Making Connections Between Applications and Theory Through Energy in Fluid Power

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Biography Dr. Jose Garcia has been involved in several local and statewide recruitment events, where he was able to develop short workshops in fluid power and STEM. He is also working on the development of a new generation of hydraulic components and systems that can operate using environmentally friendlier fluids. Dr. Garcia has plans to actively continue the development of practical teaching tools that bring industry applications to the classroom.

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Work in Progress: Making Connections Between Applications and Theory Through Energy in Fluid Power

Abstract

This work presents the introduction of an of activity designed to help students enrolled in a basic fluid power course for the second year of the Mechanical Engineering Technology at our University. The students reflect on their own learning experience of energy in the context of a fluid power class (hydraulics and pneumatics). This educational research project started with the initial goal of highlighting students' energy literacy, and the relevance of this topic with respect to the course materials. Initially, one course learning objective was selected, and the specific course topics related to that objective were identified. A specific in-class assignment was developed for the purpose of highlighting the connections between the class material and general energy concepts. The activity during class required the students to use the Bernoulli equation in a guided step by step process to estimate at the energy requirements in a hydraulic system. After this activity, the students were given a survey to provide their own perspective about their perceived knowledge about energy and how these activities were of importance to them in their career. A total of 86 students responded to the survey. Approximately 45% agreed this activity will be useful in their future career and 30% responded that this activity helped them increase their interest in the topic. This project is investigating how creating active learning tasks in fluid power classes allowed students to direct their learning and apply energy concept and theory based on actual experience working on focused problems. This work in progress article documents preliminary results from the first implementation of the activity and survey in a class. Data from later implementations into this and other courses will be reported in future articles.

Introduction

One significant learning objective for Mechanical Engineering and Mechanical Engineering Technology students is to learn how to transfer, convert and/or store energy from various sources. However, these students often have a hard time visualizing and identifying energy magnitudes and/or energy flow paths. In other words, students can calculate how much energy it takes to perform a job but it is difficult for them to know if the resulting calculation is reasonable or not. There is a wide variety of literature aimed at estimating the amount of electric power consumed by different activities in daily life [1]-[5]. However, there is very little instructional material for the topics of transfer, conversion and storage of energy for various non-electrical processes. In general, Engineering and Engineering Technology students can be more effective professionals in their early years if they have a better understanding of energy flows and conversion. Our personal experience as instructors is that students tend to plug numbers into equations to obtain an answer in the classroom and lab. This is particularly true for mechanical engineering related topics in hydraulics and pneumatics, thermal sciences and rotational equipment. Very often the students' answers are orders of magnitude away from being correct, and they don't even realize it because they don't have a working understanding of the magnitudes or units.

Motivation

This project seeks to motivate the students to understand, learn and discover how energy is transferred, converted and stored by creating connected topics and by inviting them to reflect on how these processes work and are relevant beyond the classroom experience. As a result, a program was designed to emphasize energy conversion and energy units in a designated list of required and selective courses specific to the Mechanical Engineering Technology plan of study. Specifically, for each of the selected courses, faculty would pick activities that would demonstrate an energy relevant topic and asked the students to reflect on their own perception of the energy concept using an online anonymous survey. Furthermore, the questions in said survey prompted the students to reflect on the relevance of the specific topic within their future careers and within other classes. This article describes and analyzes the questions used and the responses of the students for the fluid power course, a required course in the Mechanical Engineering Technology program at our university with an average enrolment of 80 students per semester.

Procedure

An online eight question anonymous survey was used to evaluate the students' perception of the energy concept being discussed in class. The specific topic of discussion and analysis for this document is the Bernoulli equation. For this instructional activity, the student classroom is organized so that students are sitting in round tables with up to 6 students per table (Figure 1).

Figure 1 Active learning classroom with round tables

Students are given a fluid mechanics problem (Figure 2) from their text book [6] to solve, and the instructor projects it on the screen and guides the students to follow a step by step procedure to find the final answer. For this activity the students are given the volumetric flow rate and horse power of the pump, the diameter and length of the piping and the fluid properties. The elevation and elbow friction factor were also given in the problem statement. The problem requires the students to find the pressure at point 2 of the diagram (inlet of the hydraulic motor). The students work in groups of 6 and are allowed to open their text books, use the Internet and ask questions to the instructor directly. The classroom time is 50 minutes and the students are requested to turn in their work online.

