Design and Construction of Modern University of Virginia Themed Pinball Machine

Mechanical Engineers and Their Relationship with Implementing Sustainability Measures

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Mechanical Engineering

By
Adam A. Centanni

November 3, 2023

Technical Team Members:
Mina Ansari, Olivia Bearman, Phillip Bongiorno, Ian Chang, Thomas Cook, Benen Crombie, Scott Durkin, Ethan Green, Thomas Habron, Matthew Leclair, Issac Leshok, Jacob Leynes, Gabriel Lu, William McClung, Patrick Nguyen, Colin Sartori, and Keith Tam

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.

ADVISORS

Prof. Pedro Augusto P. Francisco, Department of Engineering and Society

Prof. Gavin Garner, Department of Mechanical Engineering

Introduction

The UVA Pinball Machine is an artifact of the Mechanical Engineering department. First worked on in 2016 by a previous Capstone group, today it is being revitalized by my technical team members and me. In a state of disrepair, my group and I were tasked with engineering a functioning pinball machine while simultaneously adding improvements. More broadly, considering the finite number of resources available on Earth and the certainty of consumption in modern society provokes a careful attitude when considering humans' relationship with material. To constantly bring new ideas to life with virgin resources is an unsustainable practice. With the Pinball Machine, the unique opportunity arose to not only imagine how our engineering education could be applied in real life, but also to think critically about how to recycle materials and work within an already existing system; how to become good stewards of material that came before us. By reengineering the UVA Pinball machine, our group is solving the problem of combining existing material with new inventions to create an improved system.

Studying the relationship between Mechanical Engineers and ideas of sustainability is outlined in two halves: a historical part and a critical part. The historical half is to understand how sustainability practice in Mechanical Engineering has evolved over time, which can inform areas of improving sustainability implementation. The critical half is to identify what sustainability means to Mechanical Engineers and consider why it is important they incorporate sustainable practices in their work. Mechanical Engineers have the ability to bring systems into reality using their knowledge. Such an aptitude for production must be considered with caution, as a finite number of resources does not allow for unlimited creation of new products. By studying the relationship Mechanical Engineers have with sustainable measures, the research is

solving the problem of identifying the barriers to implementing sustainability in designs and highlighting areas of improvement in sustainable designing.

As our technical team works on redesigning and fabricating the Pinball Machine, applying a lens of sustainability broadens the understanding of our design, as the Pinball Machine is not being built in an isolated manner. Recycling and reusing some of the 2016 Pinball Machine design requires that we look to the past work of the previous Capstone group and interpret their designs for the machine. Fabricating new parts requires that we consider how to implement them in the existing system and find where to source materials from. By looking at the past work and designing within an existing framework, we are reducing the amount of material output by reusing designs and adding new ones.

However, beyond recycling the Pinball Machine, it is important to consider where Mechanical Engineers stand today in their relationship with sustainability. Working on the Pinball Machine provides an opportunity to explore ideas of sustainability, but this project is not an isolated example. Across the Mechanical Engineering practice, many engineers, and many projects, have had similar potential for implementing sustainable ideas, ensuring that the product utilizes an efficient amount the finite number of resources available (Brown, 2011). By working on the UVA Pinball Machine, our technical team can gain experience on how to design sustainably, and by studying the relationship of Mechanical Engineers and sustainability, it can be understood in a broader context what responsibilities Mechanical Engineers have and how to improve sustainable design.

UVA Pinball Machine

My technical team and I have been tasked with retrofitting a pinball machine worked on previously by a Mechanical Engineering Capstone group in 2016. The UVA Pinball Machine provides an opportunity to utilize the theoretical knowledge from our Mechanical Engineering education and gain experience in engineering design.

