Implementation of a Design Project in a Freshman Engineering Physics Course

Dr. Inci Ruzybayev, York College of Pennsylvania

Inci Ruzybayev is Assistant Professor in Engineering and Computer Science at York College of Pennsylvania

Benjamin J. Zile
Dr. Scott F. Kiefer, York College of Pennsylvania

Scott Kiefer has spent the past eighteen years teaching mechanical engineering at four institutions. As an exemplary teaching specialist in mechanical engineering at Michigan State University, Scott received the Withrow Award for Teaching Excellence, given to one faculty member in the College in Engineering for outstanding instructional performance. Scott specializes in machine design, vibrations, and controls. He started his career at the University of Puerto Rico at Mayaguez in the traditional role of teaching and administering a modest research program. At Trine University, a small private school in Angola, Indiana, Scott taught ten different courses from introductory freshman courses to senior design, while serving as advisor to many undergraduate research projects. For the last seven years, Scott has been at York College of Pennsylvania where his concentration is on undergraduate education in mechanical engineering.

Taylor Schmidt

Implementation of A Design Project in Freshman Engineering Physics Course

Abstract

Published literature clearly agrees that one of the key factors contributing to good students leaving engineering in their freshman year is that the students get bogged down in technical courses and fail to see the application of engineering in a real-world context. Students often fail to see the relevance of the technical skills they are learning in their basic math and science courses because they are presented with very few opportunities to apply these skills in actual engineering problems. In addition, many schools have included hands-on projects in first year engineering courses that concentrate on developing project management and teamwork skills. While these projects are certainly beneficial to student development, the types of projects assigned are usually solved using trial and error methods and rarely require the application of the concepts the students are learning in their math and science courses. These projects can solidify the idea students hold that math and science background is not required for design work and that the courses are merely intended to "weed out" students. Furthermore, it can cause students to become disillusioned with the engineering curriculum.

This paper suggests that physics classes are a good place to apply the basic skills being covered in the course to real-life situations. Specifically, it explains how to take a large-scale design problem actually encountered in a capstone course (the design of a SAE design competition vehicle), break it down into smaller pieces, and examine it within the structure of a physics course in engineering mechanics. The project is divided into parts that are covered throughout the semester focusing on force, power, and torque analysis. The overall goal of the project is to access preliminary design specifications given for the engine and transmission system in a new vehicle. The analysis includes an exploration of minimum torque and power requirements, gear ratios, efficiencies, and vehicle performance goals.

1. Introduction

1.1 Project Motivation

Although the demand in engineering graduates is high, the graduation rate suffers more than many other majors. According to the study done by Yoder [1], the median rate for graduation in 2013 from an engineering school within six years was 54%. Niemi and Warke [2] made some recommendations to increase the retention rate by examining the improvements made by other universities. They emphasized the importance of freshman year on the retention rate and made several suggestions; getting familiar with the engineering field, boosting student-faculty interactions by creating first-year interest groups and experiencing engineering practices in a first-semester course.

Problems and examples provided in recent physics textbooks are in general very realistic, however, some engineering students fail to see why they need to solve those problems in the first place. The project implemented in the freshman engineering physics course aims to increase the interest in engineering by showing them examples of what they learn in class will be applied to real-life problems when they graduate. Thus, students will be given the bigger picture from the beginning of their engineering program and will have a better understanding of what is expecting them in the near future as an engineer.

1.2 Project Background

Automobiles are complex machines resulting from over a century of engineering. Besides mechanical engineering, the disciplines of electrical and computer engineering are extremely important in the modern automobile, and civil engineering has created the infrastructure that allows us to build and utilize automobiles.

Designing the individual components for an automobile requires years of education and experience from a team of engineers. However, some aspects of automotive design come from a basic understanding of physics. This project introduces students to how a general understanding of physics can be applied to the design of a real-world machine and gives them a taste of what is involved in a senior capstone project.

2. Design/Method

2.1. Capstone Project Details

Many of the engineering schools across the country participate in the Society of Automotive Engineers student design competitions, and the projects are often done as a part of the senior capstone course. The most popular of these competitions involve the design of either a formula style race car or mini-baja off road vehicle. These projects are usually very visible to first year students, and sharing some of the design work that goes on behind the scenes can be very motivational for younger students. While these students may not be ready to perform sophisticated dynamic analysis or complex stress calculations, there are many opportunities for them to apply the concepts they are learning in an freshman physics course. They are ready to investigate things such as the effect of torque and gear ratios on the performance of a vehicle, how rolling resistance affects speed and acceleration, and how static and dynamic friction play a major part in the design.

