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”No-Lecture Fridays” - Engaging Students on a Weekly Basis with Open-Ended Active Learning Problems in an Undergraduate Vibrations Course

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Abstract

In math-intensive engineering courses, a traditional, lecture-based style of instruction can lead to a loss of engagement and focus amongst students. Additionally, students often have a hard time connecting the mathematics they learn in the classroom to real-world engineering applications. Conversely, transitioning to a wholly active learning curriculum, or even flipping the classroom, can help demonstrate how the material applies to real-world problems, but these approaches can lead to mixed results in learning outcomes. We attempted to strike a middle ground between these two extremes in a mechanical engineering, junior level vibrations course at Villanova University by implementing what we called “no-lecture Fridays.” Each Friday session of class was dedicated to allowing students to work on an often open-ended, real-world application of the content presented in the classroom earlier in the week. Students used the full Friday class session to work through these problems in small groups and submitted their solutions to be assessed for credit in the course. These sessions challenged students to approach problems that may not have a single correct solution and to think creatively about how they can apply the course content to a unique application. The no-lecture Friday format was implemented during the Fall 2019 and Fall 2020 semesters across five total sections of the course. In this paper, we will thoroughly explain the no-lecture Friday format, present example problems, and discuss faculty and student perceptions of the format.

Introduction

Historically, engineering education has been very “lecture" based. This is the scenario where a professor stands in front of the room and talks *at* students and in turn they are expected to seamlessly absorb and understand the content. However, in the past several decades, pedagogical research has proven that this is not a very effective way of teaching [1]. Research has shown that by including active learning exercises in an engineering classroom, student’s learning and retention is significantly increased, and the achievement gap between underrepresented students and their counterparts can be narrowed [2, 3]. These exercises are often loosely defined as “any instructional method that engages students in the learning process" [1]. There are a variety of styles and approaches to active learning in an engineering classroom. These exercises can range from a simple poll or discussion in class to the extreme of completely flipping a classroom in which students learn content outside the class and use class time to work on problem sets, active learning exercises, projects, or similar activities. The latter extreme hopes to allow students to work on problems in a more controlled and collaborative environment than doing problem sets at home on their own. Flipped classrooms have shown positive results in some engineering courses, but this is not universal for all implementations in engineering courses with some studies showing mixed results in learning outcomes [4].

At Villanova University, all mechanical engineering students are required to take a vibrations course as part of the curriculum during their junior year - ME3102: Dynamics II. The content in this course is quite derivation heavy and mathematically intensive. We have noticed in the past that students often have difficulty connecting the content of the course to real-world applications, for example when abstracting a physical system into a lumped parameter model, as they get very fixated on the mathematical equations while losing sight of how these equations are applied to physical systems. Additionally, because this course is mathematically difficulty, students can struggle working independently. For these reasons, we sought an active learning implementation for the course that could better promote collaborative learning among students as well as aid in helping them connect content from the course to real-world applications. We wanted an approach that would allow for course content to be delivered in a synchronous and engaged lecture-style classroom setting, while also allowing students to attempt problems in a collaborative, open-ended environment. This led us to a course model that sets aside one day per week to work on active learning problems in class with no lecture. We did these on Friday, hence the name ‘no-lecture Fridays’. The no-lecture Friday format was implemented during the Fall 2019 (3 sections of 25, 24, and 16 students) and Fall 2020 (2 sections of 31 and 25 students) semesters across five total sections of Villanova’s Mechanical Engineering Vibrations course, Dynamic Systems II. The sections averaged approximately 24 students, although the methodology could be implemented in larger classes given a sufficient number of instructors. Due to the Covid-19 pandemic, the Fall 2020 implementation of no-lecture Friday was done online via Zoom. We would like to note that the observations we have made about student learning that led us to this approach are not unique to a mechanical engineering vibrations course and what we are about to present can be emulated in any engineering course where it is felt that students are struggling to connect content with real world applications.

