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Instructional Setting on Student Learning Effectiveness Using Flipped Classroom in an Engineering Laboratory

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INSTRUCTIONAL SETTING ON STUDENT LEARNING EFFECTIVENESS USING FLIPPED CLASSROOM IN AN ENGINEERING LABORATORY

ABSTRACT

Improving Engineering Education, which plays an important role in shaping the future engineers, has always been a major concern. However, until recently more engineering educators have been involved with the implementation of various different educational and learning techniques. As part of this movement, this paper is aimed at analyzing and thereby assessing how different methods used in a flipped classroom setting will impact student-learning effectiveness. The study compares flipped classroom instruction to a traditional teaching method which is used as a reference for control study. Data gathered for the analysis is based on a non-biased uniformly distributed lab setting focused on using smart materials to determine the vibration frequency of a cantilever beam. The lab setup is a part of a Green Energy Materials & Engineering course offered in the summer 2014 semester. This class introduced students to the concepts of Green Manufacturing, Green Technologies in industries, and Fabricating advanced Green Energy devices. The framework used for gathering unbiased data, identifying a learning approach, and on quantifying the student learning is explained in detail. It is found that the instructional setting plays a significant role in flipped classroom learning effectiveness. Flipped classroom learning setup does not guarantee better learning effectiveness if not set up appropriately in a laboratory setting.

Keywords: Flipped Classroom, Project based learning, Energy, Engineering Education.

INTRODUCTION

The term Engineering Education refers to imparting the knowledge of professional engineering practice to students in advanced educational institutions towards enhancing and improving their knowledge. In United States, Engineering Education is a part of STEM (Science, Technology, and Engineering & Mathematics) which is mostly used to address in improving educational policies for increased educational and technology development [1]. Mills & Treagust in their paper on application of problem-based and project-based learning in engineering education identify critical issues to be addressed in the philosophy and delivery of engineering education. The identified issues are [2]:

- Curricula being too focused on engineering science rather than providing integrated topics related to industrial practice.
- Providing insufficient design experience to students
- Lack of teamwork and design experience to students
- Outdated culture of learning strategies and a need towards identifying more student centered teaching

The most commonly prevailing model in engineering education, being practiced from 1950's, is the large student in-class lecture delivery system. This norm particularly involves a lecturer's discretion on how a class is organized along with how the student interactions in a class take place. The interactions here are defined by a debate, student to student discussion, student to lecturer discussion and so forth [3]. Such interactions play an important role in quantifying & analyzing if the goal of improving a student's knowledge is achieved. Over the past few years, current trends are being observed in stimulating various interaction patterns among students and lecturers in an educational setting to identify effective teaching principles.

Traditional engineering classroom setting compromises a one-to-many teaching structure where the lecturer plays a crucial role in the course disclosure. It is a structured 2 step process where lecturer transmits information and students receive and process the information. Students sometimes tend to selectively receive and process information and ignore the rest. This results in students learning, partially learning or not learning the material [4]. This setting does not prepare students in cultivating soft and team working skills along with other similar attributes widely required in industries. On the contrary, many educational institutions are embracing the technique of flipping a classroom. Flipping a classroom takes many forms such as web based learning, video based learning, interactive laboratories, interactive classrooms, peer based learning and so on, inverting upon traditional classroom structures [5]. According to Harrison Keller, Vice provost for higher-education policy at University of Texas at Austin, Flipping classrooms allow educational & research institutions which has big classes allow students to be more productive [5]. A survey of literature based on several case studies suggests that there is a significant increase observed in the learning curve of the students along with their participation and inter-activeness. Though encouraging there is no much evidence supporting the influence of flipped classroom in student learning improvement [6]. Please see Bishop & Verleger [6] for more details.