One design opportunity that relates very well to the physics curriculum is the design of the drivetrain. The first step in drivetrain design requires the students to choose gear ratios. In order to choose appropriate ratios, they must consider many different factors and explore how they interact. For example, trying to maximize the top speed of the vehicle would require a very different gear ratio than trying to maximize the torque available for vehicle to climb a steep hill. Furthermore, it is possible to provide too much torque depending on the friction forces present between the tires and the ground. Taking it a step further, how the gear ratios chosen affect fuel economy is an important question. While the entire drivetrain design does require taking into account several interactions and requires making compromises to determine the best design, the calculations are well within the scope of a first-year physics course. With a well-structured activity, it can also be used to show students how to apply the concepts they are covering in class to a real-world design problem.

2.2. Engineering Physics Project Details

2.2.1. Engineering Physics - Mechanics Structure

Engineering Physics – Mechanics course is taught in the second semester of freshman year and it is a 5-credit course with 4 lecture hours and 3 lab hours. Class size is 40-45 students with 2 instructors present. One instructor takes the lead role and the other the support role during activities and problem solving. Fundamentals of Physics textbook from Wiley is used for reading, self-studying and homework and Exploratory Physics active learning workbook [3] is used in-class. The details regarding the workbook's active learning strategy was discussed elsewhere [4]. To promote critical thinking, students are required to solve homework problems in a structured layout and initial results were shared in another study [5].

2.2.2. Goal

The students are to perform a preliminary analysis of the design of a new car or truck. Given a chart of target specifications and goals for the new vehicle, a variety physics problems are solved throughout the semester that are directly related to the topic being covered at the time. The results of these problems are used to assess the limitations created by the stated specifications and check the feasibility of meeting the stated goals. In addition, there are opportunities for them to calculate data meaningful to people without physics and engineering background, such as maximum vehicle speed and fuel economy (i.e., miles per gallon). Specifically, the students complete the following tasks:

- Calculate the applied force required for the vehicle to achieve the stated goals.
- Find the approximate net force imposed on the road surface in the worst-case scenario.
- Calculate the engine power required for the vehicle to achieve the stated goals.
- Find the approximate highway fuel economy for their vehicle.
- Determine how engine speed and torque limitations will impact vehicle performance.
- Draw conclusions from the calculations (for example, why is the transmission needed, and which design targets will be most challenging to achieve).

Only minimal automotive background needed to complete the project, and students are provided with this background as the project progresses (no prior automotive knowledge or experience is necessary).

The students choose the type of vehicle (car, SUV, truck, etc.) for their project, and they are provided with customized specifications based on their choice:

- Vehicle weight (the maximum gross weight of the loaded vehicle).
- Engine fuel type (gasoline or diesel).
- Drag parameters (drag coefficient and cross-sectional area).
- Tire parameters (size and coefficient of rolling resistance).
- Engine limits (maximum speed and torque).
- Drivetrain gear ratios, including the transmission (variable gear ratio) and the differential (fixed gear ratio).
- The approximate energy efficiencies of the engine and drivetrain.

There are also three performance goals specified for each vehicle (again, customized based on the type of vehicle):

1. Start on and climb up a specified grade.
2. Maintain a specified speed while climbing any interstate highway grade (up to 6%).
3. Accelerate from 0-60 mph on a level surface in a specified time.

Each goal is addressed as the students complete a three-part analysis (force, power, and torque) as described below.

2.2.3. Part 1: Force Analysis (Chapters 5 and 6)

Students do the force analysis in two stages. Beginning with a basic analysis, they calculate the applied force required to meet the three performance goals if the vehicle was simply a box sliding on a frictionless surface (neglecting all resistive forces). These calculations serve as a good warm-up for the students, as it has a similar feel to the traditional textbook problems in the early parts of the force chapters.

Towards the end of the force chapters, the students are ready to do a full analysis of the forces acting on their vehicle. They again calculate the applied force required to achieve each of the three performance goals, but now considering all key external forces. A free-body-diagram (FBD) is drawn for all 3 cases, including all external forces (weight, normal, friction, drag, and rolling resistance). The internal details of the vehicle are still unimportant and can be ignored at this point (the vehicle is treated as a rolling box).