No-Lecture Fridays

In the in-person implementation of no-lecture Fridays, students attended a normal 50 minute class session on Mondays and Wednesdays where the underlying theory and mathematics of the course content was taught. These lessons were presented in a traditional classroom setting with short active learning exercises included into the lesson plan meant to keep students engaged, such as polling, discussions, and think-pair-share exercises. On Fridays, students would attend a 50 minute no-lecture Friday session that would take place in a classroom specifically designed for active learning sessions. This classroom had large communal tables to best facilitate collaborative learning and display monitors at every table. Students were asked to self-select groups during the first no-lecture Friday sessions and then sit with this group each Friday.

During the first few minutes of these sessions the instructors would describe an open-ended problem that applied that week’s content to a real-world application. Student groups then spent the rest of the class session working on the problem as the instructors (who in this case were the professors teaching the course, but could also be TA's) circled the room guiding groups by asking questions meant to make them think more deeply about the problem. Students would submit their solutions to the problem as part of that week's homework assignment. In general, this addition to the homework resulted in little to no reduction in the homework assigned without no-lecture Friday as the no-lecture Friday projects were designed to be finished in one class period. All submissions were graded on a participation basis and feedback was given to the groups about their approach. Students who missed a given session were asked to work their group on the assignment, but not penalized for missing class. During the Fall 2020 implementation of the no-lecture Friday module, all class sessions were done online via Zoom. The group exercises on Fridays were conducted using Zoom's breakout room feature.

A supplemental question was added to the Villanova's standard end of the semester Course and Teaching Survey (CATS) to evaluate the effectiveness of the no-lecture Friday implementation. These surveys are completely voluntary and the responses are kept anonymous. Students were asked to rank their agreement with an assessment statement using the five point Likert scale which ranged from 1 (Strongly Disagree) to 5 (Strongly Agree) [5]. The statement students were presented with was "The 'No-Lecture Friday' format of the course helped to better facilitate my learning of the presented course material." These data are presented in the results section of this paper and its inclusion is approved by the Villanova Internal Review Board IRB-FY2021-172.

Example Problems

The main goal of the no-lecture Friday exercises was to have students connect the course content to real-world applications. As such, many of the exercises required students to consider physical systems and see how they could apply what they had learned in class to the problem at hand. One such problem that we presented the students with was the design of a simple hammock, see Fig. 1 for the problem handout. We told students that dozens of these hammocks were going to be installed on campus and it was their task to select the appropriate material from an online retailer for the cabling that would be used to support the hammock. Students took a variety of approaches in how to model and analyze this system. Some modeled the hammock as a simple pendulum while others abstracted it to a mass-spring system. Some analyzed the model using pencil and paper to work out the equations of motion by hand while others used numerical simulation methods in MATLAB, that we had covered in previous class sessions, to simulate the system. The students engaged in thought provoking conversations considering what scenarios the hammock would need to face during their analyses. Would there be one person in the hammock at a time? Two? Three? (These would be on a college campus after all.) What would the initial conditions of the hammock be? Is it possible that someone would jump into the hammock with a running start? How would the length of the material chosen change the natural frequency of the system? Given their analysis and discussions, students chose a material and wrote a short memo describing their eventual material choice, approach, and calculations.

In another no-lecture Friday session, we highlighted how the course content could be used to identify system parameters. Rather than tell students that the linear equations of motion we studied in class are a simplified representation of real-world systems, we wanted them to discover this find-

ME 3102: Dynamics II, Fall 2019

No Lecture Friday #2 – Due Wednesday, September 11th **at the Beginning of Class**

<u>Objective</u>: Use the dynamic analysis techniques we have been discussing in class to make design decisions

<u>Deliverables</u>: In groups of two to three, write a short memo summarizing your results to the problem below and upload it to Blackboard with your HW2 assignment (an example memo is attached on the next page). As an attachment, please include any support material that helped you make your design decisions.