Aiming towards exploring different methods and scenarios for effective flipped classroom setting, this paper explores the impact of traditional classroom and flipped classroom in an engineering laboratory on student learning effectiveness. The later sections of this paper explain the objective and perceived student learning outcome of the flipped engineering laboratory , a part of *Green Energy Materials and Manufacturing* course developed as a deliverable of *DoEd-Minority Science and Engineering Improvement Program (MSEIP)*Grant for fostering 21st century Hispanic sustainability leaders. Framework used for analyzing student learning effectiveness is then explained in detail which includes how students were divided towards a traditional and flipped setting, the lab experiments assigned, instructional method followed for traditional and flipped classroom along with data gathering and analysis. Finally, a summarized conclusion of the paper along with discussion of the obtained results is included.

GREEN ENERGY MATERIAL & MANUFACTURING COURSE *(IE 4395/5390; MECH 4395/5390)*

Green energy materials and manufacturing class was developed as a deliverable of *DoEd-Minority Science and Engineering Improvement Program (MSEIP) Grant* for fostering 21st century Hispanic sustainability leaders. The main objective of this course was directed towards a focus on several themes combining renewable energy design and manufacturing with importance to cyber-infrastructure issues providing diverse information rich content to the students on how to conduct research in the area of nano-materials, manufacturing and building systems. The course focus was mainly subjective to Overview of Green Energy and Manufacturing, Green Energy Storage Devices, Green Energy Harvesting materials and devices, Nano-Materials, and Nano- Manufacturing. To successfully meet the said objectives, the course was divided into three different modules and an engineering laboratory project.

Figure 1: Classroom Lecture during Module-I

Module-I focused on fundamental concepts of environmentally benign manufacturing to acquaint students with energy and environmental issues surrounding product and process design decisions. Life cycle assessment case studies to identify and develop strategies, techniques and methods that can be used to make environmentally responsible decisions were explored. Figure 1 illustrates a snapshot of an active classroom session in Module-I

Module-II introduced students to green technologies and their use in industrial and commercial applications. This included efficiency measurements taken from green energy devices such as solar photovoltaic panels, composite material wind turbine systems, thermo electrics, and on estimation of the performance of these materials. Students were encouraged to actively participate in fundamental discussions from energy perspective including financial considerations and from an efficiency perspective. This module also emphasized on project-based practices of green energy technology. Figure 2 illustrates a snapshot of an active hands-on Laboratory session in Module-II.

Figure 2: Lab Session for Module-II

Module-III exposed students to state-of-the-art fabrication advancement of green energy devices such as solar cells, advanced lithium-ion-batteries, super capacitors, vibration energy harvesters, thermo electrics, and electro chromic coatings. Main emphasis was on nano-fabrication technologies such as hydrothermal, chemical vapor deposition, and physical vapor deposition for thin films, nanoparticles, and nanowires. The structure, objective, goals and the experimental setup used for the engineering laboratory are explained in detail in the later section.

ENGINEERING LABORATORY SETTING

The laboratory setting was designed to expand on the physical behavior of piezoelectric materials and their applications; a topic covered as part of the summer course *Green Energy Materials and Engineering.* The experimental setup consisted of an aluminum cantilever beam, an attached piezoelectric ceramic sensor near the base of the beam and a digital oscilloscope for data collection. The student objective was to determine the vibration frequency of the cantilever beam analytically and experimentally, as provided by the oscilloscope, and compare the results. The experimental setup used is illustrated in Figure 3.

For the experiment and data gathering, seven teams consisting of five to six students chosen at random were formed. These groups were then separated in traditional and flipped classroom teaching methods based on even and odd group numbers assigned, respectively. Before the experiment, an explanation comprising the basics of the laboratory practice and the specific objective was given to the whole class.