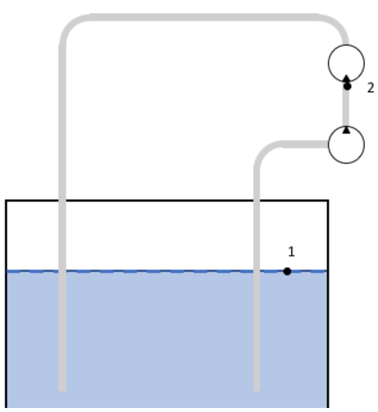

Figure 2 Fluid mechanics problem for Bernoulli equation activity [6]

For this problem, in preparation for the activity the students were asked to identify the terms in the Bernoulli equation that they already knew from the problem statement. Students were prompted to realize that the reservoir is vented to atmosphere p_1 and the velocity v_1 of the fluid at the liquid level was zero (point 1 on figure 2). The elevation term at point 1 Z_1 was set as a reference. They also were guided to realize they had the information for the elevation Z_2 at point 2. Equation 1 shows the equation presented to the students.

$$Z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + H_p - H_m - H_L = Z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g} \qquad (1)$$

Step 1: Students discussed if they needed to know the head loss at the hydraulic motor. Step 2: Students were tasked with finding the velocity at point 1, they already knew the answer from the preparation discussion. Step 3: Students were asked about the pressure P_1 at point 1. Step 4:

They were asked to re-write the Bernoulli equation with the terms that were not zero. Step 5: Students used the continuity equation $\rho V_1 A_1 = \rho V_2 A_2$ to calculate V_2 from the volumetric flow.

$$H_p - H_L = Z_2 + \frac{p_2}{\gamma} + \frac{V_2^2}{2g} \tag{2}$$

Step 6: They used V_2 to estimate the term V_2/2g. Step 7: Students used the Reynolds equation. Step 8: They the determined the flow regime from result in Step 7. Step 9: The students select the equation to determine the friction factor in the pipes. Step 10: They calculated friction factor in piping. Step 11: Students estimate head loss due to friction in piping. Step 12: They found the pump head loss from the given horse power assuming 100% efficiency. Finally, Step 13: Students replaced all known values in equation 2 and solved for the p_2. With the help of the instructor the students were able to complete the activity on time and they were instructed to complete the short survey just after finishing this activity.

Results

A set of 12 Likert-type questions with a 5 point choice scale were used to assess the students' perception of impact of the activity on their professional career, and on their interest in learning the material. The survey questions used for assessing their impression is presented in table 1 below. Questions 1, 3, and 6 were focused on their perception of the activity on their career. Questions 11, 10, 9, and 7 were skill development questions, and questions 12, 8, 5, 4, and 2 were topic engagement questions.

Table 1 Survey questions

Q.1. As of today, are you 18 years of age or older?
Q.2. I identify as (gender):
Q.3. Please answer each of the questions below based on your experience in fluid mechanics. Use the following scale for each of the questions: *1=Strongly Disagree 2=Disagree 3=Neutral 5=Strongly Agree*
Q.3.1 I can see the relationship between what I did on this energy activity and what I want to do in the future.
Q.3.2 It was important to me to complete this activity to the best of my ability.
Q.3.3 Working on this energy activity made me think of alternative applications of this concept.
Q.3.4 Completing this energy activity has given me a new insight into energy in fluid power.
Q.3.5 Working on this energy activity increased my interest in hydraulics.
Q.3.6 This energy activity increased my motivation to learn more about energy.
Q.3.7 This energy activity helped me develop skills that I can use in the future.
Q.3.8 I was primarily interested in earning a good grade on the energy activity.
Q.3.9 Working with others (alone if solo), increased my motivation to do well on this energy activity.
Q.3.10 I feel confident in applying the concepts I learned in this energy activity.
Q.3.11 Working on this energy activity made me interested in learning more about problem solving.
Q.3.12 Working on this energy activity allowed me to understand the importance of how energy impacts my daily life.
Q.4. List 5 key concepts from this energy activity that are important to you
Q.5 Working on this energy activity most piqued my interest in: write an answer below.
Q.6. What is one way that this energy activity could be improved for the future?