It can be very challenging for students to grasp the role of friction in a vehicle application. The students are asked to answer a series of questions about the role of friction for a human walking, and then discover that it is analogous to an automobile driving. They must learn that static friction does not always oppose the direction of intended motion, but rather direction of intended sliding. As the tires attempt to rotate backward, the tires push backward on the road, causing the road to push forward on the tire. This is an excellent opportunity to challenge them and improve their understanding of Newton’s Laws and friction concepts.

Drag force is very important in many real-world problems, but it is often covered only very briefly in physics courses. This project gives the students extra practice with drag. They are asked specific questions to help them figure out if the drag force is negligible, constant, or variable. For the variable case, they need to calculate average drag using calculus. Acceleration is approximated as constant, which is an acceptable assumption given the scope of this project.

The final resistive force to consider is rolling resistance. Even without a friction force opposing the motion, the tires still oppose the motion because they are non-ideal springs and are constantly flexing as they get squeezed against the road. To help with a conceptual understanding, it is helpful to first envision a soft object rolling on a soft surface, as shown in Figure 1. When stationary, both the object and surface are under compression, with all horizontal force components canceling. As the object rolls, both the surface and the object are under greater compression in the front, causing the net force on the object to tilt backward. This net force can be split into a perpendicular component (the normal force) and a parallel component (the force of rolling resistance). The same effect happens even on a relatively solid surface like pavement since all materials flex under load.

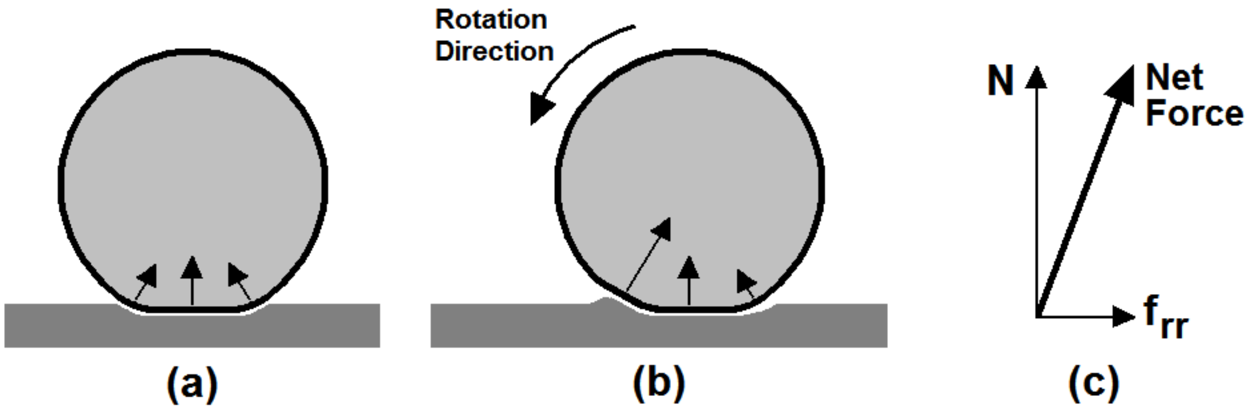

Figure 1. Exaggerated illustration of rolling resistance. (a) When a soft object rests on a soft surface, the net force on the object due to the surface is directly upward. (b) As the object rolls to the left, the net force becomes unbalanced and tilts to the right. (c) The net force can be split into normal and rolling resistance components.

Although rolling resistance is not strictly a friction force, it behaves like friction from an analysis standpoint:

- The force of rolling resistance (f_{rr}) is drawn on the FBD opposing the direction of motion of the vehicle at the surface (similar to how f_k is drawn for a crate sliding on a surface).
- It is calculated by multiplying the normal force (N) by the coefficient of rolling resistance (μ_{rr}): $f_{rr} = \mu_{rr}N$
- The coefficient of rolling resistance can be approximated as constant for basic analysis, so μ_{rr} is used similarly to how μ_s and μ_k are used in friction calculations.

Aside from the extra conceptual explanations, the analysis described above is of similar difficulty to problems normally encountered by students in this course. Alternately, the rolling resistance topic could be delayed (or even skipped entirely) if there is concern over confusing the students. In the scope of this project, only the fuel economy calculation is dramatically impacted by the rolling resistance.

