Make Students Confident in Thermodynamics: The Project Based Learning Methodology

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Abstract

The traditional teaching method, lecture-based learning, is currently changing to a model focusing on student-centered learning, such as problem-based or project-based learning (PBL). Typically, thermodynamics courses are taught by lecture-oriented methodology, and the course introduces many new concepts, laws, definitions, and variables. Unlike concepts in other engineering courses, these concepts are not easy to visualize, tangible, or tactile senses in daily life. Therefore, many students struggled to understand the concept, or even though they understood the definitions, they had difficulties applying these concepts to the actual engineering problems. The authors developed the EML-based project to help students apply their knowledge to engineering problems. The project contains one extra class experiment, including measurement, discussion, and report delivery. To measure the improvements in students' understanding and confidence in thermodynamics concepts, we conducted a pre- and after- survey. After the project activity, a majority of the student answered they gained the confidence to solve the thermodynamics engineering problems in different aspects.

Keywords

Project-based learning (PBL), Entrepreneurial Minded Learning(EML), Thermodynamics, Hands-on activity, Survey

Introduction

The traditional teaching method, lecture-based learning, is currently changing to a model focusing on student-centered learning, such as problem-based or project-based learning (PBL). The teacher-centered method is based on teachers directing students to learn through memorization and recitation techniques, therefore not developing their critical thinking, problem-solving, and decision-making skills. The student-centered method, which includes PBL, aims to engage the students for a better experience; teachers become mentors/guides of the students. PBL method is becoming one of the most used methodologies in the current engineering education [1]–[4].

One good example of PBL is challenging students with real-world problems and empowering them with curiosity, connections, and creating values. The PBL methodology offers advantages to students throughout various activities; conducting research, integrating theory to engineering problems, applying knowledge and skills to provide the solution, and teamwork [1]–[3]. In addition, the PBL method facilitates the understanding of concepts and applies the concepts to real-world engineering problems. PBL also takes into consideration that students have different ways of learning reading/writing, kinesthetic, visual, and auditory learning styles.

In this paper, with the support of the mentorship 360 of the KEEN foundation, the authors created the Entrepreneurial Minded Learning (EML) activities which can be implied into the

Thermodynamics I curriculum. Similarly, PBL enriched by EML activities is keyway to train and equip the next generation of engineers, scientists, and leaders with the skills needed to solve our most challenging problems.

The class and project

The class was a typical introductory sophomore level undergraduate engineering (3 credit hours) course with approximately 40~60 students per session. It is a requirement for all engineering students at Wichita State University. Typically, large class thermodynamics courses are taught by lecture-oriented methodology, and the course introduces many new concepts, laws, definitions, and variables throughout the course. Unlike concepts in other engineering courses, these concepts are not easy to visualize, tangible, or tactile senses in daily life. Therefore, many students were struggling to understand the concept, or even though they understood the definitions, they had difficulties applying these concepts to the actual engineering problems. Typically, the student had some difficulty in integrating the material until they arrived at the final chapters involving the power and refrigeration cycles [3]. Therefore, the authors developed the EML-based project that can help students to apply their knowledge to engineering problems.

Since this is a pilot study, we only conducted one semester, thermodynamics I class, which includes two sessions, and this project was optional for students. The project was an extra credit activity (5-8% of the total points for the course grade) for students who wanted to participate. Since the students were told that the project is a significant portion of their grade, 44 students participated in this extra credit project. The project contains one extra class experiment, which includes measurement, discussion, and providing the report. Our project has the following objectives.

- Apply the principles of engineering design and analysis to the solution of engineering problems
- Develop visual, physical, and mathematical models in support of thermodynamics problem design and analysis
- Collect, analyze, and present data in an appropriate manner
- Begin to develop professional habits necessary for success as a practicing engineer, including engineering ethics and written and oral communication.

Also, before and after the project, we surveyed to measure improvement in students' understanding and confidence in their knowledge.

Methods

This project was given to students after they learned chapter 5 (The second law of thermodynamics) to ensure that relevant topics were covered in class. The project included basic information with hands-on experimental activities with the stirling engine. The stirling engine is an external combustion engine that operates on the principles of a thermodynamic power cycle where thermal energy is converted into work[5].

