The Smithinator: Recumbent Vehicle Design and Entry for the 2020 ASME Human-Powered Vehicle Challenge

(Technical Paper)

Investigating the Expanding Role of Makerspaces in Fostering STEM Engagement and Inclusivity in K-12 Education

(STS Paper)

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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

INTRODUCTION

The discrepancy between U.S. math and science scores versus other advanced industrial nations, along with the underrepresentation of women and people of color in STEM-related fields, has called into question the American education system. Experts agree that a leading cause of this phenomenon is the inability to spurn interest in STEM at a younger age (DeSilver, 2017). Along with improving the quality of the standard curriculum, there needs to be an emphasis on making classes more interactive and engaging. One attempt to do so that is recently gaining traction is the adoption of makerspaces into schools and libraries. Makerspaces serve as collaborative spaces that encourage creativity and hands-on exploration of science, engineering, and design. Developing a plan for their incorporation into youth education, done in a way that is accessible to all social groups, would certainly bolster STEM education and interest.

The technical portion of the prospectus contains the design and manufacturing of a Human Powered Vehicle (HPV) for a competition in April. We are also considering the overarching theme of the vehicle's social impact, especially as a potential means of environmentally-friendly transportation. The specifications for the vehicle and competition are given by the American Society of Mechanical Engineers (ASME), and notably have an emphasis on safety and sustainability. In order to design and build an HPV that exemplifies these qualities, our team of 14 divided up into sub teams to tackle different components of the assembly. The majority of the vehicle is self-built, and most of the tools used for its construction are found in a typical makerspace: 3D printers, CNC machines, 3D modeling software, etc. The ability of nearby makerspaces to provide the tools and collaborative space for our group to complete this project reinforces their effectiveness and relevance in the sphere of academia.

TECHNICAL REPORT

Studies on the impending dangers of climate change have incentivized a push towards more environmentally-friendly transportation with lower carbon emission. The common approach to designing vehicles of this nature is to either harness electricity or human powered energy. In our case, we are in the process of designing a human powered vehicle to be entered into an ASME competition in April. The competition is divided into 3 parts: a design event, speed event, and endurance event. Building a vehicle that optimizes performance in these categories, along with considering the safety and sustainability of the vehicle, is the goal of our 14 member team.

Performing market research was the first step in understanding which vehicle attributes consumers rate as most important. The study suggested that safety, cost, and comfort are deemed to be the most valuable to consumers, while speed and sustainability are not regarded to be as important. Our team then researched designs from other universities that competed in past

ASME competitions. This research allowed our group to decide on a tadpole design (2 wheels in front, 1 in back) with a full fairing.

Given that safety was deemed to be a major concern, these design choices are most appropriate in ensuring that the vehicle maintains a constant balance and can protect the driver in case of a collision. In the case of such a collision, a rollover protection system (RPS) is required by ASME in order to protect the sides and top of the vehicle, along with preventing the rider from being ejected from the vehicle. Finite Element Analysis (FEA) was then performed to predict and analyze how the RPS would perform under different loads, with the resulting deflection factoring into our design of the vehicle's frame.

In order to minimize cost while maximizing performance in other criteria, we created a design matrix to decide which material would make up the vehicle's frame. Chromoly steel was then chosen as the best material once strength, manufacturability, weight, environmental impact, and cost were considered. Building a lightweight vehicle is not only more accessible and easier to maneuver, but also leaves a smaller carbon footprint during manufacturing. The carbon that is emitted during the mining of iron, shipping of the metal, and its manufacturing were considered. Utilizing this knowledge, we are applying for a carbon free certification from the Carbon Fund, which uses life cycle assessments to determine the greenhouse gas emissions over a product's entire life cycle.

Biomechanical data taken from The Center of Applied Biomechanics will also be used as a method for optimizing the accessibility of the vehicle. By performing experiments with markers placed on riders' bodies, one can analyze which muscle groups are being activated during cycling. From this information we can optimize the angle of the frame to provide the most efficient configuration for the rider. Computational fluid dynamics (CFD) are also being performed on the vehicle's fairing for the same purpose of optimizing the utility of the vehicle. CFD simulates the vehicle's reaction to fluid flow and the coefficient of drag we would expect from the design. Iterating this design to minimize the drag acting on the vehicle will allow us to optimize the aerodynamics of the vehicle.

When all of the data has been gathered and the chromoly steel ordered, the team can move forward with the manufacturing of the vehicle. The frame, drivetrain, steering, and innovation teams will merge and we will proceed with welding the steel into the desirable frame. The rest of the spring semester would then be devoted towards the build of the vehicle, along with training for the competition in April.

STS THESIS

As competing countries such as China have recently made an aggressive push towards promoting STEM education, U.S. students' lackluster math and science scores are increasingly alarming. STEM, an acronym for the fields of science, technology, engineering, and math, is widely considered a driving force of our economy. The ability to produce a new generation of STEM professionals and entrepreneurs not only creates high-demand careers, but also provides the best shot to tackling local and global problems, from waste management to climate change. Recent data from international math and science assessments indicate that U.S. students rank an underwhelming 38th out of 71 countries in math and 24th in science (Desilver, 2017). Not just this, there is a disturbing lack of representation of women and minority groups that are entering the STEM workforce. In order to combat this and remain competitive on the global stage, the American education system requires significant changes to cultivate interest in STEM subjects. One such change would be the inclusion of makerspaces into public school libraries and standard curriculum.