The playground and leisure equipment design firm you work for (Jungle Jim's) has been asked to design hammocks to be installed on Villanova's campus. After some work, the conceptual design for the hammock is shown in Figure 1.

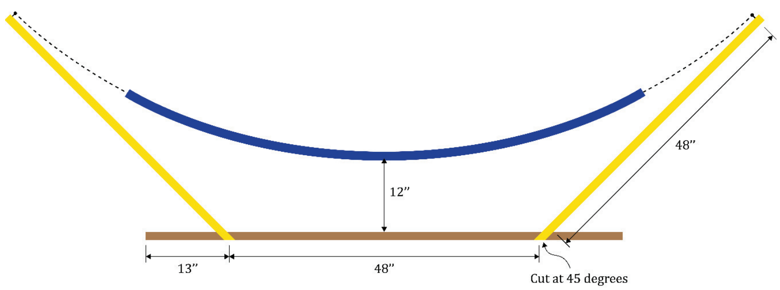

Figure 1: Conceptual design for the VU hammocks by Jungle Jim's

Before you can build a prototype, you need to choose a material for the support cables of the hammock (shown as dashed lines in the figure). In the process of choosing the cables, please do the following:

1) Determine the weight that the hammock should support.

2) Model the hammock as a simple pendulum. Is this model sufficient? Is using this model for the hammock "as good as" using it for a swing (as we did in class)?

3) Determine the expected max tension in the cable. Make sure you think about all the possible operating conditions the hammock will be put in.

4) Based on this information, specify the cable material and size – you might have to resurrect some mechanics knowledge to take this step.

Figure 1: Handout for the hammock design problem used in Spring 2019.

No-Lecture Friday	Semester	Description
Simulating Dynamic Systems	Fall 2019 & 2020	Used MATLAB to simulate the motion of a simple mass-spring system and compared to the exact solution identifying differences.
Hammock Design	Fall 2019 & 2020	Modeled a simple hammock to determine anchoring cable material choice.
Diving Board	Fall 2019 & 2020	Modeled a diving board based upon video of the oscillating system to determine the Young's modulus of the board.
System Identification from Free Response	Fall 2020	Identified the natural frequency and damping ratio of a mass-spring-damper model to best fit real data collected from a demonstration of a system's free response from perturbation.
Identifying Damped Systems	Fall 2019	Identified real-world overdamped and underdamped systems around campus and recorded a video of each to post to a class discussion board. Estimated the natural frequency of the underdamped systems.
System Identification from Forces Response	Fall 2019 & 2020	Identified the natural frequency and damping ratio of a mass-spring-damper model to best fit real data collected from a demonstration of a system's free response from perturbation.
Introduction to Laplace Transforms	Fall 2019 & 2020	Solved multiple practice problems of Laplace and inverse Laplace Transforms.
Modeling Input to Robot Using Laplace	Fall 2019 & 2020	Estimated the piece-wise input function to a robot given a provided video and then mathematically modeled the function and performed a Laplace transform on it for analysis.

Table 1: A full list of no-lecture Friday exercises presented during the Fall 2019 and Fall 2020 semesters.

ing on their own. We performed a simple mass-spring-damper demonstration with an educational lab setup. The mass of the system was perturbed from its resting position and the data of its free response were collected and distributed to students electronically. Students were then tasked with identifying the damping ratio and natural frequency of the system. Some students approached this problem using trial and error in MATLAB while others used methods learned in class, like the log-decrement method. Toward the end of the session, inevitably, student groups began to wonder if they could ever perfectly match the response. This led student groups to interesting conversations about linearity and what is overlooked in the linearized modeling process used in class.

A full list of all the no-lecture Friday exercises along with a short description of each can be found in Table 1. Because of the online nature of the Fall 2020 semester, some no-lecture Friday lessons that were presented in the Fall 2019 semester could not be accommodated in the Fall 2020 semester.