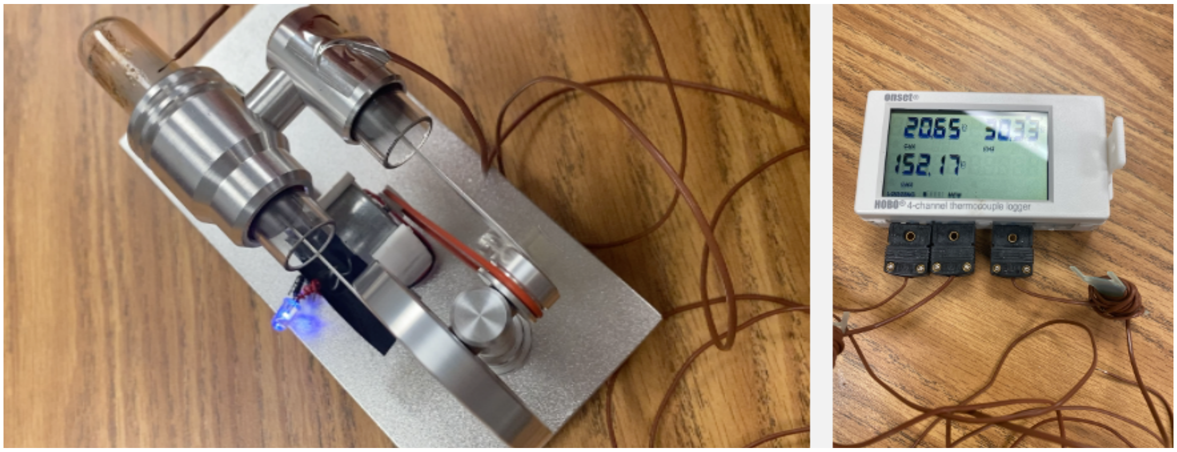

Figure 1 Stirling engine and sensors for the hands-on activity

We formed groups with 4~6 students per group, and they were burning fuel to make the stirling engine work so it could light up the LED lights. During this experiment, students were asked to

- Measure the necessary properties to calculate energy transfer by heat and work; such as temperatures of a hot reservoir, a cold reservoir
- Make assumptions to simplify the thermodynamic system
- Calculate the energy transfer by heat ($\dot{Q}$) and generated work ($\dot{W}$) based on their measurement
- Research the necessary equations to calculate the energy transfer by heat ($\dot{Q}$) and generated work ($\dot{W}$)

After the in-class group activity, students spent time with their group members to calculate the actual thermal efficiency (η) and the maximum theoretical thermal efficiency (η_{max}) of this stirling engine. After calculation, in their report, there was a discussion part that students should provide suggestions to improve the stirling engine's efficiency.

For this activity, students should have understandings in
- Energy balance equation
- 1st law of thermodynamics
- 2nd law of thermodynamics
- Energy analysis of cycles
- Irreversibilities commonly encountered in engineering practices

Assessment
Since the purpose of this project is to improve students' understanding and confidence in thermodynamics concepts, we conducted pre- and after- survey, as shown in Figure 2.

Survey – Before the activity

How confident are you in your ability to

Make assumptions that successfully simplify a complex problem to make it easier to work with

1	2	3	4	5

Collect, analyze and present engineering data related to thermodynamics

1	2	3	4	5

Apply your knowledge in thermodynamics and skills to solve a real-world problem

1	2	3	4	5

Use the equations to calculate energy transfer by heat and work

1	2	3	4	5

Suggest the engineering solutions to improve the power cycle's effectiveness?

1	2	3	4	5

Survey – After the activity

To what extent do you agree

My experience improved my understanding of engineering thermodynamics system so I can make assumptions that successfully simplify a complex problem to make it easier to work with

1	2	3	4	5

My experience improved my ability to collect, analyze and present engineering data

1	2	3	4	5

My experience improved my ability to make evidence-based engineering problem solving (Apply your knowledge in thermodynamics and skills to solve a real-world problem)

1	2	3	4	5

My experience improved my ability to use the equations to calculate energy transfer by heat and work

1	2	3	4	5

My experience improved my ability to suggest the engineering solutions to improve the power cycle's effectiveness

1	2	3	4	5

Figure 2 Pre- and After- survey

The survey questions had the consistency to measure students' improvement, as shown in figure 2. The survey questions measured how confident you in your ability are to (1= Very disagree, 5 = Strongly agree)

- Make assumptions to simplify the problem
- Collect, analyze, and present data
- Apply your knowledge in thermodynamics and skills to solve the problems
- Use the equations to calculate energy transfer by heat and work
- Suggest the engineering solutions

Results (students' feedback)

As shown in Figure 3, the result was organized by each question. Before the project activity, most of the students answered neutrally in their confidence to make assumptions to simplify the problem to make it easier to work with. However, after the activity, a majority of the student gained the confidence to make assumptions to simplify the problems. For question 2, because while this activity, students had the experience of measuring properties and applying this experimental data to the simplified equation they made, overall students' confidence level was improved. Questions 3,4, and 5 also showed a similar trend that while the in-class activity (experiment) and preparing the report, students should do their own research to find additional information to calculate and provide the solution. This experience helped students to have a unique experience as an engineer to apply their classroom knowledge and skills to solve real-world engineering problems. Also, this experience provides students to gain written and communication skills.

