Interactive, Four-Stroke Educational Engine Model
(Technical Topic)

The Development of Mechanical Engineering Education at George Mason University, The University of Virginia, and Virginia Tech
(STS Topic)

A Thesis Project Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

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Fall, 2024

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

A traditional undergraduate mechanical engineering curriculum at any university includes courses such as statics, dynamics, thermodynamics, fluid mechanics and heat transfer. A key concept in such education is understanding how an engine works. The four-stroke engine, specifically, is a culmination of many mechanical engineering subject matters, including fluid mechanics (Radcliff, 1997, pp. 9, 107-109). A typical undergraduate mechanical engineering student may learn about the four-stroke engine through class lectures or may be able to gain hands-on experience through an automotive or motorsports related club. In recent years, engineering institutions, such as U.Va. have started to place more of an emphasis on hands-on experiential learning (Feigenoff, 2012, p.1). Unless students are continually engaged in this topic of internal combustion engines (ICEs), there is a possibility that they may not actually internalize the subject matter. Professor David Harris at Harvey Mudd College in California even claims that the lack of engagement in theory classes results in low retention of material (Harris, 2001, p. 367). With almost all ICEs being four-stroke engines, it is a topic that should not be forgotten (Colwell, 2019, p. 3).

It is also important to note the increasing presence of electric vehicles (EVs). Manufacturers such as Tesla, Ford, and General Motors have all designed EVs that are currently for sale. Some states have even set forth legislation to ban the sale of new gasoline powered cars. However, as of 2022, these EVs only make up 4.6% of the global new car market (Caparella, 2022, p. 2). This continues to show that ICEs are a topic that should not be forgotten.

So why is it that some engineering institutions teach such important mechanical engineering topics in different ways (i.e. lecture vs. experiential learning)? Why do some engineering institutions emphasize hands-on learning more in their curriculum – and is this directly shaped by universities? Could this difference produce graduates from different engineering institutions with different skill sets? In my limited work experience, I have always heard that engineering graduates from different Virginia schools (specifically, U.Va. and Virginia Tech) are best suited for different engineering roles. This is why I wonder how different engineering institutions can impact their graduates' skillsets. The study and development of engineering education methods is already a point of interest and discussion for many in higher education. In fact, Virginia Tech has a Department of Engineering Education and Ph.D. program dedicated to this type of research (Gonsalves, 2024, p. 6).

For current-engineering students, as well as prospective engineering students, this subject matter is of the utmost importance. It is beneficial to understand what a student will gain and benefit from a program – especially with the steep cost of a college education. Most students are also probably looking for different things in their college education after all. A certain type of engineering program may be what leads a student to pursue a career in engineering as opposed to another field. For potential employers of engineering graduates, this is also useful to understand, as some employers may be looking for graduates with distinct skill sets.

By building an interactive four-stroke engine model, our group hopes to provide the university with a new means to teach students about four-stroke engines, as well as provide ourselves with a meaningful project that will expand our knowledge regarding engines. The STS research hopes to look at how various public, Virginia engineering schools have developed their mechanical engineering curriculums over time, and how relevant social groups play into this development. More specifically, it will investigate how and why these programs have placed emphasis on different styles of learning and why some might support hands-on learning more than others.

Technical Topic

The first four-stroke internal combustion engine was built in 1876 by Nikolaus Otto – namesake of the Otto Cycle, a thermodynamic cycle that is covered in a typical undergraduate thermodynamics class (Radcliff, 1997, p.5). As its name suggests, the four-stroke engine relies on four strokes to create combustion and output power. These strokes are the intake stroke, compression stroke, combustion stroke, and exhaust stroke. Four stroke engines are commonplace in gas-powered vehicles, although it is important to note that other, less common engine types, such as the two-stroke and rotary engines do exist (Colwell, 2019, p. 3).

Engines make use of many different engineering subject matters, but none of the internal movements can be seen from the outside of the engine. This is due to design constraints requiring a closed control volume for the necessary internal combustion. Not being able to view the internal workings of the engine makes it much more difficult to understand the mechanisms that are utilized in a four-stroke engine. An interactive, open, four-stroke engine model will be created to help resolve this issue.

The deliverable, a four-stroke engine model, will be a single-cylinder engine for the sake of simplicity. This will be built from scratch and will not explicitly build on any previous work. However, it will gain inspiration from educational models such as the Rolls Royce AE 3007 and 3-D printed jet engine that can both be seen on the 2nd floor of the U.Va. Mechanical & Aerospace Engineering building (Figure 1). As a prototype for our main technical deliverable, we will also build a 3D printed single cylinder engine model.

