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# Undertaking Undergraduate Research in Mechanical Engineering as a Nontraditional Student: A Personal Perspective

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# Undertaking Undergraduate Research in Mechanical Engineering as a Non-Traditional Student: A Personal Perspective


## Abstract

This paper documents our educational experience related to on-going research in carbon fiber reinforced plastic extrusion and fused filament fabrication under the supervision of faculty from the mechanical engineering program at Utah Valley University (UVU). This study, which was initiated at the beginning of the Fall 2023 term, is funded by an internal institution grant. The project runs for two years and covers expenditure for student wages, equipment, and materials to perform the work. The research team comprises two undergraduate students and three mechanical engineering faculty acting as research mentors. As students involved in this project, we present here the practical research framework, mentor-mentee activities performed, challenges in undertaking undergraduate research work, lessons learned, and the research activities conducted within the first semester and a half of the study's 2-year term. Our personal perspective as students, gaining knowledge and experience in conducting engineering research, developing research methodologies in executing the assigned tasks, time management, and how it relates to enhancing our educational learning experience are presented in this paper. Our preliminary work has already proven to be beneficial in providing an impactful experience that strengthens our understanding and deepens our knowledge of how to conduct scientific research. We also report on research activities that provided an experiential learning experience. This paper reports some of the activities and findings that supplement theories we learned about in the undergraduate mechanical engineering curriculum such as Materials Science and Engineering. An example is provided where we have attempted to reflect on the experimental data that is collected based on fundamentals of mechanical property behavior that we learned about in that course. This research work presents unique challenges we have faced in getting involved and performing the assigned work. This paper can be used as a platform for other institutions with similar populations on practices and instruction that can get non-traditional students involved in impactful research and in the process gain invaluable knowledge and a meaningful undergraduate experience.


## Introduction

UVU is an open-admissions public teaching institution of higher education with a dual mission that aims to combine the resources and rigor of a major university yet keep the accessibility of a community college. The institution’s students are markedly non-traditional compared to those of a research focused institution: 37% are first generation, 80% work while enrolled, 30% are over 25 years old, and only 48% are full-time students. The U.S. Department of Education states that non-traditional students are those who have one or more of the following characteristics: delayed college enrollment by a year or more after high school, parttime course enrollment, financial commitment to themselves and/or their dependents, being a single parent, working full time

while enrolled, or did not receive a high school diploma (Radford, Cominole, & Skomsvold, 2015). These students often face many extra-curricular challenges when pursuing an undergraduate degree, which include financial, cultural, and institutional hurdles (Remenick, 2019). A typical example may involve the student having to work (which can involve juggling more than one job and amount up to more than 20 hours/week) and care for dependents. Having enough time and energy to focus on studying, while balancing all other responsibilities is a common challenge that non-traditional students face. Non-traditional students may also have a feeling of always being the oldest student on campus relative to their counterparts. Some may often have a feeling of not knowing when or if they will be able to complete their degree. The problem is compounded when there is a lack of realization that these students have many responsibilities outside of schoolwork (Tyson, 2012).

Yet, these students still enroll in college and universities for multiple reasons. A study found that typical non-traditional students expect to utilize college for career preparation and were less likely to be focused on the social scene (Forbus, Newbold, & Mehta, 2011). Another study cited a personal desire to complete what they started, being a role model for their children, and the financial incentives to improve their economic situation (Bohl, Haak, & Shrestha, 2017).

Providing a meaningful undergraduate experience to non-traditional students will go a long way towards enhancing learning, transforming their predisposition towards learning and higher education, and attitudes for becoming a professional in their discipline (Bamber & Tett, 2010). Three important teaching strategies for ensuring non-traditional student success are: (i) teach the value of advanced/higher education, (ii) teach self-worth and empowerment, and (iii) teach the transformative power of education (Johnson, 2022).

One of the pathways that enriches the non-traditional student's undergraduate experience, thereby also widening pathways beyond graduation, is via undergraduate research. Studies have found that undergraduates who participate in research obtain better grades and have a higher likelihood of graduating. It has been proven to improve retention, persistence, and has been linked to a boost in students' motivation to learn (Ditta, Strickland-Hughes, Cheung, & Wu, 2020). Undergraduate research experience was also found to better equip students for graduate school or careers (Sell, Naginey, & Stanton, 2017; Altman, et al., 2019). Through undergraduate research, students learn professional skills such as maintaining notes, identifying research problems, reading scientific literature, collaborating with peers in a research setting, and writing and presenting findings to an audience in their field of discipline (Carpenter & Pappenfus, 2009).

Undergraduate research is said to be one of ten high impact practices shown to enhance and improve college student performance and success (Kuh, 2008). A report by the National Survey of Student Engagement (NSSE), in which about 323,000 randomly selected freshman and senior students at 610 four-year colleges and universities in the U.S. and Canada, stated that faculty-led undergraduate research is one of several high-impact practices which results in enhancing a student's ability in "thinking critically, solving real world problems, and working effectively with others" (Report, 2007). It has even been suggested that involvement in undergraduate

research is “most effective in promoting the retention of students that are at a greater risk of attrition,” and that it helps to ensure they are motivated to perform better in class, stay in school, and engage in the scientific community (Nagda, Gregerman, Jonides, Von Hippel, & Lerner, 1998).