As a final exercise in force analysis, students are given the opportunity to view the automobile from a civil engineering standpoint. Civil engineers that design roads and highways must consider the forces that vehicles impose on roadway surfaces (this affects roadway material selection, thickness, construction techniques, etc.). Students are asked to find the largest net force (magnitude and direction) that their vehicle may impose on a level road while undergoing acceleration. Students are given the weight distribution split among the tires, and they assume all of the vehicle's applied force occurs at a single tire (worst-case scenario).

2.2.4. Part 2: Power Analysis (Chapters 7 and 8)

As the students enter the chapters on energy and power, they are ready to use the results of their force analysis to find the average engine power required to achieve each of the three performance goals. Power is another topic that is sometimes covered only briefly in physics courses, so this provides them with extra practice. They perform the following steps:

- Decide which performance goals actually have a power requirement. The first goal (grade climbing) does not specify a rate or time requirement, so there is no power requirement to satisfy that goal.
- For the other two goals, they need to calculate the average power based on their calculated force and average velocity. This gives them the power required *for the vehicle* to achieve each goal.
- Using the given drivetrain efficiency, the average power required *of the engine* to achieve each goal can be calculated. Figure 2 shows a simple schematic of vehicle energy usage to explain where energy losses are. This is a good opportunity to introduce them to the meaning of energy efficiency and how to use it in calculations.
- Finally, they convert their results to the units of horsepower and compare to real vehicles in their category.

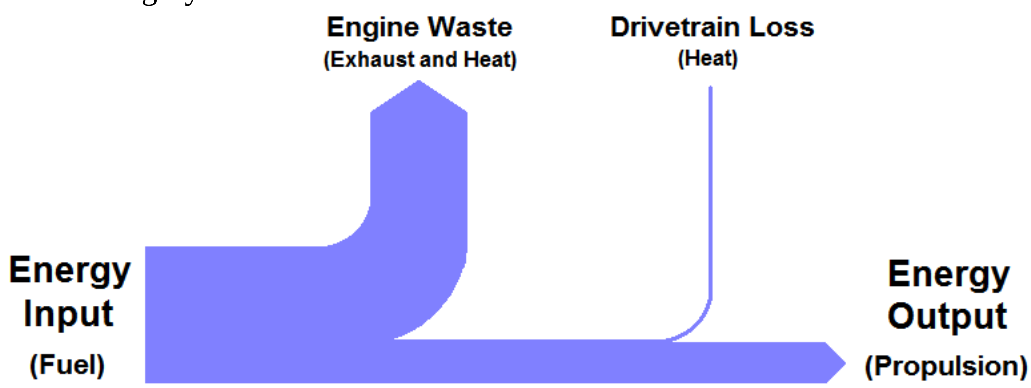

Figure 2. Simplified Sankey Diagram

The energy and power chapters also provide an additional opportunity for students to see that their calculations produce real results. With just a little bit of extra background information, they have all the tools needed to estimate the highway fuel economy (i.e., the miles per gallon) for their vehicle:

- Using their experience from the force analysis section, the students can easily calculate the force needed to push the vehicle down the highway at 60 mph on level ground.
- The students can also estimate the available work from each gallon of fuel. Starting with the energy density of the fuel used in their vehicle (approximately 125 MJ/gal for gasoline and 135 MJ/gal for diesel), they can use the given engine and drivetrain efficiencies to calculate the usable energy (available work) per gallon of fuel. This is an excellent opportunity for students to see a preview of thermodynamics, and how much energy gets wasted by engines due to the laws of thermodynamics.
- Knowing the available work per gallon and the force, they can calculate the distance per gallon (which can be easily converted into miles per gallon for comparison to real vehicles).

The fuel economy calculation is approximate because engine efficiency is highly variable. Nevertheless, with properly chosen specifications, the calculations do indeed produce results comparable to real automobiles, as shown in Table 1.

Table 1. Calculated highway fuel economy for student vehicles based on project specifications.

Vehicle Type	Weight Range (lb)	Efficiency (%)		Calculated MPG @ 60 mph
		Engine	Drivetrain	
Car (gasoline)	3000 - 3500	25	95	37.8 - 40.0
Crossover (gasoline)	4000 - 4500	28	95	31.6 - 33.0
SUV (gasoline)	5000 - 5500	30	95	22.5 - 23.1
Pickup (gasoline)	6000 - 6400	30	95	16.9 - 17.1
Pickup (diesel)	7000 - 7400	35	95	20.4 - 20.8
Dump Truck (diesel)	60000 - 70000	35	95	6.3 - 6.7

2.2.5. Part 3: Torque Analysis (Chapters 10 and 11)

This third and final analysis provides students with a simplified yet complete picture of how the vehicle operates. The link between all the specifications and goals becomes clear, and the students are able to draw conclusions about the basic design elements of their vehicle. They fill out the chart shown in Table 2 as they complete the analysis.