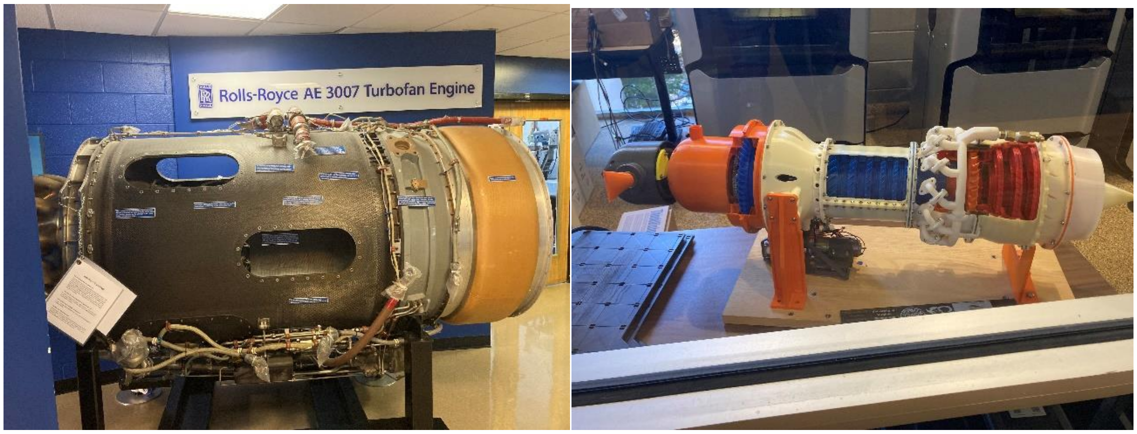

Fig. 1. Rolls Royce AE 3007 and 3D printed jet engine both seen in the U.Va. Mechanical and Aerospace Engineering building.

Using a single-cylinder engine, as opposed to a multi-cylinder engine, will ensure that only necessary and important components are included in the model. The engine model will also be relatively small, to allow for it to be moved to different lecture halls and labs for demonstrations. This small-scale, single cylinder engine will be cut in half, allowing for adequate viewing of the engine internals. A vertical mill will be used to cut the engine. The model will also include a display screen, LEDs, buttons, and a motor to improve its interactivity and functionality. The display screen and buttons will be used together to create an information display. The goal with this information display is to provide students and potential users with information regarding the engine; this could be information concerning the compression ratio of the model, or what the four-stroke process is. The buttons will allow for the user to interface with this display, as well as allow for the user to start and stop the motor. The motor will be a DC brushless motor that will power the crankshaft and move the internal mechanisms of the engine. The end goal of this is to create a model that will address and help users learn about how an internal combustion engine functions. By exposing the insides of the engine for easy viewing, the hope is that every U.Va. student will know exactly how a four-stroke engine model functions, and all the components that go into it. This four-stroke model will also help to emphasize the important concepts that may have only been covered in a non-tactile environment (lectures).

Similar deliverables have been completed by others prior to this. These models have been completed on all sorts of engine types, and to varying levels of automation and electrification. See Figure 1 for previous models completed at U.Va.. The main challenge with this deliverable will be implementing the electronic aspects of the model. Although our project group has experience in the field of mechatronics, we do not have extensive knowledge in some of the more advanced electrical engineering topics.

STS Topic

Engineering education is a growing research field for many university faculty members (Kondrashev et al., 2024, p. 1). In the Department of Engineering Education at Virginia Tech, their goals include improving teaching and learning practices, as well as improving organizations and systems within engineering education (Gonsalves, 2024, pp. 6-7). In recent years, the U.Va. School of Engineering and Applied Science has placed an increased emphasis on hands-on education – what they deem "experiential learning." This led to building the Ann Warrick Lacy Experiential Learning Center (at Lacy Hall). This building gives students an open space to work on hands-on projects with engineering organizations such as Virginia Motorsports, or Hoos Flying. Former professor George Cahen makes the point that these experiential learning opportunities allow for students to gain engineering experience separate from the standard practice of attending lectures and reading textbooks (Feigenoff, 2012, p.1). Meanwhile, Virginia Tech has opted to incorporate hands-on activities directly as a part of their freshman engineering courses (EF 1015 and EF 1016), ensuring every engineering student will have some sort of hands-on experience. Some of these activities include building a bridge and a ping-pong ball launcher (Connor & Malzahn Kampe, 2002, pp. 7.563.1-7.563.2). Harvey Mudd College in California has found success using laboratory courses in their Department of Computer Engineering to bring together theory and hands-on experiences (Harris, 2001, p. 368). This is after a shift back to an emphasis on design, after a focus on the math and science aspects of engineering for many decades (Froyd et al., 2012, pp. 1346-1347). This example involving computer engineering laboratory classes is equally relevant to other engineering programs as they also frequently include laboratory classes (Fisher et al., 2007, p. 12.739.5). Just as these three examples show, many schools have different methods of delivering their engineering education and hands-on experiences. Other engineering institutions might not be able to place such an emphasis on experiential learning in their mechanical engineering curriculums. These other institutions may have had different social groups shape their curriculums, causing for a different style of education, such as a theory-based education.