ME 3102: Dynamics II, Fall 2019

No Lecture Friday #6 – Due at end of period (but not graded)

Your goal today is to find the damping ratio (ζ) and natural frequency (ω_n) of the spring-mass-damper system we just tested. You have the following plots (and corresponding Matlab script and data available on blackboard) that were obtained experimentally.

Deliverable: Two sentences about how you approached the problem and your answers.

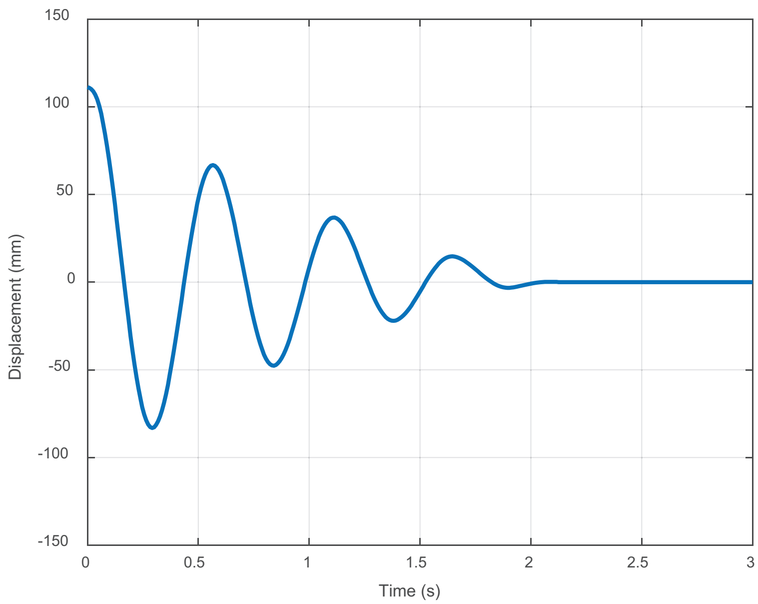

Figure 1: Experimental Step Response

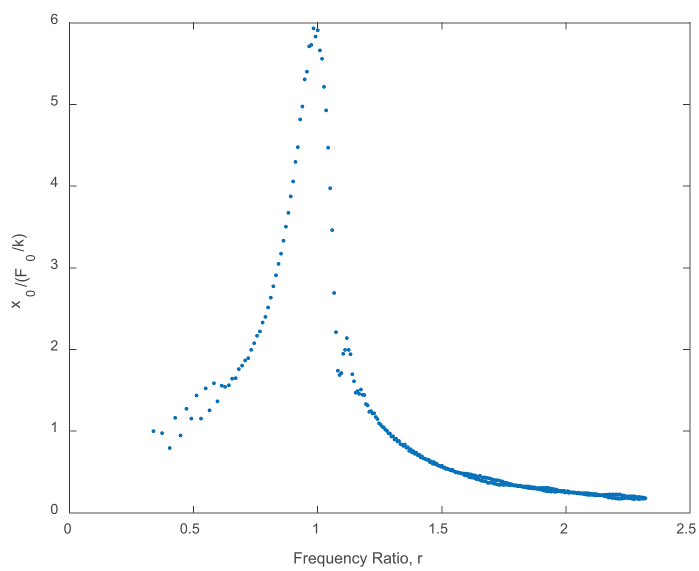

Figure 2: Experimental Frequency Response (derived from the chirp signal you saw)

Figure 2: Handout for the system identification problem used in Spring 2019.

Results

From a teaching perspective, anecdotally we felt that the no-lecture Friday format led to more, in-depth discussions about the course topics. We believe this stemmed largely from the open-ended nature of some of these exercises along with the collaborative work environment in which the students participated. Many of the end of the semester feedback comments spoke positively about the no-lecture Friday format. Of the 121 students enrolled across the five sections of the course that no-lecture Friday was implemented in, 95 completed the CATS supplemental question pertaining to the no-lecture Friday format. Students were asked to respond using a Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree) to the statement “The ‘No-Lecture Friday’ format of the course helped to better facilitate my learning of the presented course material." From the 95 responses, the average response was 4.2 with 81.1% of the students responding with a 5 (“Strongly Agree") or a 4 (“Agree"). A full distribution of the responses is shown in Fig. 3.

