their cycle and write a conceptual description. Students again struggled with providing concepts, so the instructor needs to provide better instructions for assignments in the future while avoiding too many details that may limit students' exploration of the topic.

Students revisited the water heater for the fourth assignment to include concepts and equations they had learned since the first module. They were asked to reflect on how their understanding had changed during the semester. As expected, most students reported that their understanding had improved. However, the statements below show that students identified specific areas of improvement:

> Aerospace engineering student: "… Compared to earlier in this semester, I can say that I have a better understanding of thermodynamics and its foundational concepts. In the future, I hope I can learn more so I can apply these concepts to real world problems."
>
> Aerospace engineering student: "… I believe that my understanding of the concepts has changed since completing the first [assignment] as I was initially focusing on each concept separately, whereas I now developed a better understanding of how all of them are interconnected. I better understand how the concepts all affect each other as well, and have gained a better understanding of the concepts in real world situations."
>
> Mechanical engineering student: "… Originally, I had a more simpler [sic] view of how a water heater worked, focusing mainly on the heating process itself. Now that I have progressed through this course, I recognize the complexity involved in balancing the flow rate and thermal distribution within the tank..."
>
> Mechanical engineering student: "When asked to first examine a water heater, I was looking at the system as a technician. Now I look at the system with an engineer's mindset. A lot of the functional aspects of a water heater have not changed for me, but now I can look at the tank and consider the first and second law of thermodynamics and be able to describe heat transfer, flow states, and work done to the system…"

Survey

For the fall semester, the two sections of the course involved in this study had 84 mechanical engineering students and 28 aerospace engineering students. Each was asked to participate in a survey about the course. Twenty-three percent responded to the survey and allowed their work to be used in this study. This survey is intended to provide a baseline for student understanding as they move through the curricula.

In the survey students were asked how well they agreed or disagreed with the following statements after completing the course:

1. I feel that I understand the concepts of conduction, convection, and radiation.

2. I feel that I understand the relationship between pressure, velocity, elevation, and friction.

3. I feel that I understand how to use the first law of thermodynamics.

4. I feel that I understand how to use the second law of thermodynamics.

5. I feel that I understand how to analyze systems using thermodynamics, fluids, and heat transfer concepts.

The Likert scale allowed a choice from 1, Strongly disagree, to 5, Strongly agree. Figure 1 shows the results of this survey for all students. None of the students selected 1 or 2 for any statement.

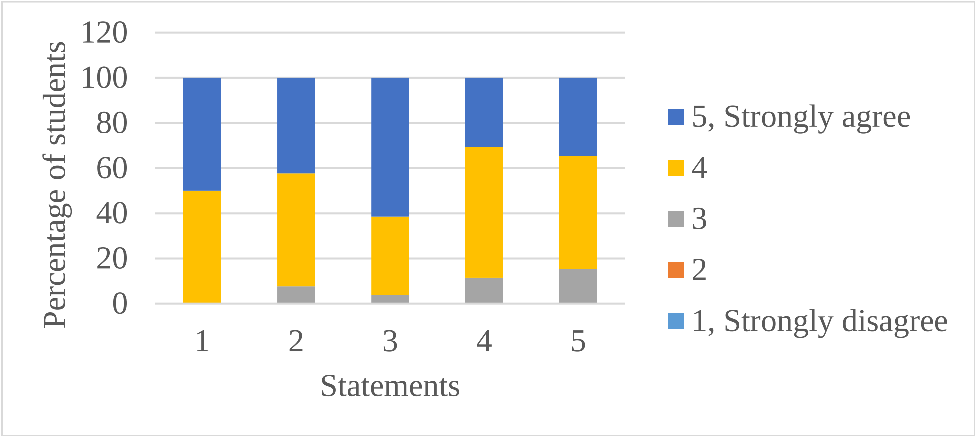

Figure 1. Responses to survey given at end of course

Almost all students agreed or strongly agreed with the statements. The least number of agreements was for statement 5, showing that more work is needed by the instructor to refine the assignments to create better connections between concepts.

The survey also asked students' permission for the instructor to contact them in the future. The majority of the students who completed the survey agreed to be contacted which is critically important to the goal of this longitudinal study which is to determine the impact of the course modification. Given the different curricula, the current survey responses were separated by engineering major so differences can be tracked as students progress towards graduation.

Of the survey respondents, 69% were mechanical engineer majors and 31% were aerospace engineering majors. Figure 2 shows that many more aerospace students strongly agreed with the statements than the mechanical students. Future surveys will hopefully help determine if this trend continues for students.

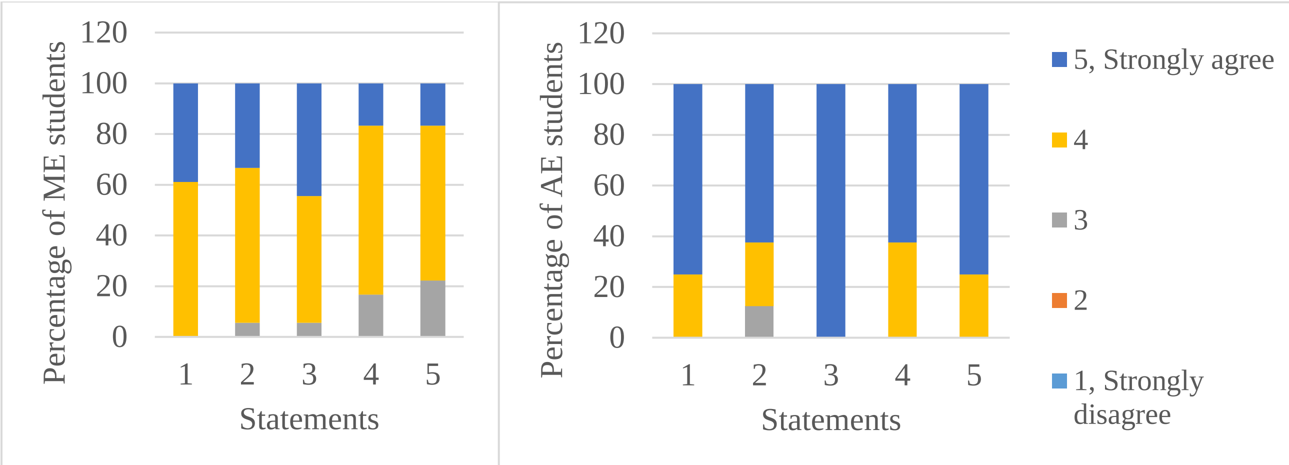

Figure 2. Mechanical engineering students' responses (left)
and aerospace engineering students' responses (right)

Future Work

The longitudinal study aims to determine if the changes made to the introductory course helped students connect the topics throughout the curriculum. Were students more curious about their future courses or applications of thermal-fluids in the real world? Did students demonstrate behaviors that indicate value creation?

For the next offering of the course by this instructor, assignment instructions will be improved to make sure students focus on concepts and to improve formatting for easier grading. Additionally most students who completed the survey agreed to be contacted in the future, so each semester students will be asked their perception of the thermal-fluids course after taking more advanced courses. The survey will ask students to reflect on their interest in the topics, motivation in their courses, and any impact the course had on their future plans.

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