Undergraduate research experiences provide immense benefits to students, especially those in the STEM field (Russel, Hancock, & McCullough, 2007). From an enriched learning perspective, benefits may be via experiential learning and from a learning by doing approach. In terms of student development, benefits may be derived from increased self-confidence (Fechheimer, Webber, & Kleiber, 2017) , self-efficacy (Carpi, Ronan, Falconer, & Lents, 2016), academic engagement and a feeling of belonging to the college (Wilson, et al., 2015) . A study on the impact of faculty-mentored research of associate degree students at 10 associate’s degree-granting colleges within the City University of New York system found that undergraduate research have a transformative potential: most students that previously attended college just for classes with little further engagement reported they enjoyed attending college and felt a greater connection to their colleges (Nerio, Webber, MacLachlan, Lopatto, & Caplan, 2019).

The faculty-student relationship developed through research mentoring will also serve as a support system that will benefit the non-traditional student. In contrast to limited interaction in the classroom setting, students form a closer and more distinct type of interaction with their research mentor. Students were found to enjoy working with an advisor in a one-one setting as this fosters a collegial relationship which may lead to a sense of satisfaction with the program (Seymour, Hunter, Laursen, & DeAntoni, 2004). The relationship that is developed often serves as the foundation for lifelong friendships and career guidance (Adebisi, 2022). Being involved in research activities such as discussions, problem solving, co-authorship in the writing of academic papers with faculty mentors play a significant role in the student’s academic development, perceived self-worth, and sense of belonging to the institution. The faculty advisor/mentor also plays a critical role in ensuring the success and satisfaction that a student derives from the undergraduate research experience (Howitt, Wilson, Wilson, & Roberts, 2010).

However, non-traditional students already face many challenges in pursuing a higher education, let alone tackling additional work such as undertaking undergraduate research. Traditional undergraduate students often have opportunities to offset the research workload during the Fall and Spring semester by undertaking summer research. They also do not typically carry additional responsibilities such as full-time work and family commitments. Many non-traditional students are geographically constrained and have a limited number of summer research opportunities available due to location, family, and work responsibilities (Ries & Gray, 2018). As clearly stressed in the personal narratives provided by the two students in this paper, time management is the critical first step to ensure success as a non-traditional student. Both students provided a narrative of significant hurdles that may hinder success.

Realizing the importance of undergraduate research for enriching the undergraduate learning experience, UVU encourages undergraduate research through various grants. This includes the

(i) Undergraduate Research Scholarly and Creative Activities (URSCA), (ii) D. Clark and Pam Turner Endowment for Engaged Learning in STEM (Science, Technology, Engineering and Math) Research Fellowships (TEELS), (iii) College of Science Scholarly Activities Committee (SAC), and the Grants for Engaged Learning (GEL). A common denominator of all these fundings is the requirement for the students to be paired with a faculty mentor/advisor. To further address the challenge of time shortage, UVU allows for undergraduate research to be counted towards upper division technical elective credits, and hence, towards the students' degree requirement. As an added incentive, these grants also provide monetary compensation for students involved in research work.

The work undertaken by two non-traditional Mechanical Engineering students at UVU, whose perspectives from a semester's work are shared in this paper, is funded by a 2-year GEL grant that started in the Fall 2023 term. The title of the research is "*Towards Establishing an Additive Manufacturing Composite Lab at UVU: Additive Manufacturing of Chopped Carbon Fiber Reinforced Thermoplastic Composites - a Parametric Study to Optimize Mechanical Performance using Filament Extrusion and Fused Filament Fabrication*." In this paper, the students' firsthand experiences are shared and focused on, rather than the technical content of the work.

## Student Perspectives

### Walker Eads (Mechanical Engineering Senior)

I have been attending UVU since 2017 and this would be my 8th year as an undergraduate. Throughout my years in college, I have always been working. At most times, I work two different jobs to keep me afloat as I attend my classes. I try my best to budget the time I have so that each part of my life is in harmony with one another. Unlike other students, my parents never helped pay for my college tuition. This wasn't for any ill intent on their part as they were trying to help me go off on my own and pave my own way through life. This push for my growth and development is what had me work multiple jobs during the school year so I could pay for my expenses while also affording tuition.

This research opportunity has brought me many new practical experiences and a deeper understanding of coursework theory that is covered in the Mechanical Engineering curriculum. In classes, especially in the lab courses, I conducted experiments to assess theories, following steps provided by the instructor. However, in conducting this research, I was only given a general scope of study. Instead of detailed step-by-step instructions on what to do, I was only given a certain objective. I was responsible for finding out how to conduct the practical work on my own. At the end of the Spring 2023 term, one of my professors approached me to enquire if I had interest in an undergraduate research experience. He had recently obtained a grant to perform work in Additive Manufacturing and was looking for two undergraduate research assistants. I was informed about the scope of the study and the research questions it sought to find an answer to, and that it will commence at the start of the Fall 2023 semester. I learned that the study would involve looking into how different carbon fiber (CF) parameters such as

chopped length, concentration, and geometry when mixed with a certain base polymer resin can be customized to optimize the strength properties of the 3D prints.

