Scholarship In Practice

The development, prototyping, and debugging of the Robotic Trash Cart (RTC) requires a collaborative effort between computer, electrical, and mechanical engineering students. It is an entrepreneurship project, meaning it needs to be a feasible commercial product and requires business acumen. Our engineering curriculum does not provide us with any sort of business or entrepreneurship foundation, which put us at a disadvantage in the business competitions we entered. In terms of the actual development of the RTC, we have been able to apply the concepts we've learned about power systems, mechanics, and controls to create a working prototype. We decided against making the RTC autonomous because environmental factors would make this excessively difficult within the scope of the project. We used aluminum for the frame of the RTC. We purchased used wheelchair motors, gearbox, and wheel assembly to simplify the integration of the drive system with the frame. Using a board compatible with Arduino, helped streamline the development and debugging of the control system. Project management is crucial when developing a product like the RTC. Proper time management would have helped us to solve problems we ran into regarding our budget, purchasing components, and welding using the machine shop. Our engineering coursework allowed us to design and make informed decisions regarding the overall functionality of the RTC, the frame, the drive system, and the control system; however, we initially lacked the business knowledge and entrepreneurship skills to properly pitch a viable commercial product to potential investors. Also, proper time management would have helped streamline our product development process.

When we were initially presented the project, the idea was to create a fully autonomous cart that would transport the waste bins to and from the curb for waste pick-up. The original design focus was for senior citizens who struggled to carry heavy loads for long distances. Researching the waste management industry and interviewing members of our community led us to believe there is a market for this product and was applicable for the disabled community; however, there are extensive issues and environmental variables that need to be considered when creating an autonomous robot operating outdoors. Driveways are not uniform and vary greatly from their lengths to changes in elevation. We needed to consider the type of terrain the RTC would be traversing. Wheels are more likely to slip on dirt or gravel as opposed to asphalt or cement. Debris, such as sticks, leaves, or dirt, could be swept onto the driveway and the weather can play a factor. Rain causes driveways to become slick or creates mud. Snow, sleet, and hail in northern states create problems that generally aren't an issue in Florida. Wooded, remote areas can cause connection issues for GPS. All of these potential factors made it impossible for us to develop a fully autonomous cart on our timeline of one school year. Companies, such as iRobot (creators of the Roomba) and Tesla, push out new iterations of their products or provide software patches to improve their autonomous functionalities. Their products are constantly needing updates and improvements. The founders of iRobot had been creating autonomous robots for space exploration and mine sweeping for over a decade before they came out with the Roomba. They had years of experience developing autonomous robots with years of research and development. We had nine months to create a prototype. We decided on an agile development approach with five modules (power system, drive system, control system, frame, and wheels). The first iteration is an open frame cart with a wireless controller. Once this has been completed, we can focus on gradually adding autonomous functionalities to the RTC. But first, the project scope needed to be narrowed.

The Computer and Electrical Engineering Department has added a design concepts course this past year, which taught us the product development cycle and how to apply design thinking when addressing a problem. We learned that once a problem has been identified the scope of the project must be outlined. The aforementioned environmental factors will impact the operation of the RTC and need to be addressed. We made five assumptions to narrow our scope. First, the RTC will operate in Florida and need to be able to operate in South Florida weather conditions, namely rain, humidity, and wind. Second, the pathway the RTC traverses will be paved. Third, the RTC will be stored outside the house, not inside the garage. Fourth, the waste engineers will return the waste bins to the RTC once the trash has been disposed. If waste engineers picked up the whole cart to empty the waste bins, the impact of setting it back down would be detrimental to the lifetime of various components and the frame of the RTC. We designed a gate into the RTC to allow easy access to the bins. We assumed that the waste engineers would place the bins back into the cart once the bins had been emptied. Lastly, the largest gradient the RTC would traverse is a five-degree incline. The Americans with Disabilities Act of 1990 (ADA) mandates the gradient of all wheelchair accessibility ramps for schools, churches, and commercial establishments can be at most five degrees. Because our customers may have a wheelchair ramp for their homes, we decided that the RTC needs to be able to go up these ramps. Some driveways are sloped even more than five-degrees, so this limits the path gradient the RTC will travel. These assumptions narrow down the capabilities that the RTC must have and make it easier to add autonomous functionalities for the next iteration of the RTC. With these constraints, we could now design the RTC starting with the frame.

When the project originally began, we decided fairly quickly on using Aluminum 6061 for the frame of the RTC. There are a couple of reasons why we chose this kind of material versus other materials. The first reason is due to its high strength to weight ratio. It has a Young's Modulus of 68.9 GPa with a tensile strength of 124-290 MPa. The second reason we chose Aluminum 6061 is due to its corrosion resistant properties. We assumed that the cart would be left outside in Florida and needed to be resistant to rain and humidity. The last reason we chose Aluminum 6061 is due to its cost compared to other lightweight, high strength materials. The machinability and good joining characteristics are also added benefits. Having taken the Mechanics and Materials course at the College of Engineering, Aluminum 6061 was well known to our team's two mechanical engineers. In this course, students are taught about the properties of different materials, how they differ, and conduct tests on materials in the lab. After the cart had finally been assembled, everything came out as originally planned; however, the motor bolt holes were slightly off position, so spacers were added to the motors. The team wouldn't change our original decision due to the accessibility and affordability of using aluminum.