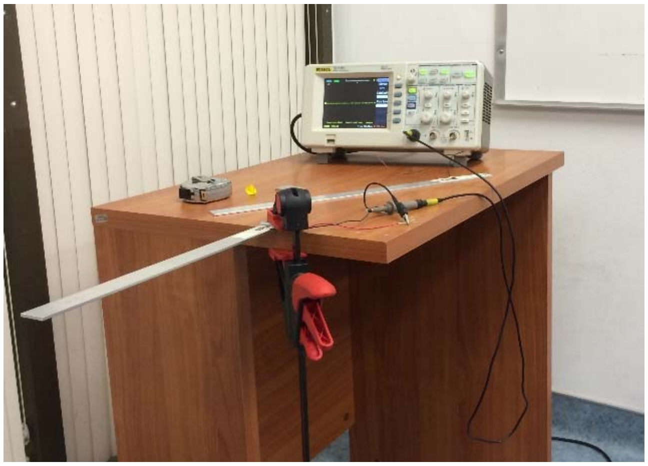

Figure 3: Experimental Setup for Laboratory Practice

However, the distinction between the traditional and flipped classroom setting groups consisted on the information provided to obtain the vibration frequency analytically and the way to relate the experimental results to the analytical value. To achieve this, groups 1, 3, 5, and 7 were instructed to research on the theory and equations needed to achieve the experiment's objective outside of the classroom. Special classes were scheduled with different objectives for the traditional and flipped classroom groups. For the former, the class covered the steps to calculate the frequency of the cantilever beam and how to relate the experimental results to the analytical solution.

For the latter, the class was specifically used to answer student questions regarding the experiment, without providing the answer to the problem. It is important to note that there were safety measures taken to prevent data sharing between the groups. The experimental groups performed the experiment on the day and time the traditional special class was being conducted and several cantilever beams with different length, and hence, different vibration frequencies were utilized. Please see *Appendix-A* for sample student deliverable based engineering laboratory experiment. Figure 4 illustrates the methodology followed to capture, identify and reflect the student analysis for this paper.

In order to determine the success of the flipped classroom activity, an individual quiz was given the next class to assess the level of knowledge of each student on the laboratory practice topic. The quiz consisted on 3 questions related to different parts of the experiment, which were expected to be learned by the students after the laboratory practice. The quizzes were graded and the results were separated by group. The average grade for the traditional and experimental groups on the quiz can be observed in Figure 5 (A) and (B), respectively.