Throughout the Mechanical Engineering coursework, many theoretical frameworks are taught that discuss how to model and design mechanical systems. Some of the most important courses relating to the pinball machine are those covering material science, stress on beams, mechatronic design, and 3D printing. These classes provided theory to help predict outcomes and inform design decisions, and their specific use is discussed further: material science provides an understanding of what properties certain materials have and which materials would be the best to use in certain situations; stress on objects concerns how objects bend or deform under a stress, or force over an area, and how to design objects as to minimize their deformation to prevent failure by breaking; mechatronic design is the discipline that combines mechanical engineering with electronics and software, helping to bring mechanical systems to life, by adding electrical components to help increase repeatability and longevity in systems; 3D printing concerns how to design forms in a Computer Aided Design (CAD) software, and then export that design to a printer, which can realize that design in real life, which can aid in fabricating unique parts special to the pinball machine. A problem can occur when Mechanical Engineers are proficient in theory but are unable to fabricate designs or bring an idea to life. The transition from an initial design to a working product is an involved process, requiring multiple iterations of design and working backwards in order to go forwards; a workflow which is not completely supported by theoretical classes. In order to improve our skills as Mechanical Engineers and to bring ideas to reality, the

UVA Pinball Machine can have theoretical knowledge applied to it, helping to mitigate the problems of wasteful design.

The pinball machine also provides ample opportunity to practice engineering design. Mentioned previously, the non-trivial aspect of engineering design is the number of iterations required to achieve a working product in real life. Being able to work on the pinball machine provides my technical team with many tasks to practice iterating. Iteration counters theoretical knowledge because not everything in real life can be modeled, and iterations can be wasteful in terms of material not used in the final product. However, iteration is a critical step in Mechanical Engineering workflow because it is in the mistakes and flaws of the design that we are able to gain insight on where to improve and how to create a working product.

The forces of theoretical knowledge and iterative design provide a unique learning experience when fabricating the UVA Pinball Machine. By utilizing the ideas from the Mechanical Engineering education, smarter decisions can be made, however not all decisions will work seamlessly in real life. By utilizing the iterative process, mistakes can be realized. and improvements can be planned. The combination of these two forces creates an opportunity for students to work with sustainability in mind. With a project to openly fabricate systems, there is greater potential to approach problems with a sustainable lens, helping to increase the amount of work Mechanical Engineering students complete concerning sustainable ideas (Brown, 2012).

Mechanical Engineers and their Relationship with Sustainability Measures

Given that Mechanical Engineers have the unique ability to use their knowledge of mechanical systems to fabricate designs in real life, there is an associated responsibility of

making sure what is fabricated is sustainable. Sustainable design is critical to preserving the planet and its resources, and by understanding how Mechanical Engineers sustainability into their designs, it is possible to see in what ways they can contribute to mitigating the climate crisis.

Identifying the barriers to sustainability implementation will help identify ways Mechanical Engineers can help create solutions to mitigate the climate crisis. In order to identify the barriers to sustainability implementation, a historical timeline is developed to understand where the relationship has been, and in what ways Mechanical Engineers have considered sustainability, and a critical perspective will be discussed, covering the modern definitions of sustainability and current examples of sustainable, or lack thereof, work Mechanical Engineers complete today.

The historical timeline will be developed by utilizing scholarly articles that describe what sustainability as a concept and its relationship to Mechanical Engineers. One of the main issues in understanding sustainability is that it has been defined in many ways by many groups of people (Fisher et al., 2021). For example, the definitions of sustainability defined in Mechanical Engineering itself differ, from understanding sustainability as a social concept (Johnson, 2022), to understanding sustainability as a means to lower cost and increase profit (Brown, 2012). Beyond the Mechanical Engineering space, there is variation in sustainability definition among higher education institutions at the Bachelor level (Segalàs et al., 2009).

Within a critical lens, many people have completed work creating frameworks to revolutionize how sustainability is approached, and scholarly articles concerning such work is studied in order to develop this lens. In order to address the complexities of the climate crisis, new solutions must be produced. For example, sustainability education is being implemented at

higher education institutions, and the design of sustainability curriculum is studied in order to see if they improve students' outcomes (Kishita et al., 2018). Beyond educational institutions, there are examples of frameworks of sustainability outlines that describe a timeline of goals in order to achieve net zero emissions in the particular region of Texas in the United States (Webber, 2023). By studying how sustainability is taught, and looking at modern examples of its implementation, it can be determined how effective sustainable solutions are in delivering their goals and if there are weaknesses in sustainability education/implementation. Within the critical lens, the barriers to sustainable design, especially societal barriers are considered. The issues of seeking increased profits and implementation of economic policies antithetical to sustainable design cause sustainability applications' realization to be slowed down (van der Leeuw et al., 2012).