Table 2. Blank chart provided to students for torque analysis results.

Transmission Setting	Driveshaft Maximum		Wheel Maximum		Vehicle Maximum		
	Speed	Torque	Speed	Torque	Speed		Force
	rad/s	N*m	rad/s	N*m	m/s	mph	N
1st Gear							
2nd Gear							
3rd Gear							

Their analysis begins at the engine. Using the given engine speed and torque limits, the driveshaft speed and torque limits are calculated based on given transmission gear ratios. To keep the analysis condensed, the transmission has only three speeds (1st gear provides a large speed reduction, 2nd gear provides a moderate speed reduction, and 3rd gear provides no speed reduction). This is very similar to real automobiles, except that modern transmissions generally have five or more gear settings available. Students are provided with an overview of how the transmission works in the context of a rear-wheel-drive vehicle, as shown in Figure 3 (the concepts and calculations are the same for any vehicle configuration). Visual aids can be used to help with the understanding of this topic (a transmission video can be used in class and a simple Lego drivetrain can be built for students to feel the effect of gear ratio changes).

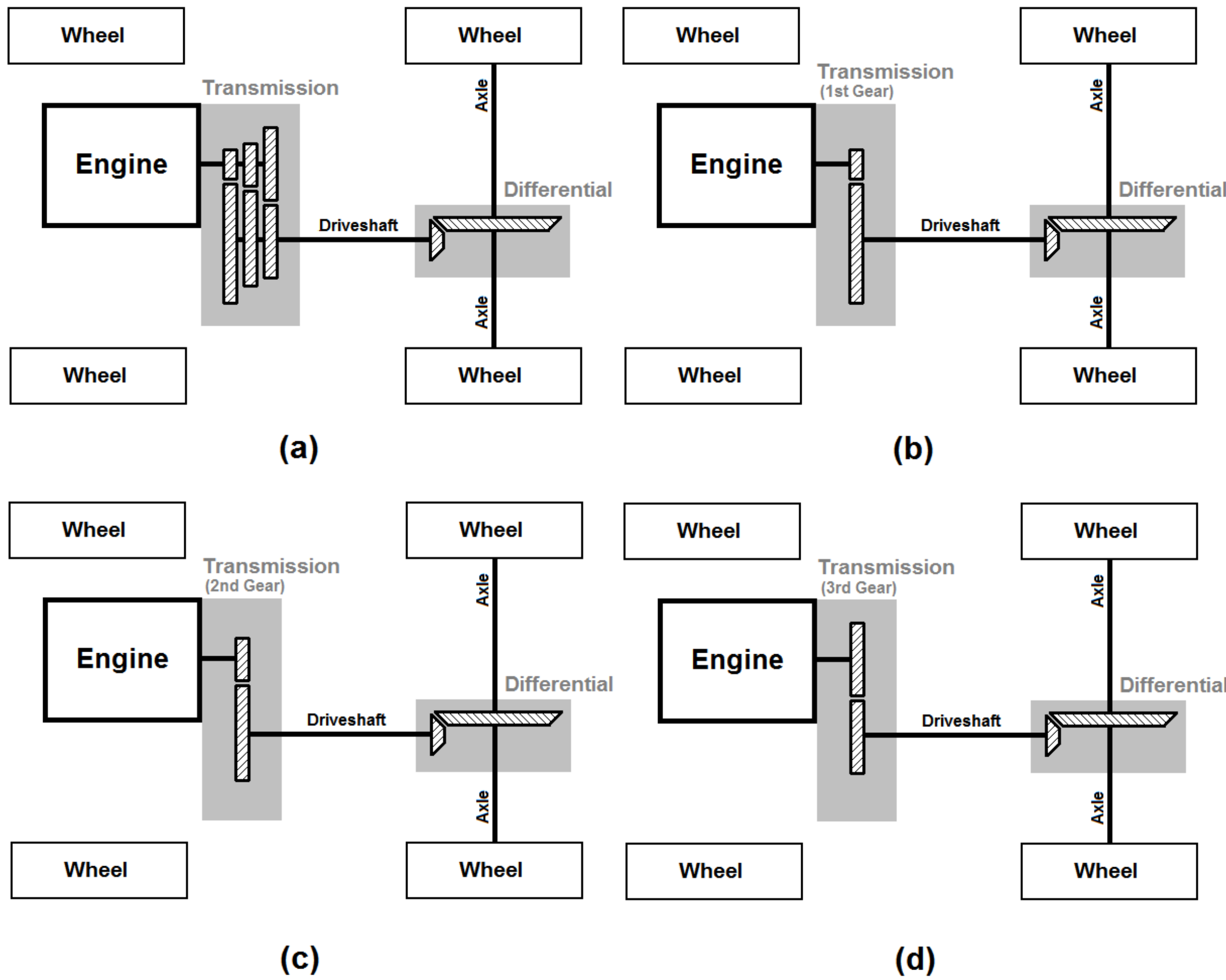

Figure 3. (a) A simplified representation of a rear-wheel-drive vehicle. For analysis, this is further simplified to show the transmission in (b) 1st gear, (c) 2nd gear, and (d) 3rd gear.

Once the driveshaft speed and torque limits are known, the maximum wheel speed and torque are calculated based on the differential gear ratio. The differential on a vehicle serves a number of purposes, but for this project it simply provides additional speed reduction and changes the torque direction. The students are instructed to assume that all the torque is directed to just one of the wheels (in reality, the incoming torque gets split between the two wheels, but the proportion depends on traction; assuming good traction, the net result on the vehicle is the same regardless of how torque is split). There is no need for the students to learn other details about how the differential operates unless they express additional interest. The axle speed and torque are equivalent to wheel speed and torque since they are bolted together and spin as a single rigid body. This is also a good opportunity to emphasize the difference between angular speed and translational speed.