Makerspaces serve as collaborative workspaces that promote learning and creativity through hands-on tinkering and self-guided experience. Typical makerspaces have a variety of equipment from computers with programming languages and digital art software to 3D printers, laser cutters, and even sewing machines. Even a space with art supplies and Lego can fall under the makerspace category. Maker programs help develop relevant technical skills in 3D modeling and printing, coding, electronics, art, and more. They foster entrepreneurship and are frequently employed as accelerators for business startups. More than anything, they stimulate STEM education by providing a creatively liberating platform for exploring ideas and hands-on projects. In order to best understand the potential integration of makerspaces into a school system, I plan on using the Charlottesville public school system as a case study. I will explore the best plan of action for incorporating makerspaces into the Charlottesville public school curriculum, with an emphasis on inclusion and accessibility for those of all gender, race, and socioeconomic status. In addition, I will employ the SCOT framework as a means of examining its social construction by analyzing the interests of the stakeholders involved.

The literature I have reviewed mainly focuses on the characteristics of a successful and diverse makerspace. John Burke's 2015 survey asked makerspace leaders what were the common reasons that their spaces were successful, and most of their answers were similar: an emphasis on developing the space around the needs of the community (making sure that purchased technology creates the most valuable opportunities for users), developing relationships with community members, beginning with a modest start, piloting maker programs, and gauging community receptiveness for such programs (Small 2017). Along with this, leaders who can clearly envision and communicate the purpose of the makerspace are vital, especially when it comes to getting the space funded. This funding is not just for the maintenance of the space and technology, but also maintaining a supportive and sustainable staffing model. Finally, there needs to be an emphasis on trusting users and giving them as much autonomy as possible, thus encouraging creativity and hands-on learning. To better understand a possible integration of makerspaces into the Charlottesville school system, I interviewed a local middle school teacher and a makerspace staff member who works at UVA. They both felt discouraged by the education system's inability to adequately adjust to recent advances in technology. Especially considering their children are more adept at smartphones and digital media, they lamented the fact that the same interest did not expand to more productive areas. We also discussed how the standard curriculum does not allow for students to prosper creatively, and tests that center around rote memorization discourage students from truly interacting with the material.

The community members that I interviewed also mentioned the inequality typically found in STEM programs like these. There is certainly a large disparity in the number of minorities and females that participate. When talking with Lucas Ames, he mentioned that many minority students feel discouraged from STEM fields because most of their teachers are white, or do not share the same background as them. Maintaining a makerspace staff that is diverse would, along with other positives, allow for students of different backgrounds to feel comfortable and accepted into the space. The Scholar's Lab Makerspace at UVA is currently addressing a similar issue in the lack of women involved in STEM fields. To do this, they are implementing a Women's Maker Program to encourage women to work in the makerspace. Studies of similar maker programs in K-16 settings have been promising, and a notable number of engaged younger girls have shown an interest and aptitude for STEM disciplinary concepts and practices (Keune, Peppler, and Wohlwend, 2019).

Another obstacle that many academic programs run into is the lack of accessibility for those that cannot afford them. Makerspaces are typically covered by grants, school or library funding, and very rarely the state government (Small 2017). Halverson and Sheridan argue that the best way to democratize the space is through libraries, given their history as "free, embedded community resources open to all" (Halverson and Sheridan, 2014). Joe Moore, the makerspace technologist that I interviewed, elaborated further on the issue and another way to address it. He mentioned that a possible solution that is gaining traction is the mobile makerspace. Mobile makerspaces function the same as regular ones, but can be disassembled and moved in a quick fashion. Typically they would move from library to library, or from school to school in a certain region. This would allow different schools and socioeconomic groups to experience the same benefits of the makerspace as those that are more privileged.

The SCOT framework will allow me to analyze the different social groups involved in the implementation of makerspaces into Charlottesville's school system. Students have their own particular interests: having fun, learning real-life skills, engaging with the material. On the other hand, administrators and teachers feel constricted by the guidelines of the curriculum they are presented and obligated to teach a rigid set of lessons. They are judged by the test scores of their students, and are not offered many flexibilities in the timing or structure of their classes. I will also delve into the strengths and challenges associated, and what opportunities and threats they might pose.

In the future, I am hoping to gather more interviews from community members of different cultural and socioeconomic backgrounds. I hope to gather more data on the benefits of the makerspaces towards STEM education and leveling the playing field for other social groups. I hope to visit more makerspaces in the nearby area to learn about their strengths and weaknesses, and communicate with makerspace leaders to better understand their work. Like with the Women's Maker Program at UVA, I hope to learn more about different initiatives that maker programs are taking to incentivize different groups towards participating. It is also important for me to meet with teachers to see how a possible makerspace program could fit into their already rigid curriculum. By speaking to a wide range of professionals and students, I hope to gain a wider perspective of the complexities of the STEM field and the role makerspaces play in making it more diverse and accessible.

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