100% of the class was older than 18 years old and, 74 students identified themselves as male, 7 as female, 1 as other, and 1 answered that they did not wish to disclose. 83 of the 86 respondents chose to complete the survey questions targeting their perspective on career, skill and interest/engagement. Figure 3 presents the responses of these students divided into these 3 focus areas (Career, Skill, Engagement). Finally, the last three questions of the survey focused on to obtaining information related how the students perceived the importance of this activity and their motivation using words of their own choosing.

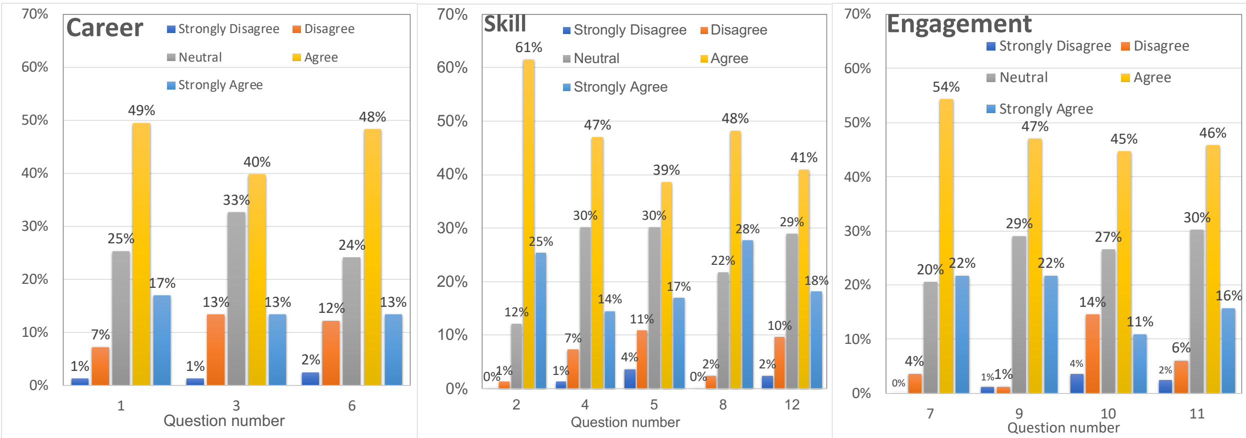

Figure 3 Survey results

Discussion

On average, close to 60% of the students agreed or strongly agreed their perception of this activity or the topic was relevant to their future careers. More than 57% agreed or strongly agreed this activity may have helped them improve their understanding of the energy concepts used and its application to fluid power. The students agreed or strongly agreed that their motivation to learn the material was perceived higher than 62% among this group. From these results, if appears that more than half of the students thought the activity seemed to boost their confidence in using a fundamental energy concept (Bernoulli's equation) for fluid power technology and did seem to appreciate its relevance for their careers. Lastly, the word cloud on figure 4 illustrates the frequency of the words used by the students to identify 5 key concepts students perceived as more important to them from this activity (*Q.4*). The larger bold face words correspond most frequent terms used by the students. They perceived the head loss, flow, regime, Reynolds number and unit conversion were of most importance in that order. The learning objective of this activity was to understand the application of the conservation of energy equation to model fluid power systems. The average grade for this activity was 84.6 with a std. dev. of 15 and mode of 97 on a total scale of 100. Approximately 75% of the students failed to properly find the head loss H_L on the piping to arrive to the correct value of the pressure p_2. Another frequent issue during this activity was the determination of pump head loss H_P due to poor understanding of the relationship between horsepower, the pressure and the flow, and how to convert the pressure differential across the pump into a head loss.

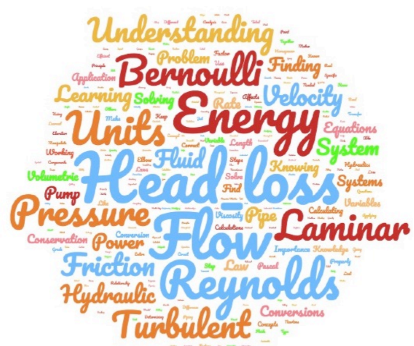

Figure 4 Word cloud for 5 key concepts

Conclusion

Overall, the fluid power energy activity resulted in positive student responses toward energy, energy usage, applications, and student confidence in applying energy equations to fluid power systems. This activity created linkages and applied units to help students contextualize energy. The activity can be further improved by additionally emphasizing the understanding head loss.

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