Once the maximum wheel speed and torque is known, the maximum vehicle speed and applied force are calculated. For purposes of this project, the moment of inertia of the wheels can be ignored, so the force calculation is quite straightforward. The chart presented in Table 2 is now complete and the students can directly compare the last two columns to the stated performance goals and force analysis results from earlier.

2.2.6. Project Conclusions

With all calculations now complete, there are many possible conclusions to be made. The breadth and depth of the conclusions section can be adjusted based on time available and the interests of the students. Here are some possible transmission questions to ask the students:

- Why is the transmission necessary? Why would 1st gear not be used all the time? Why would the highest gear setting not be used all the time?
- Explain the trade-off involved with gear reduction.
- How would the transmission be used to achieve performance goal #1? Which gear ratio is best and why?
- How would the transmission be used to achieve performance goal #2? Which gear ratio is best and why?
- How would the transmission be used to achieve performance goal #3? Describe how the gear ratio should change as the vehicle accelerates.
- Would additional gear settings be desirable for any of the performance goals?
- There are also conclusions to be made regarding the vehicle design and given specifications:
- Are any of the performance goals not achievable based on the current specifications? Explain.
- How could the design of the vehicle be changed to make goal #1 easier to achieve? What about goals #2 and #3?

3. Survey Results

Feedback was collected from senior students who are in Capstone II and working on their design. 25 engineering senior students responded to the survey. The survey data is shared with the freshman in the engineering physics course and used as an encouragement.

As shown in Figure 4, 84% of the seniors participated in the survey agrees that there is not enough project and design experiences during freshman year to prepare them well for Capstone Project.

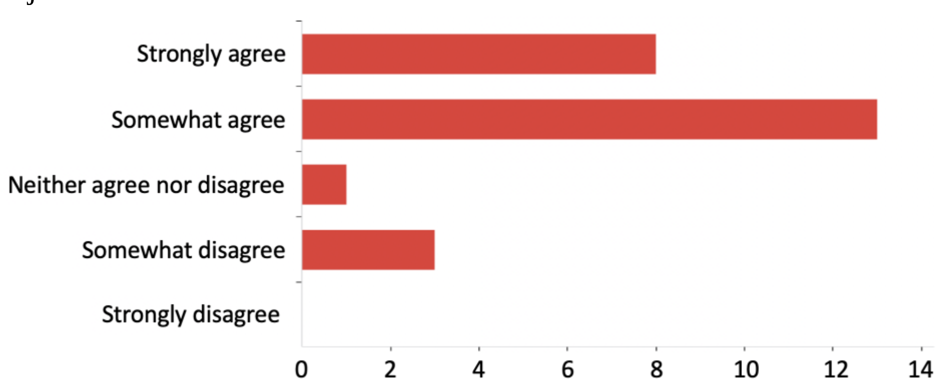

Figure 4. Survey results for the statement 1: “Do you agree that there is not enough project and design experiences during freshman year that prepares you well for the Capstone Project?”