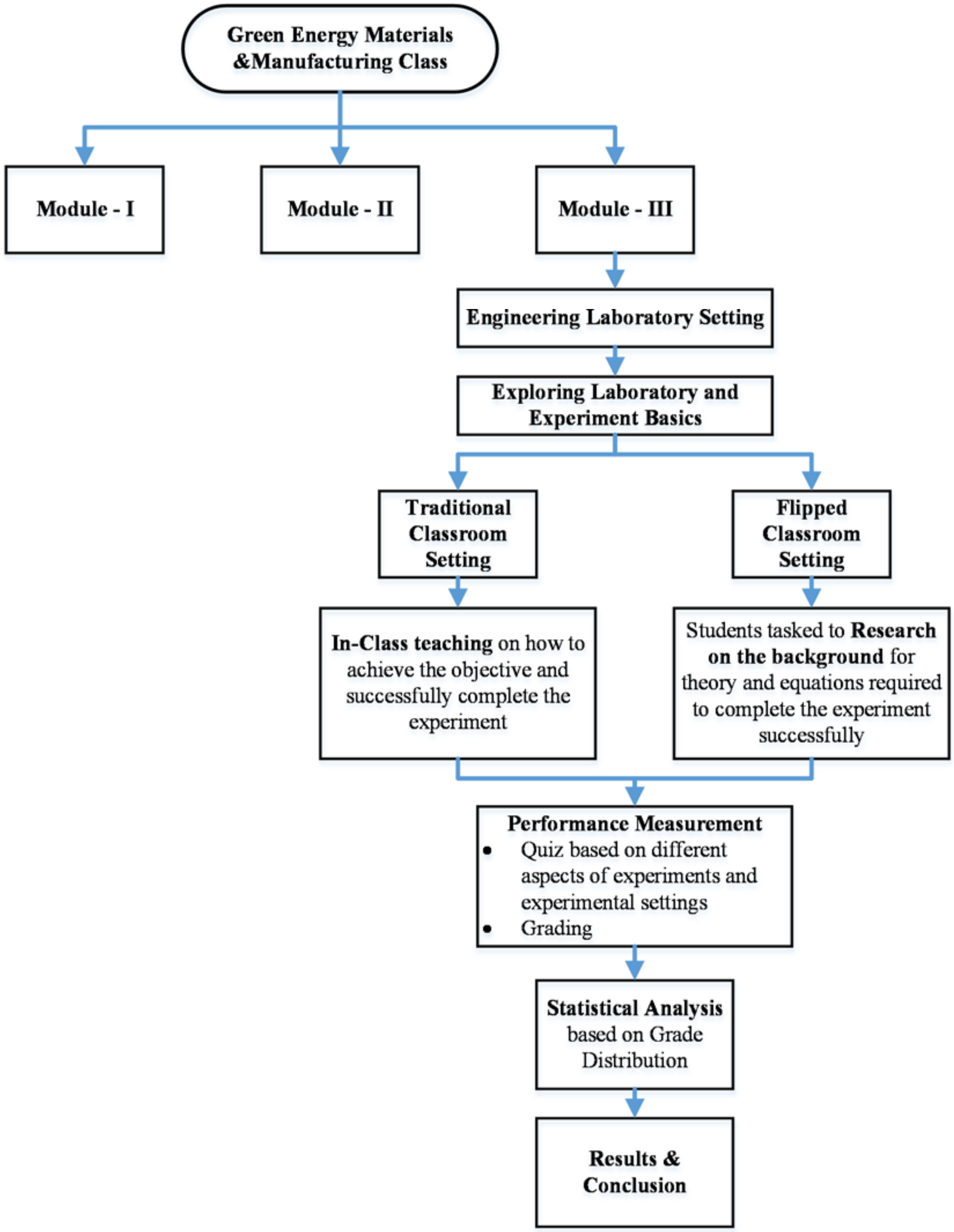

Figure 4: Methodology Followed

From the results, it can be observed a wide range of average grades for both the traditional and experimental groups. For the traditional setting a wide grade average was observed with maximum and minimum average grades of 83.33 and 38.67 were observed. For the experimental group demographic, a similar minimum grade was observed. However, the maximum average grade was lower with the average grades ranging from 69.44 to 33.33. A comparison between the averages for experimental and traditional groups can be observed in Figure 6.

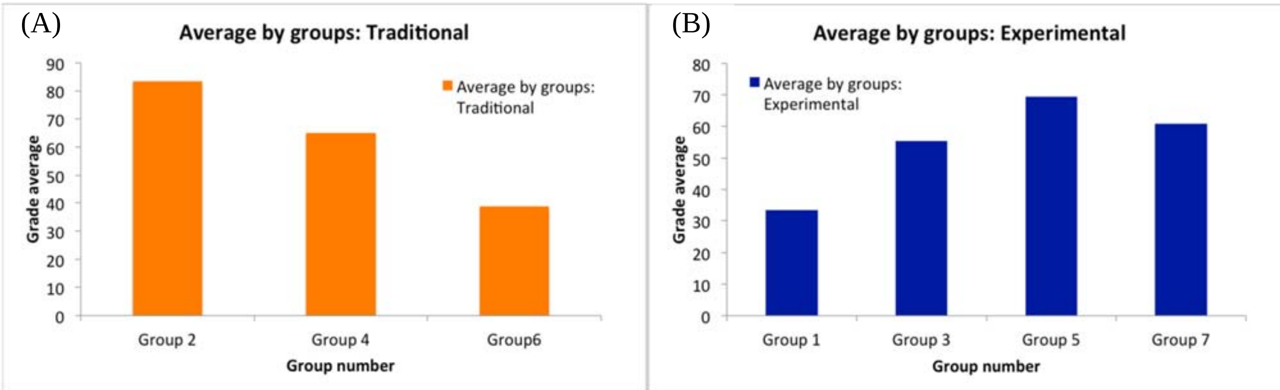

Figure 5: Average quiz results for *(A)* traditional and *(B)* experimental groups

