Impact of a Design Project on Engineering Physics: Motor does it really motivated our students?

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Abstract

Engineering physics courses are the key gateway courses in engineering. Most engineering students take one year of physics courses. The first semester materials cover mechanics based physics, which are taught in great detail at several high schools, but the second semester of physics, electricity and magnetism are somewhat new to several students. Motivating students to learn these concepts individually in addition to the materials covered in class is a challenging task. One way to deal with this issue is to assign a design project as part of the course requirement. In this effort, students were given a team project to design and build an electric motor and optimize its performance. Converting electrical energy to mechanical, and mechanical energy to electrical in the magnetic domain are the fundamental and practical concepts of this course, and fit well with the goal of this study. There are several interesting physics concepts involved in this project such as voltage, resistor, current, circuit, magnetic field, magnetic flux, and magnetic force on current carrying wire, torque and more. The project also helps students to learn about the physical process and the theory behind building the motor. For example, logic such as the force produced by the magnetic field on a current carrying wire is the fundamental behind rotation. This report will present detailed information about design requirement; materials provided, constraints, outcome and student feedback via assessment. At the end of the semester, a survey was done to see how much the motor design project motivated our students to learn the course materials. About hundred students participated in the survey. The data was analyzed using a spreadsheet and the outcome will be reported in this paper.

Introduction

Project based teaching is an interesting concept and is in practice at several institutions¹⁻². How much these activities influence learning is always a varying opinion³⁻⁵. Like other colleges, at our institution most of the engineering students take Engineering Physics 1 and 2. As part of Engineering Physics 2 course requirement⁶, a design project to build Electric Motor⁷ was assigned, (details given in appendix1). In order to build the motor, students have to understand the function of the motor, and also learn to deal with several practical issues: how to mount the coil and to make contact for the motor to rotate continuously. This is like dealing with rotor and commutator in the industrial motors. The project helps students to master several important concepts, Ohms law to deal with current and resistor, magnetic flux via Faraday's and Lenz's laws, the Lorentz force, the torque on the coil, and the right hand rule to determine the direction of rotation.

Project Approach

As the first step, four member teams were formed in classes, and set of guidelines were given to teams (details in appendix 1). As constraints, each team was given the same magnet, 1 meter length of wire and requested to use only a 1.5 v battery. In general students made a loop using the given wire and suspended it over a magnet using various approaches and passed current through the coil. In practical DC motor current direction was reversed using commutator to

produce torque in the same direction, but in this design students didn't have the commutator setup to reverse the current. They overcame this issue by stripping half of the insulation at one end of the wire to avoid reversing the direction of the torque. Figure 1 shows the theoretical set up and Figure 2 shows the actual or practical design.

Figure 1

Figure 2

For this project students used several engineering physics 2 concepts and equations, for example, $R = \rho L/A$, to determine the resistance of the given wire. Where, L is the length of the wire and A is the cross-sectional area of the wire, and resistivity ρ of AWG-28 copper wire from the table. Then Ohms law $V = IR$, to estimate the current in the coil provided by a 1.5 V battery. They calculated the magnetic moment $\mu = NIA$, where N is the number of turns, A is the area of the coil/loop. Torque obtained using $\tau = \mu \times B = NIAB \sin\theta$. Students were requested to show detailed calculations and to optimize torque for higher angular speed.

Data Analysis

Upon completion of the project at the end of the semester, several survey questions were asked. Appendix 2 shows the list of questions. About one hundred students took part in the survey. The data obtained for each question was analyzed using a basic excel spread sheet. The following survey questions were analyzed for this report.

Q1: Rate your knowledge / background in motor related Physics concepts before doing the project.

Q2: Rate your knowledge / background in motor related Physics concepts after doing the project.

Q3: Rate the motor design team activities from very interesting (5) to uninteresting (1).

Q4: Do you think that the motor design team project motivated you to learn the engineering physics concepts? (Circle one)

Figure 1 shows that our students' knowledge about electrical motor concepts generally varies. About 70% rated their knowledge at 3 or below. This represents a considerable number that needed to learn the concepts, which is the main focus of the engineering physics 2 course.

Figure 2 demonstrates students' knowledge about the motor based physics concepts after they did the projects, see responses to the second question (ii). This figure shows that about 77% rated their knowledge at 4 or above, within which about 21% rated their knowledge as very high: that is 5. These results show that the students who participated in the survey are confident about the concepts that we introduced during this process.