Some students commented on the 1st statement (to make it clear to the readers the year of courses mentioned in the comments added in italic by the authors):

- Having to think for yourself and apply the laws of physics to real world applications helps in understanding the principles.
- I feel like students in freshman year should have some sort of involvement in capstone to learn the projects and what they like for when they actually get to work on the project.
- Capstone is very challenging and the Machine Design project, *junior year course,* along with the multiple labs performed in other classes somewhat help with knowing what to expect going into Capstone.
- I think that without my background in different types of manufacturing it would have been much more difficult.
- Not much experience in the machine shop.
- I did not expect any design/fabrication projects during my freshman year. I was focused on passing Physics.
- The Mechanical Engineering (ME) side of Engineering Practice and Design Studio (EPADS), *freshman year course,* was better, and Intro to ME, *freshman year course,* did a lot of part design, so that was good. CS101, *freshman year course,* was good because it introduced a lot of important concepts in programming, too.
- Anything that involves learning how to manage deadlines will help mitigate future ones (i.e. machine design was good but somewhat overwhelming)
- As a Freshman, I think the EPADS project was sufficient. However, I would strongly agree that there is not enough design experience between Freshman and Senior year. Most 'design' projects are too guided and they appear as just plain old labs.
- Show the importance of research and using the machine shop.
- Half of EPADS was valuable.
- We do a lot of projects and making things, but I don't think we do enough of actually designing things that we then have to make.
- If you work hard and get good grades in your classes it's not hard to do well in capstone.

88% of the seniors also agreed on the benefit of having projects in the Engineering Physics course as shown in the Figure 5.

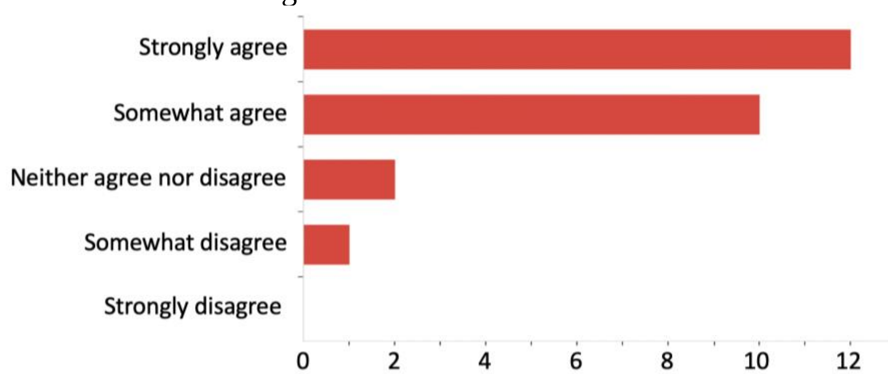

Figure 5. Survey results for the statement 2: “Do you agree that having projects in Engineering Physics: Mechanics course related to Capstone Projects would be beneficial to students?”

Some students further commented on the 2nd statement:

- Practice on determining forces and inertia in actual devices.
- Maybe running calculations for actual applications of physics for project teams to assist the capstone/check what they have done.
- I do not think that they necessarily need to build a project of their own, but I do think that it would be worthwhile for them to get a better understanding of what Capstone is prior to taking the class. Help them to understand how much work it is actually going to be. Give physics problems that deal with scenarios that baja and formula will experience.
- As long as it didn't take over the class and add a ton of work.
- Would like to learn more about cars before capstone
- They may not understand why they're doing projects, though. I wouldn't understand if I was a freshman and had a long class, plus extra classes
- As I am in the drone project, we have an Airframe team that probably deals a lot with mechanical physics. As an electrical engineer myself, I would like to ensure there is a role that involves more electrical work. Connecting the disciplines would be extremely beneficial, and I see that most capstone projects already do this.
- It would depend on the scope. Some find physics to be difficult enough. The project would provide a huge help.
- There are already enough projects in this program.
- Should also do one in E&M, *sophomore year physics course*!
- I think what would work best is something not structured like a lab, but more of a project that you find interesting, and select on your own, and can approach with the professor's guidance. Something decided for them leaves a lot to question about the program/discipline.
- I believe that it is too early to do a "capstone" for students in the freshman year. A "capstone" during sophomore year would be great since the students would have had some engineering classes to understand the process required to design and fabricate something.
- The issue I see with this is students struggling even more in physics than what they already do, as it is known that it's the first of many difficult courses that begin to weed out students from the engineering program. Putting a capstone style project on top of an already difficult course this early in a student's career may put even more stress on the student.