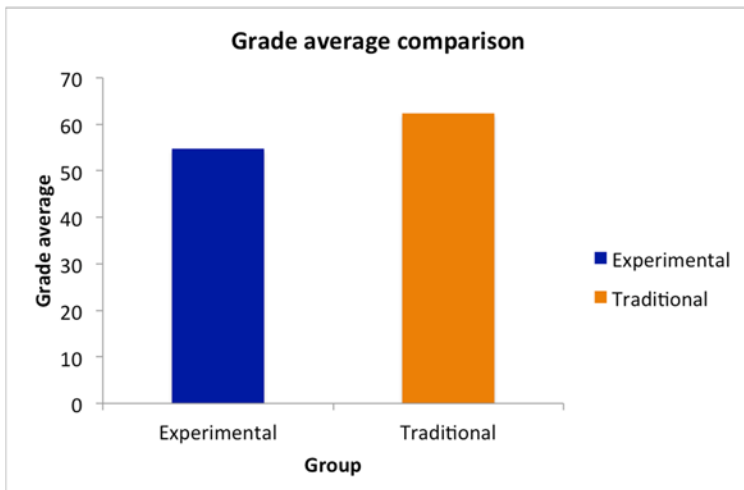

Figure 6: Average grade result comparison for experimental and traditional groups

Overall, better quiz performance and grades were observed for the traditional groups, with an aggregated average of 62.33, while the experimental groups obtained an aggregated average of 54.74. The assessment results for the performance of the flipped classroom activity portrayed minimum change in graded learning outcome from the laboratory experiment. A remarkable thing observed was that higher or lower grades for the quiz did not lean towards one learning method or the other, but instead they followed a per-individual approach. Therefore, grades as high as a 96 or as low as 0 were found in students from both groups, contributing to the similar averages obtained from the graded quizzes. This suggests that different learning methods are effective depending on the type of student and different factors, such as student motivation, also play a role in learning. Further research can be conducted to better assess the effectiveness of flipped classroom methodologies on a laboratory setting.

CONCLUSION

This paper describes the Green Energy Material & Engineering course at University of Texas at El Paso offered in the term of summer 2014, which introduced students to the concepts of Green Manufacturing, Green Technologies in industries and Fabricating advanced Green Energy devices. The experimental lab setup associated to the class is also explained. The methodology used for gathering unbiased data, identifying a learning approach and on quantifying the student learning is illustrated in detail. In addition, a well-defined framework for quantifying student learning along with both the traditional and nontraditional settings is presented in this paper. It is found that the instructional setting plays a significant role on student learning effectiveness in a flipped classroom setting. Also based on the data gathered at the conclusion of the projects first year, it is found that Flipped classroom learning setup does not guarantee better learning effectiveness if not set up appropriately. It is to be noted by the readers that the Modules developed and delivered are an initial step towards acknowledging the deliverables in first year of the grant. This project is a work in progress and will be of a great help to the authors for improving the methodology followed to gather and analyze the data on flipped classroom setting to avoid inherent student bias.

ACKNOWLEDGEMENT

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Appendix A – *Sample Engineering Laboratory Student Project Report*
Piezoelectric Material Analysis and Comparison to Natural Frequency First Response

Introduction

Piezoelectricity is the electric charge that comes from mechanical stress. Since its discovery in 1880, piezoelectrics have found their way into our day-to-day lives. For example, they are used in the automotive industry for accidents. The stress created from an accident will move the piezoelectric, and the voltage created will deploy the airbags. In this experiment, we studied the first natural vibration of a bar and its correlation to the voltage provided by the piezoelectric mounted on top as a result of the movement.

Abstract

For this experiment, we measured the voltage over time of a vibrating 364.6 X 25.3 X 2.8 mm 6061 aluminum bar, for a little over a second on an oscillator. Voltage is at its peak (of about 0.3 V) at the very beginning, so as a result, we wanted to calculate the first natural frequency of the bar. Both the theoretical and experimental first natural frequency was calculated, using two different formulas. The experimental formula uses some of the data collected while the theoretical formula uses the measurements of the bar and other constants. The theoretical and experimental data were calculated to be 17.01 Hz and 13.9 Hz, respectively, and the error calculated between the two values is 18.28%. We believe the reason behind the error may have been that connections (the beam to the table and the wires between the piezoelectric and the oscillator) were not completely secured to each other.