Figure 3 illustrates that most of the students who took part in the activity enjoyed learning the concepts via designing and team work.

Figure 4 displays the responses to the question, “Do you think that the motor design team project motivated you to learn the engineering physics concepts?” This reflects the students’ view regarding the effect of the project in learning the course. The majority of the students, about 75% felt that motor design motivated them to learn engineering physics 2 concepts.

Conclusion

The project aids students to work as a team and to integrate their design ability and physics concepts, also forced them to recall several physics concepts. Simply, this assignment guided them to think outside the box. The traditional teaching methods are essential for learning, but integrating with projects like this make the classes interesting and help students to learn additional non classroom problem solving issues. On average, about 70 % of students were not

very familiar with the key concepts of this project before doing the project. This number is unpredictably high for engineering students because most of them had high school physics. The survey analysis also shows that freshmen engineering students with proper guidance can handle challenging projects. This approach builds their self-confidence to face new and demanding tasks later in their higher level classes. Based on this particular study and figure 4, the answer to the title question, “Does Motor design project really motivate our students?” is evidently answered: it indeed motivated them to master the key concepts of the course. Figure 3 shows students not only learned the fundamentals of physics but also enjoyed doing it and considered this as an interesting activity. This study is only a sample; additional studies are needed to reach firm conclusions regarding the effect of design projects in engineering physics courses.

References

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Appendix 1:

Design Project Electric Motor

Goal: Build a running electric motor and demonstrate its operation to your ILS faculty.

Teams:

- Teams of up to 4 in each ILS
  - Three will be OK
  - Five if absolutely necessary – no more than five in a team
- Students may choose which team to be on
  - Instructor will assign those who can't do this as a team
- Students will let their ILS instructor know who the members of their team are
  - They may (not necessary, no points for this) name their team or their motor

Materials:

- D-cell battery – one
- Permanent magnet – one
- Length of “magnet wire” – 1 meter
- Any material you come up with to support your coil as it runs.

You will be provided with:

- One small permanent magnet
- A 1 meter length of magnet wire

The procedure to be followed is:

1. Investigate and understand the operation of such a simple device
2. Perform a design study on the way you will carry out the project. This will include:
  - a. The coil to be used:
    - i. Dimensions
    - ii. Number of turns
    - iii. The approximate resistance of their coil
    - iv. You may use any length of wire up to the 2 meters provided
  - b. The method for mounting the coil over the magnet
  - c. The method for getting the current into the coil
3. You are to write a report which discusses:
  - a. the theory of operation of your motor
  - b. the calculations used in your design
  - c. the problems that you ran into and how you solved them
  - d. Conclusions
    - i. lessons learned
    - ii. how to improve the design if it were to be repeated
  - e. References:
    - i. You may use any including YouTube videos
4. You may replace the battery as it runs down
5. You are to present the motor in your ILS to instructors who will determine that it does run
6. The instructors will determine (together) which of the teams in ILS had the best result based on the written report
  - a. Level of understanding
  - b. Quality of English usage

- c. Value of “lessons learned” and future work
7. Each member of the best team in each ILS will receive five points added to their Final exam scores.
- There will be one team per ILS, which will be determined to have “won” a competition with the others in that ILS.**

Grading:

Motor Demo

- Working Motor Demonstration
- Ease of Operation
- Reliability
- Aesthetic
- Performance (speed)
  - Instructor will measure and use sliding scale to assign actual percentage.

Project Report

- Understanding of principles / physics
- Report organization
- Quality of the writing
- Proper References (cite them in the proper location in the report).

Appendix 2

Survey topic Motor Design Project

Respond to questions below by using the give rating on the questions:

1. Rate your knowledge / background in motor related physics concepts before doing the project, 5 (high) to 1 (low).

2. Rate your knowledge / background in motor related physics concepts after doing the project, 5 (high) to 1 (low)

3. Rate how easy (5) or difficult (1) motor design physics concepts are:

4. Rate the motor design team activities from very interesting (5) to uninteresting (1).

5. Rate, how much the motor design motive you to better understand the physics 2 electromagnetic concepts? 5 (high) to 1 (low).

6. Do you think that the motor design motive you to better understand the physics 2 electromagnetic concepts? (Circle one)

Yes	No

7. What could be done to improve the motor design project (Brief Comments)?