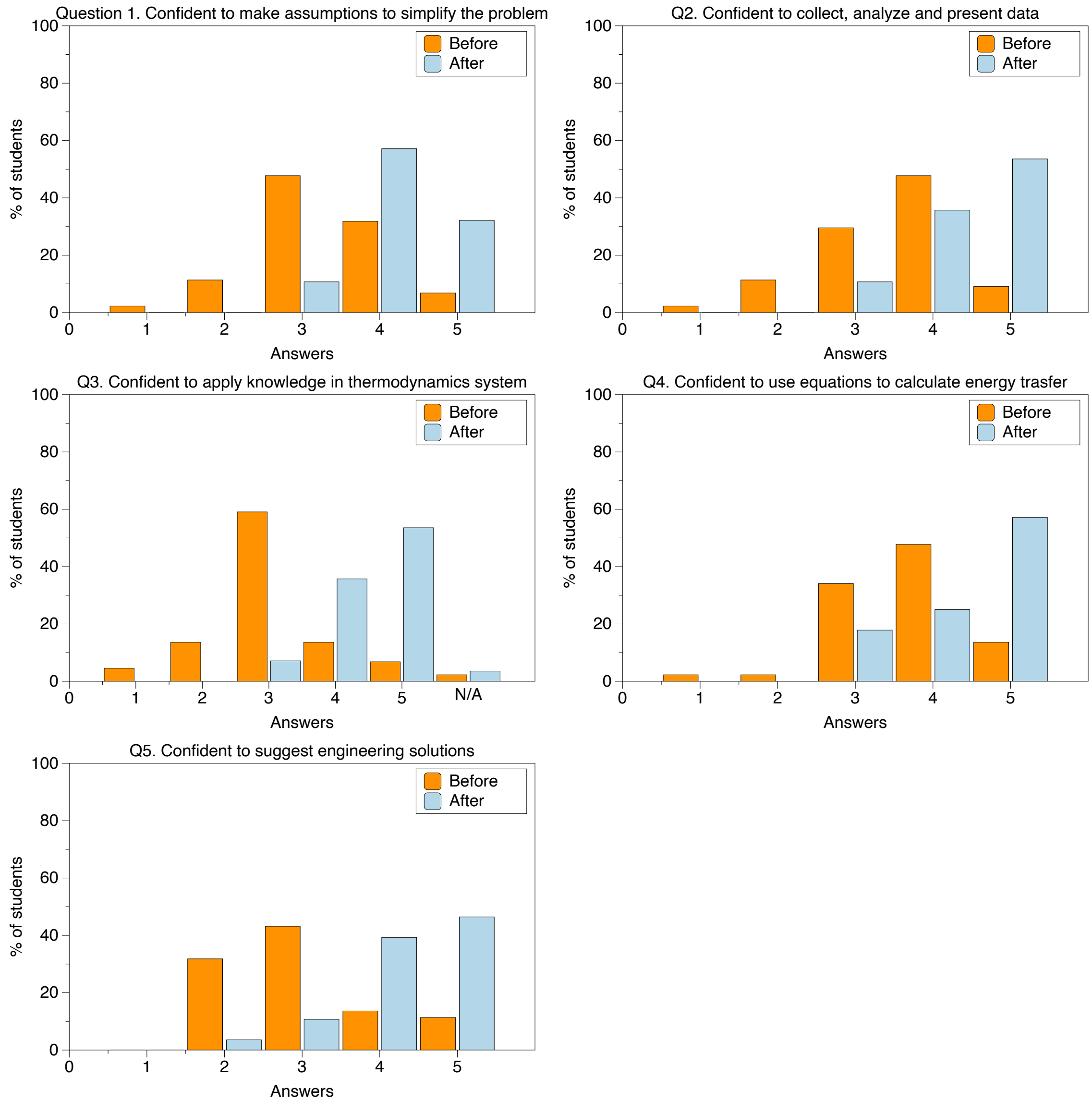

Figure 3 Survey Results

After the project, some students emailed instructors with comments “I really learned a lot during my hands-on activity”, “I enjoyed the project, thank you for putting it together”, and “We really appreciate you taking the time to create this activity for us to apply what we have learned from Thermodynamics I, and etc.” The survey results and students' comments showed that students enjoyed the hands-on activity. Also, they mentioned that now some of the thermodynamics concepts feel tangible.

Based on students’ survey results, comments, and reports on this project, the authors found well-organized answers and a deep understanding to improve the system and connect it to real-world problems. Therefore, this experiment has allowed students to think and connect a thermodynamics system to real-world challenges.

Conclusions

The pilot study implementing the PBL method in Thermodynamics has been positive and promising. This project delighted students and improved the student's confidence in various aspects of thermodynamic system problem solving; 1) making assumptions to solve the problems, 2) collecting, analyzing, and presenting data, 3) applying knowledge in real-engineering thermodynamics systems, 4) use equations to solve the problems, and 5) suggest engineering solutions. Due to the positive feedback we received with implementing the PBL methodology, the authors and instructors will revise and modify the project and are planning to integrate the project into the class project from Fall 2022 (it will not be optional).

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Biographical Information

Dr. Kim is currently an assistant professor in the Department of Mechanical Engineering at Wichita State University. She has more than 10 years of experience in the building science research field. Her main research expertise is building indoor air quality studies, including building systems, occupants' perception, and building energy and environment.

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