Using Science and Engineering History to Increase Engagement and Conceptual Learning

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Abstract

There are many interesting stories and discoveries in the historical development of thermodynamics and related technology. This paper discusses some initial attempts to bring these scientific laws and engineering technologies to life in the classroom by incorporating some of the historical context for their discovery and invention. This paper will discuss two ways in which the instructor incorporated historical context into engineering courses. Historical context was incorporated into course lectures and into a group project which required students to write about either the development of a scientific law or of an engineering technology. The students in the study were surveyed to determine their perception of the impact of this historical context on their engagement and conceptual understanding.

Keywords

Thermodynamics, History, Student Engagement

Introduction

The history of the development of scientific laws and engineering technology is filled with fascinating stories, experiments, discoveries, and inventions. Most of the scientific laws and concepts that are explored in engineering courses were heavily debated and opposed at one time. And the path to the modern form of these laws and concepts often included very simple yet intriguing experiments. Additionally, many of the technologies studied in the engineering classroom today had amazing impacts on the quality of life in previous generations and were developed through a surprising path of exciting discoveries. Unfortunately, however, the presentation of these same concepts and technologies can be very dry and abstract in the engineering classroom. The significance and meaning of these topics is often lost when concepts are just stated as facts. Students tend to just seek to learn the method for solving problems and accept a minimal understanding of the course concepts. Similarly, the significance of current configurations of technology can be missed if the student does not know any of the alternative configurations that have been tried and the innovations that were made in the past.

Thermodynamics is an engineering course that could be greatly enhanced by including elements of this rich historical context. Many students struggle to develop a mature understanding of the many abstract scientific and mathematical concepts in this course. Instead of understanding the concepts, students often attempt to move forward in problem solving with only a formulaic understanding.

Some educators have made attempts to incorporate historical context into thermodynamics courses. For example, D. Visco[1] had students build projects that demonstrated thermodynamics concepts including replications of Joule's experiment. While there are only a few works that studied historical context in engineering courses, there are several works that present attempts to include thermodynamic history in a physics context. I. Galili[2] emphasized the importance of using past erroneous scientific conceptions to help students understand the nuances of current concept formulations. Additionally, N. Kipnis[3] discussed the advantages of using history in teaching energy conservation.

This article discusses an attempt to use historical elements to build engagement and conceptual understanding in a thermodynamics course in the mechanical engineering curriculum. The methods used included PowerPoint based discussions and a group writing project. A Likert scale survey was conducted to determine student perception of the historical elements of the class.

Classrooms Examples

Throughout the semester, various topics and concepts were introduced using historical elements in the form of brief PowerPoint presentations. The goal of these presentations was to engage the students with the very interesting historical context from which thermodynamics arose. Approximately 6 different historical presentations were given which ranged from 5 to 15 minutes in length. In some cases these longer presentations were given as an introduction to a new section of notes; in other cases briefer presentations were interwoven with the introduction of new concepts in the notes.

One example of a longer presentation was a historical presentation given to introduce the thermodynamics course. The presentation began with a discussion of the vastly different quality of life that existed before the industrial revolution. Issues such as infant mortality, literacy, prevalence of infectious diseases, and many others were vastly improved after the industrial revolution which was largely brought on by inventions such as the steam engine[4]. Then, students were presented with details of the historical development of the steam engine and how it led to the development of thermodynamics. Along this path there were some fascinating examples of how things were accomplished before the steam engine such as the use of horses attached to complex wooden mechanisms to raise water out of mines. After receiving this historical context, the students were invited to join in this rich tradition of using thermodynamics to bring improvements to the quality of human life. Longer presentations of this form were also given later in the course to show the experimental and theoretical foundations of the 1st and 2nd laws.

In other cases very brief presentations were given to improve engagement and understanding of various concepts. One example was a discussion of Guericke's (1654) demonstration of atmospheric pressure. In an experiment that baffles the imagination, Guericke demonstrated that 2 teams of 15 horses could not pull apart two evacuated hemisphere which were only held together by atmospheric pressure. Another example of a brief presentation was a discussion of Willem Gravesande's (1722) demonstration of the kinetic energy principle by dropping balls into soft clay from various heights.

Group Project

Another area where historical context was emphasized in the course was through a group essay project. One option was to study a major historical steam engine design from either Thomas

Savery (1697), Thomas Newcomen (1712), or James Watt (1776). The essay was required to include a description of the working principles and innovative impacts of the designs. The other option was for the students to write about Joule's experiment. They were required to read the original article where Joule presented his experiments related to the mechanical equivalent of heat and explain his apparatus and method. They were also required to discuss the significance of Joule's experiment.

Results and Discussion

The students were asked to complete an anonymous survey to assess the impact of the historical elements discussed above on their engagement and concept acquisition. Of the 25 students 13 students completed the survey. The survey included 6 Likert scale based questions and one open discussion question. The results of the Likert scale questions are summarized in Table 1.

Table 1. Summary of student responses to Likert Scale based questions

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Question	# (%)	# (%)	# (%)	# (%)	# (%)
I enjoy hearing about the historical development of thermodynamic concepts such as the 1st law, 2nd law, kinetic energy, pressure etc.	7 (54)	3 (23)	3 (23)	0	0
I am interested in hearing more historical context in class	6 (46)	4 (31)	3 (23)	0	0
I enjoy hearing about the development of the steam engine in class and its impact on human life.	7 (54)	4 (31)	2 (15)	0	0
The historical content in the thermodynamics course has helped me understand concepts such as kinetic energy, the 1st law, the 2nd law, work, heat, and pressure.	5 (38)	4 (31)	3 (23)	1 (8)	0
I am really interested in the course project on a historical technology/experiment.	4 (31)	6 (46)	1 (8)	1 (8)	1 (8)
Doing the course project has helped me to solidify concepts discussed in class.	2 (15)	6 (46)	4 (31)	0	1 (8)

Additionally, 10 students responded to the open discussion question. The comments were all positive, and every one of the historical elements presented in the class were mentioned. The Guericke experiment was the most mentioned in the comments.

The survey results reveal that the students generally appreciated the historical elements in the course. Students tended to feel more strongly that the historical elements improved their engagement than their concept acquisition. Additionally, many students were less enthusiastic about the project than about the lecture presentations. This may be due to the writing component in the project.

Summary and Conclusions

The goal of this study was to explore the potential of using historical context to improve student engagement and concept acquisition in a thermodynamics course. The study used a combination of PowerPoint presentations and a group project. The student response was generally positive, particularly with respect to engagement. There is much potential for development in this area. It would be interesting to include actual demonstrations of original experiments and historical technologies in future studies.

References

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