The historical perspective then lends to the critical lens a timeline of where the definition of sustainability has been. This is critical to understand, as the changing conditions of the climate crisis require the understanding of sustainability to evolve with it, and by seeing what sustainability has considered, new areas can be identified and added to the definition in order to properly consider new aspects in sustainable design.

Conclusion

My technical team and I will be working on a UVA Pinball Machine, with the opportunity to see how sustainability can be incorporated into the design process. Studying the relationship between Mechanical Engineers and sustainability will help to inform where Mechanical Engineers have been in terms of producing sustainable solutions and will identify in

what ways we can improve in order to meet the increasing and complex demands of the climate crisis.

With a project such as the Pinball Machine, sustainability design can be a challenging lens to implement, and the study of Mechanical Engineers and their relationship to sustainability will help to provide examples and inspiration to see how sustainability is a broad topic with many applications. By furthering the understanding of sustainability, the study will provide a broader, interdisciplinary definition of what sustainability is, which can provide engineers with a wider perspective on the multitudinous ways sustainability can be applied in any design.

References:

Brown, A. S. (2011). ASME's third annual survey finds that engineers are still trying to understand how sustainability fits into their workflow. *Mechanical Engineering*, *133*(11), 36–41. Military & Government Collection.

Brown, A. S. (2012, October 1). Penetrating the engineering culture: According to the latest ASME/Autodesk survey, more engineers than ever before are working on green projects. Is sustainability simply becoming part of what engineers do? *Mechanical Engineering-CIME*, *134*(10). Gale Business: Insights. https://proxy1.library.virginia.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edsbig&AN=edsbig.A305249622&site=eds-live

Fisher, J., Arora, P., Chen, S., Rhee, S., Blaine, T., & Simangan, D. (2021). Four propositions on integrated sustainability: Toward a theoretical framework to understand the environment, peace, and sustainability nexus. *Sustainability Science*, *16*(4), 1125–1145. https://doi.org/10.1007/s11625-021-00925-y

Jennifer Hirsch, R. Y., & Wu, Y.-C. S. (2023). Teaching students to collaborate with communities: Expanding engineering education to create a sustainable future. *Engineering Studies*, *15*(1), 30–49. https://doi.org/10.1080/19378629.2023.2176767

JOHNSON, M. (2022). ENGINEERING A MORE SUSTAINABLE FUTURE: Today's engineering innovation and solutions cannot become someone else's problem tomorrow. *Mechanical Engineering*, *144*(5), 14–14. Military & Government Collection.

Kishita, Y., Uwasu, M., Hara, K., Kuroda, M., Takeda, H., Umeda, Y., & Shimoda, Y. (2018). Toward designing sustainability education programs: A survey of master's programs through

semi-structured interviews. *Sustainability Science*, *13*(4), 953–972. https://doi.org/10.1007/s11625-018-0546-5

Segalàs, J., Ferrer-Balas, D., Svanström, M., Lundqvist, U., & Mulder, K. F. (2009). What has to be learnt for sustainability? A comparison of bachelor engineering education competences at three European universities. *Sustainability Science*, *4*(1), 17–27. https://doi.org/10.1007/s11625-009-0068-2

van der Leeuw, S., Wiek, A., Harlow, J., & Buizer, J. (2012). How much time do we have? Urgency and rhetoric in sustainability science. *Sustainability Science*, *7*(1), 115–120. https://doi.org/10.1007/s11625-011-0153-1

WEBBER, M. E. (2023). TEXAS CAN GO BIG TO REACH NET ZERO: Getting the world's dirtiest emitters to net-zero is more straightforward than you think, Setting out a path for the Lone Star State could lay out the blueprint for the world. *Mechanical Engineering*, *145*(6), 38–43. Military & Government Collection.

WINTERS, J. (2023). ASME'S UNIQUE APPROACH TO CLIMATE CHANGE. *Mechanical Engineering*, *145*(5), 34–39. Military & Government Collection.