Waste Pro USA is responsible for the waste management of Tallahassee. Their garbage bins have a 95-gallon capacity. The recycling bins have a 65-gallon capacity. We assumed the RTC would weigh 250 pounds worst-case scenario. We found motors that we assumed could output the necessary torque to carry a 250 pound load up a five-degree incline. During our second senior design presentation in the fall, we were marked off for not having calculated the necessary torque for our worst-case scenario. We used the concepts taught in engineering mechanics to create the free body diagram for the RTC and found that the motors could not provide the necessary torque. We needed a motor that could provide at least 1.15 N-m of torque to go 0.1 m/sec. We learned that as engineers we cannot assume something will work out. You need to do the necessary calculations and triple check your work, because lives could depend on it. There have been over 18 recalls from car manufactures in the month of March 2019 alone. Some of these recalls deal with faulty airbags. As an engineer, your job can put lives at stake and it is imperative that you do not take shortcuts. We came up with the idea of using the drive system of a motorized wheelchair, because they are made to carry loads in excess of 300 pounds. The motors we found came with gearboxes already assemble and wheels. The motors can output 3 N-m of torque, which is more than what we need. We looked at individual motors, gearboxes, and wheels and found using the wheelchair drive system to be the cheapest option for the RTC.

For our control system, we're using an ESP-32 to interface with a gaming controller and a Cytron SmartDriveDuo motor controller using Bluetooth and PWM, respectively. At Florida State University, we are taught object-oriented programming, specifically C++ and C. These are low level languages that give us greater control of functionalities on boards, especially C. These languages are more difficult to code in than higher level languages, such Python and Java. The ESP-32 is Arduino compatible. Arduino is an Integrated Development Environment (IDE) that uses a simplified version of C++. This makes it user friendly and easy to use. We were taught in our Microprocessors class to code in C using TI boards and Code Composer Studio, which is more complicated and requires bit manipulation. We created motor controllers using PWM. This gave us the technical knowledge and coding skills to program in both high- and low-level languages and made it easy to use Arduino. Initially, we were going to use a Raspberry Pi to interface with the motor controller that was provided with the wheelchair drive system, but it did not come with a motor controller. We could have continued to use a Raspberry Pi, but we would have needed to load an operating system onto it and it is more difficult to debug code using a Raspberry Pi. The switch to the ESP-32 and Cytron SmartDriveDuo was done out of necessity but made testing much easier.

The engineering curriculum does not have any business-oriented coursework. The Design Concepts class is the only one that teaches product development and entrepreneurship but is not in depth. We entered two business competitions: the InNOLEvation Challenge and the Engineering Shark Tank. We made it to the semifinals of both competitions but found that we were at a significant disadvantage during the InNOLEvation Challenge due to our lack of business acumen. We were pitted against entrepreneurship, business, and finance majors, who had experience creating a business model canvas and making business pitches. Dr. Mike Devine, the engineering entrepreneur-in-residence, guided us through the process. Our senior design presentations are all technical. Generally, our professors are not interested in our primary and secondary markets, the value proposition, revenue stream, or customer relationships. The judges for the InNOLEvation Challenge do not want to know how you created the product, but will instead, grill you on your cost structure, revenue streams, and customer segments. We created our company, Artists in Waste Removal (AWR), but our business pitch was too technical and not as developed as other teams. If we were to enter the InNOLEvation Challenge again, we would use the resources at the School of Entrepreneurship and the School of Business to better develop our company, product, and business model.

Project management is vital to senior design. We developed a work break down structure for each semester but did not follow it rigorously. Time management would have greatly helped to completing the RTC as stress free as possible. We began ordering parts in January and were not aware that the College of Engineering has contractual vendors. The parts were generally more expensive from these vendors and increased our budget. We had to request more funds from the Dean's Office. This set us back on our timeline for assembling the frame. We spoke to the machine shop and they generally had a two week minimum wait time for welding projects. We chose to use fiberglass for the base of the RTC due to its lightweight and high strength properties; however, the machine shop would not cut the fiberglass grating we had purchased and refused to weld the whole cart until the base had been cut. This made no sense to us, since the fiberglass would sit on top of the aluminum frame and was not needed to weld the frame. No one on the team had ever cut fiberglass and there are significant health hazards when handling fiberglass. In the end, we wet cut the fiberglass outside using respiratory protective equipment and covered any exposed skin. We should have began assembling the frame in the fall after the CAD drawings had been completed. This would have given us enough time to find alternatives for the fiberglass grating, more time to mount the motors and wheels, and more time for testing. We would redo our Gant chart and been more diligent delegating specific tasks with deadlines. If the deadlines were not met, then we would update our timeline. We had a little more than a month for testing and were unable to meet our stretch goals. With better time management, we could have had time to begin implementing autonomous functionalities.

Developing the RTC was a group effort and required the expertise of mechanical, electrical, and computer engineers. The most important change we would make to our project is improving our time management. Following the established timeline more diligently would have helped us to solve unforeseen purchasing issues and fiberglass restrictions in the machine shop in a timely manner and reduced our budget. We chose not to make the RTC autonomous because it would have been put us over budget, again, and was not feasible given our timeline. The constraints and assumptions we made helped to narrow our project scope and create a detailed design. We chose to make the frame from Aluminum 6061 because it's cost effective, easily available, and our previous experience handling it in lab. The drive system we initially chose did not meet our requirements. It was not spec'd to go up a five-degree incline with a 250-pound load. We had assumed it would. We learned to not take shortcuts and that doing the hard work is why we are payed to be engineers. If we make a mistake, then we are liable for the consequences. For the control system, we had to change our design because the drive system we purchased did not come with a motor controller. Fortunately, our changes improved our design and simplified programming and testing of the RTC. When working on an entrepreneurship project, you will face problems that you're not qualified to resolve. You will need to make yourself knowledgeable in numerous disciplines, including finance and business. We had no previous experience with business models and pitches. We had to take on different roles and become proficient in them. This is part of being an entrepreneur. If you make yourself the person that will learn and do whatever is necessary, then you will continue to grow and eventually succeed. This is the most important lesson that this project taught us.