4. Discussions and Conclusions

In this study, we presented the implementation of a simplified Capstone Project into Engineering Physics course curriculum. An auto project was selected as the first implementation of a Capstone Project since the majority of students work on a race car in their senior year and the selected project covers many topics learned in Mechanics.

Although current physics textbooks provide realistic examples and problems in students' perspective, the assigned textbook problems are usually a way to collect points to pass the class. It is hard for them to anticipate what real problems they will encounter in real life after they graduate. Introducing simplified Capstone Projects makes it more realistic as they realize that the project is an example of what they may end up doing after graduation.

Freshman are also encouraged to talk to seniors about their Capstone Project and discuss the challenges they experience and examples of how to overcome those challenges. This will help freshman understand, at some level, what it takes to be an engineer and motivate them from the first year of their program.

This project is implemented into freshman year Engineering Physics: Mechanics course curriculum such that students are given assignments in lieu of some of the homework problems assigned in the homework assignments. The topics are covered in class and project related material is especially emphasized. The number of homework problems assigned for each chapter varies depending on the project assignment for that chapter. The project should not bring extra load to students' already heavy schedule. On the contrary, working on such project that covers several important topics of the course help students see the connection between topics and the real-life applications.

In conclusion, more students leave college after first year. Having projects like these could be the bridge we need as instructors to guide students in the right direction and help them see the future awaits for them. The knowledge of fundamental laws and theory is crucial for success in understanding the concepts in design projects. However, if we want to keep the good students in their program we should consider introducing more projects starting from the first year since these students want to see where they will apply the knowledge they gain in class right away.

5. Future Plans

There are many options available for implementing this kind of a project. Overall, the goal is to spread the material throughout the course as much as possible so that the workload for the students is not intense. It is also good for students to revisit and analyze their results frequently so that it stays fresh in their minds. With this in mind, it may be desirable to introduce some concepts and calculations earlier. For example, students could begin learning about vehicle speed and acceleration concepts prior to the force chapters. Basic conceptual questions can be asked, unit conversions can be covered, and acceleration can be calculated. This is a good opportunity for students to become acquainted with the list of specifications and what it means.

There are also opportunities to extend the conclusions section of the project if time permits. The students could be provided with examples of engine torque and power curves. From this, students would conclude that real engines cannot produce full power and torque at all speeds. They could then be asked how this would impact their results and the vehicle design.

Students may or may not enter physics class with an existing interest in cars, but automobiles serve at least an indirect role in all of our lives, so it is a good place to start with introducing real-life problems to an engineering physics class. Nevertheless, other Capstone Projects may be implemented in near future. Giving the students a choice of projects will further increase student interest in the course. However, it will take several years to collect quantitative data to measure the effectiveness of these type of projects.

References

[1] B. L. Yoder, “Engineering by the Numbers: ASEE Retention and Time-to-Graduation Benchmarks for Undergraduate Engineering Schools, Departments and Programs” in *American Society for Engineering Education, ASEE, Washington, DC, USA, 2016.*

[2] A. D. Niemi and R. W. Warke, “Facing our Retention Challenge: a Self-Portrait” in *American Society of Engineering Education, ASEE 2011 Annual Conference & Exposition, Vancouver, BC, June, 2011*, https://peer.asee.org/17982.

[3] T. J. Garrison, *Exploratory Physics: An Active Approach to Learning Physics*. currently self-published, 2014.

[4] T. J. Garrison, (2015, June), “Active Learning Laboratories in a Restructured Engineering Physics–Mechanics” in *American Society of Engineering Education, ASEE 2015 Annual Conference & Exposition, Seattle, WA, USA, June, 2015,* 10.18260/p.23489.

[5] I. Ruzybayev, “Reinforcing Critical Thinking Skills Using a Homework Layout in Engineering Physics Course” in *American Society of Engineering Education, ASEE 2017 Annual Conference & Exposition, Columbus, OH, USA, June, 2017,* https://peer.asee.org/28789.