This is all equally applicable to other engineering degrees such as biomedical engineering, electrical engineering, and software engineering. It is even applicable to other non-engineering degrees like architecture, biology, and business. All of these degree programs have different means of teaching students. Although my research only plans to examine the field of mechanical engineering, the SCOT analysis approach used could easily be applied to these other fields to examine why exactly they have different means of teaching students. A business student may have the opportunity to go to Wall Street and learn the ways of a New York stockbroker. They may also have lecture-based classes, where they can learn about marketing or finance. A software engineering student might have an undergraduate program that emphasizes project-based learning, or active learning (Aničić & Stapić, 2022, p. 76). Nevertheless, varying undergraduate degrees can be delivered in a plethora of ways to appeal to different types of students.

In mechanical engineering curriculums, there truly are no two schools that are the same. It may be very hard for all schools to implement experiential learning opportunities such as U.Va. and Virginia Tech; they may be limited by factors such as geography, or even finance. There are a lot of different factors that will go into determining a school's curriculum, and a lot of different types of programs will result from this. For example, some schools have opted for online undergraduate programs which allow full-time workers to continue their education (Dunham, 2003, p. 2). Elite institutions such as Harvard University and the University of California at Berkeley offer online degree programs – that helped educate 350,000 online students in 2003 (Dunham, 2003, p. 1). For the universities that offer online engineering programs, it may be a challenge to implement laboratory and design experiences, something that has been such an integral part of a traditional engineering program (Fisher et al., 2007, p. 12.739.5). This all raises the question, who has helped shape these engineering curriculums? Why have some institutions shifted their mechanical engineering curriculum to a hands-on approach? Why have some created online degree programs? Surely these different institutions have been influenced in creating their mechanical engineering programs by different groups of people – such as students, faculty, alumni, and accreditation agencies. This is what my STS research hopes to identify and understand.

In my limited work experience, I have had the opportunity to work with engineers and engineering students from many different universities – mainly from the state of Virginia. I have been intrigued by how engineering students and graduates from different universities have varied skill sets. A manager I worked with noted how recent graduates from these universities are more likely to follow different career paths in engineering. For example, U.Va. engineers are more likely to pursue management roles, while Virginia Tech graduates are more likely to pursue technical roles. Could this be due to different emphases in mechanical engineering programs? And consequently, how have different relevant social groups helped develop these mechanical engineering programs with different emphases?

With such varying prices of a college education today, it is important to understand what students are receiving in their education (specifically, a mechanical engineering education) – and how this can vary at different universities. In the example of U.Va. and Virginia Tech mechanical engineers, there could be a pay gap between these different types of engineering roles. This is just one of presumably many differences varying engineering education backgrounds creates among engineering graduates in their respective fields.

My STS research hopes to dive deeper into the development of mechanical engineering programs at the University of Virginia, Virginia Tech, and George Mason University. Each of these institutions is a relatively large public university in the state of Virginia. The research will look at various social groups and how they have played into developing different mechanical engineering programs at the universities. It will help with understanding why some engineering institutions have shifted towards hands-on learning, why some have stuck with traditional lecture-based classes, and why some have even switched to offer fully online programs. This will be analyzed using the Social Construction of Technology (SCOT) theory. This theory claims that relevant social groups help to shape the development of technology (Klein & Kleinman, 2002, pp. 29-30). In this case, the technology will be mechanical engineering programs and the three relevant social groups to be examined will be those partaking in mechanical engineering programs (students and alumni), those developing the program (faculty and accreditation agencies), and those who indirectly benefit from the program (industry hiring managers and researchers). Following this theory, the impact and effect that these social groups have helped to construct this technology (mechanical engineering programs) will be analyzed. The main goal of this analysis is to see how these different social groups have helped shape mechanical engineering programs with different emphases.

The main challenge with this research will be the problem scope. Since the research will have a small scope (three Virginia mechanical engineering programs), it will most likely be challenging to find any research regarding the topic. The STS research will make use of any available research but will involve directly reaching out to these relevant social groups. Surveys will be utilized to gather necessary info from current engineering students and alumni, and interviews will be performed with the remaining, smaller social groups. These surveys will be distributed to students via email through student coordinators in each schools' mechanical engineering departments. An example of a survey question that could be asked of students could be, "What changes have you seen in your department during your time at the school, and have you had an impact on this change?" An example of an interview question that could be asked to faculty could be, "What do you hope students gain from their education here, and how do you implement this into the curriculum?" The overarching goal of these questions will be to understand how these programs have been shaped over time. The final deliverable will include a SCOT analysis of the three selected mechanical engineering programs in Virginia, with the main goal of seeing how this has led to differences in these mechanical engineering programs.

Conclusion

The anticipated final technical deliverable of this will be a single-cylinder, four-stroke educational engine model. This model will have many features that will benefit students and improve their overall understanding of the important mechanical engineering concept of engines, and specifically four-stroke engines. The anticipated STS deliverable will be a SCOT analysis of three different mechanical engineering programs in the state of Virginia. This will look at how three distinct social groups have helped construct or develop these mechanical engineering programs. If successful, the technical deliverable will help students to better visualize the internal components of a four-stroke engine, allowing for understanding of each components' function. The STS deliverable, if successful, will help with understanding why different universities and their engineering departments can produce engineers with such varied skill sets. This will also help with understanding of the unintended consequences that might result from this, such as pay-gaps and varying engineering education costs.

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