Nomenclature

ω_{nf}= First Natural Frequency (rad/s)

f= frequency (Hz)

α= 1.875 (constant)

E= Young's Modulus of Aluminum (Pa)

I= Polar Moment of Inertia

m= mass (kg)

b= length (meters)

h= height (meters)

L= total length of bar (meters)

ρ= density (kg/m^3)

T= time (seconds)

Background Theory

The goal of this experiment is to compare the theoretical natural frequency with that of the tested natural frequency. Natural frequency is the frequency at which an object oscillates freely without damping forces. This can be found using:

$$\omega_{nf} = \alpha^2 \sqrt{\frac{EI}{mL}}$$

The letter "I" denotes the polar moment of inertia of the rectangular aluminum bar being tested. This can be broken down into:

$$I = \frac{bh^3}{12}$$

The mass of the object can be acquired by using the density of aluminum:

$$m = \rho * bh$$

To obtain the natural frequency in Hertz:

$$f = \omega_{nf} * .159155$$

The experimental frequency is obtained by:

$$f = 1/T$$

Experimental Setup

This experiment was set up by adhering a piece of Piezoelectric material to an aluminum bar with sensors attached to measure vibration readings that in turn would be read in voltage output. Our group was not able to set up our apparatus due to time constraints but our lab technician and professor's assistant, Ricardo Martinez, was able to set up an aluminum bar with the piezo material adhered to the top of the bar, securing it to a surface edge to allow vibrations, and attaching the sensors to the piezo material that would give readings on a digital oscilloscope. We assumed the metal bar to be aluminum and based our calculations with aluminum properties. Below we display how our apparatus was set up to collect data. The blue bar attached to the top of the beam shown is assumed to be the piezo material adhered to the aluminum rod.

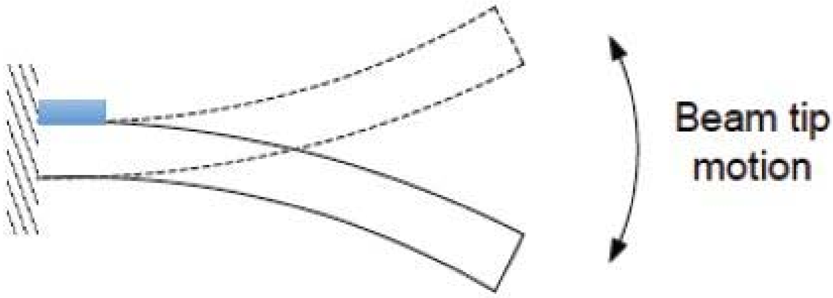

Figure 1: Beam's reaction when force is applied to beam's non-fixed edge

The results were gathered using an oscilloscope and we were to read and analyze the data to compare it to a first response natural frequency of a cantilever beam that was to be fixed on one edge. The following image is an oscilloscope similar to the one we used in our experiment. The sensors on the piezo material were transferring any data collected to this machine, which would give us data to analyze frequencies.

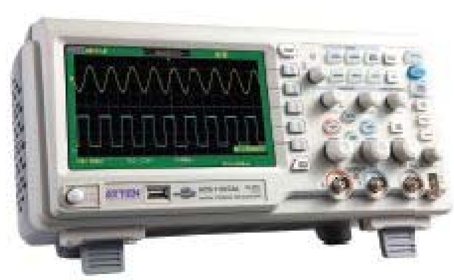

Figure 2: Similar oscilloscope to what was used in experimental trials

CHARTS:

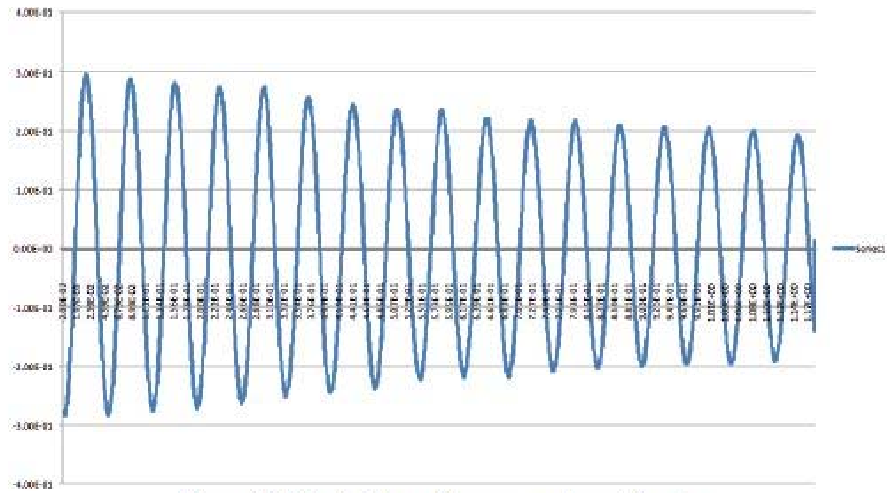

Figure 3: Data Retrieved from experimental setup

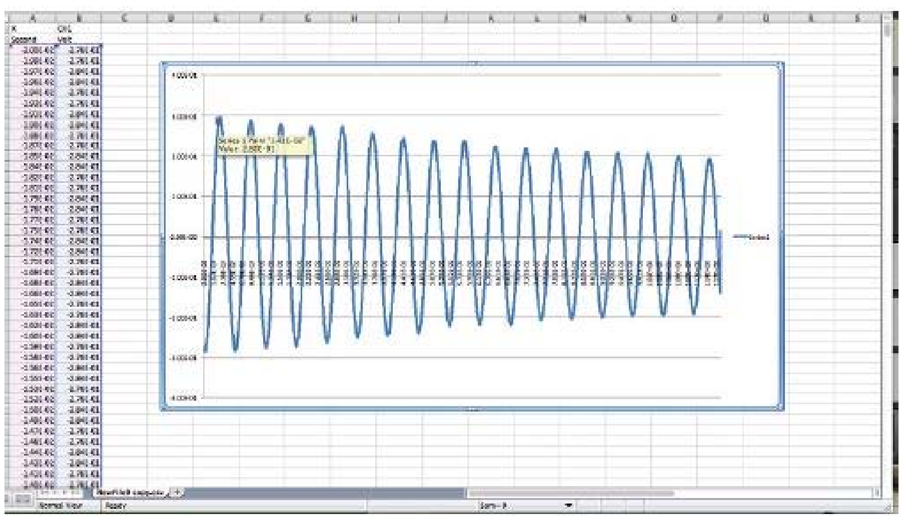

Figure 4: Data point chosen as X_1

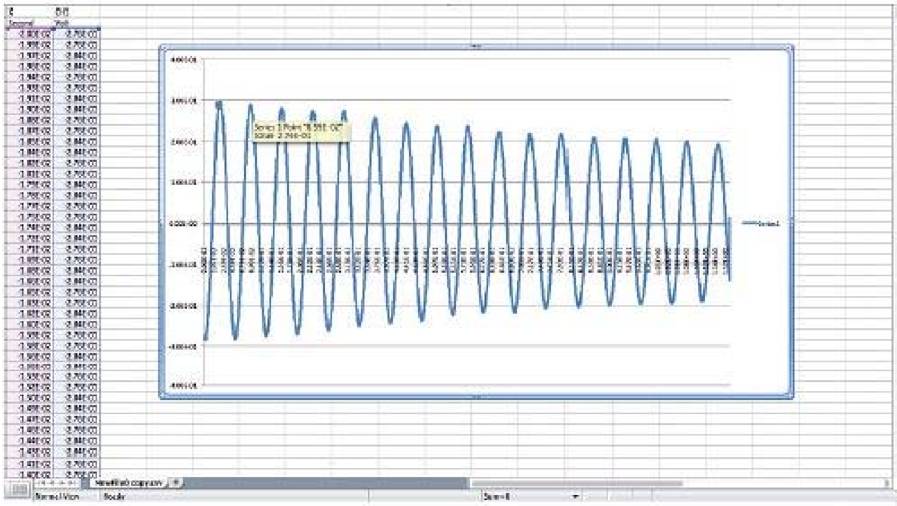

Figure 5: Data point chosen as X_2

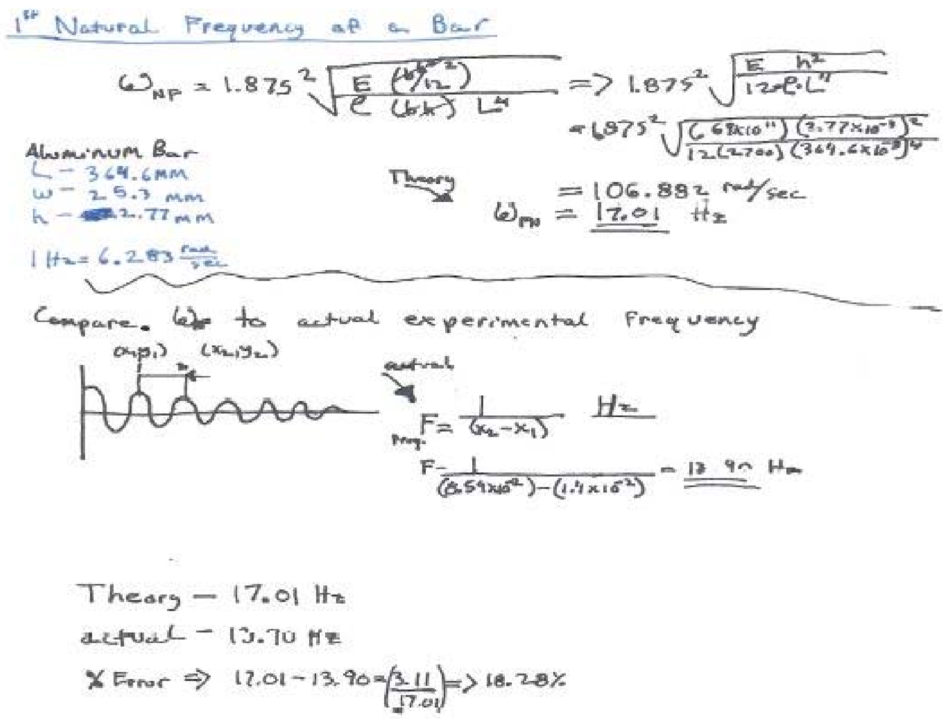

Figure 6: Calculations used to compare experimental/theoretical results of natural frequency

Discussion/Conclusion

For this experiment we calculated the natural frequency of the bar. The graph shown above is the Voltage vs Time graph we obtained from the readings on the oscilloscope. Using the graph readings and dimension of the bar we calculated an experimental natural frequency of 13.90 Hertz. We also calculated the theoretical natural frequency; to compare the both frequencies and we obtained a result of 17.01 Hertz. There is an 18.28 percent error between the frequencies. The error could have been caused by many things such as the placing of the piezoelectric, a faulty wire to the oscilloscope, or a lose screw securing the wires. One other factor that could have given us error in our results was how rigid our fixed end was. We only had our apparatus secured with a clamp but if it were to truly be fixed in position using a strong adhering material or fixed it to the edge by bolting it down, it may have given us a more precise result of what we were experimenting.

Natural frequency of a bar is defined as the frequency at which a system tends to oscillate in the absence of any driving or damping force. Theoretical and experimental calculations will not match up perfectly due to losses in the experimental setup and testing, however these losses can be calculated and determined to be theoretical with certain equations. Assuming losses engineers can calculate the precise natural frequency of a system, or bar, to determine its design limits. Now, why is natural frequency important? If a system response is dominated by a very lightly damped second order response, there will be an extremely large oscillation at the resonant frequency. If they forces within the system exceed the design limits, it may be destroyed. Shown from calculations and charts obtained in doing the experiment and theoretical approach to discovering the natural frequency of the bar, the group calculated the theoretical value to be 17.01 Hz while the experimental value cameo it to be 13.9 Hz giving a percent error of only 18.3%. For the aluminum bar used in the experiment this allows understanding of how it would react if used in the design of a machine part, tool part, etc... so as to help engineers used the best possible material and/or thickness to design said part.