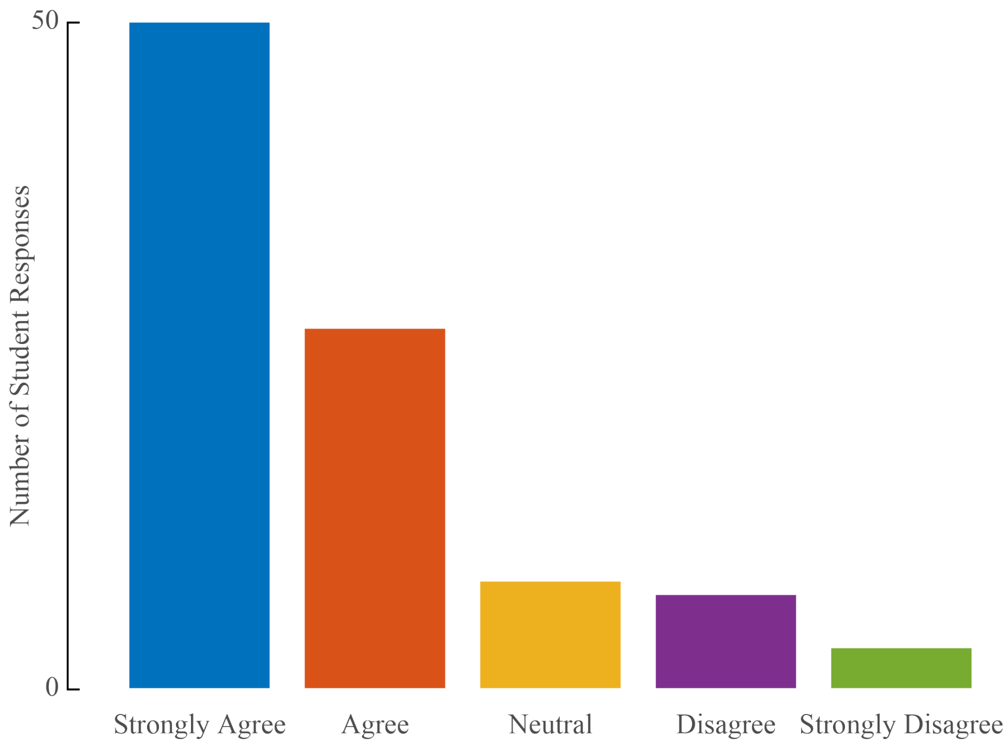

Figure 3: Distribution of student responses to the supplemental CATS question “The ‘No-Lecture Friday’ format of the course helped to better facilitate my learning of the presented course material."

Discussion & Conclusions

Through the no-lecture Friday format, we sought to introduce real-world examples to an undergraduate vibrations course in a engaging and collaborative learning environment. This approach allowed students to engage with the mathematically intensive content of the course in a creative way on a weekly basis. Anecdotally, we found that students were able to engage with the content on a different level than a traditional lecture based classroom. Given the end of the semester feedback survey, most students seemed to have perceived that the no-lecture Friday format was aiding their learning process. However, it is worth noting that these feelings were not universal. We acknowledge that students have different learning styles and preferences and, like all pedagogical techniques, the no-lecture Friday format is not going to be perfect for every student. We also acknowledge that this format of teaching may reduce the amount of content covered in a course – in the vibrations course discussed above, slightly less time was spent on multi-degree of freedom systems (less than 5% of the entire course content), but we felt as though that trade off was worthwhile given the increase in engagement we observed. Given the findings presented in this paper, we plan to implement the no-lecture Friday format for the undergraduate vibrations course at Villanova University in future semesters to come.

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