After being heavily involved in the initial work, I feel that this is the first time I have ever undertaken research to this degree. Learning the steps and challenges to conduct an effective study have provided me invaluable knowledge and experience. Foremost, I believe that I have learned the fundamental steps in how research is conducted. I learned that the first step in undertaking any research is to perform a preliminary literature review within the study's scope. This is the stage where we determine what others have done and how we can build on the knowledge base of the scientific community.

One of the initial experiences I had was finding articles that related to what we would be doing. Doing an initial *Google* search was not sufficient in finding proper articles that had substantial information we could use as reference. To help with this, I was informed that a better option was *Google Scholar* to find more focused articles on whatever topics I was researching. I did not know that this tool (*Google Scholar*) was available and found it to be extremely useful for finding information. In this sense, I would say that being at the first step, undertaking research has taught me how to be resourceful in finding information. I would like to also add that reading the scientific articles expanded my knowledge about our topic of study. I also learned about the concept of what peer-reviewed articles meant. I have also learned that research in this topic is not only here in the US but also worldwide.

Another initial challenge was identifying and purchasing the equipment and materials necessary to conduct our study. In the first semester of the work, we had to find an appropriate filament extruder, 3D printer, and filaments for our project. We were also informed about our budget for the semester and instructed not to stray from it. My advisor empowered my partner and I with this initial responsibility. It felt like a huge step for us to be making decisions which would have a direct impact on the work.

I did not have any prior experience designing and 3D printing parts and I found learning how to do so to be exhilarating. I have also learned about the general properties of several different types of thermoplastics and the unique set of printing parameters and associated challenges when printing each type. One such thermoplastic that took some trial and error to print was polypropylene (PP). When using a cool build plate on the 3D printer, we observed that the PP prints were not adhering to the build plate. This continued to happen as we tried different glue sticks to apply onto the build plates. We also tried a range of extrusion and build plate temperatures. Eventually, I went online to try and solve the problem without more trial-and-error efforts. I found a webpage about printing PP correctly. The article noted that a special glue stick meant for printing PP as well as an exceedingly high plate temperature were highly recommended. I investigated further and found the glue stick mentioned as well as a higher heat tolerance build plate that should be used. Applying these changes ensured successful printing with PP. This was a great learning experience for me where I learned that trial and error is not always the best method when it comes to doing research. I learned that seeking online

information, even if it does not relate to what is being done, can help progress one's own knowledge on solving issues.

I have also learned about the importance of codes and standards in engineering. I learned about standard test samples specific to plastics, such as the ASTM 638-14 which we printed for tensile tests on our Universal Tensile Tester. We also produced our own unique way of printing a small tab on the flat dog bone sample end, to ensure that all samples are placed in the same place between the tensile grippers. We developed this tab solution to address our mentor's advice that eliminating variations between test samples and the test themselves were important. This small-tab idea was something I thought of to ensure the tensile samples were each gripped at the same location for east test run. I noticed that whenever we tried to get the samples onto the machine it always took an extra amount of time to get them correctly placed between the test grips. If this was not done, then there would be a slight variation in the data gathered. I took a step back and analyzed the grips and sought to find a way to make it easier to replicate the process of getting the samples in the correct location each time. This is when the idea of the small tabs on the ends was formed. I took some tested samples and marked where the tensile grippers were placed. From that, I created a CAD model with appropriately spaced tabs on the ends of the samples to ensure the correct placement with each test. This experience helped me see how I could practically solve a problem related to the work I wanted to perform. It made me realize that any idea you have could be a good idea and you just need to run with it.

The main challenge I faced during this semester was dividing time between this study, a tutoring job I had on campus, and undergraduate courses that I was taking. This included Capstone Design which took up a lot of time and commitment. As the semester progressed, the amount of time I had each week became more difficult to balance. However, as I became more adept to the research work that was required, I grew to be more efficient in my time management. It really helped that our advisor gave clear weekly targets and expectations.

One such experience about time management sticks out above the rest: there was a week when I was waist-deep in work on my Capstone project. I was tasked with 3D modeling a motor box for a rotating wire system. Creating the 3D models for this design ate up most of my time that week and I still needed to get my responsibilities done for the research. To help get my work done that week I had to create a schedule for myself on which times I would allocate solely for research. Creating this schedule helped me be more on track for the tasks I had been assigned that week as well as a continued time frame that I would always put towards any future tasks thereafter. This taught me how crucial time management is to ensure that all responsibilities are met.

Another challenge that I found while undertaking this research was the use of the 3D slicing software connected to the 3D printer. It was completely new and foreign to me, and I spent a lot of hours each week looking over the variations one could input for each individual print. There were times when I would print something for our research that resulted in failed prints. I learned many things related to 3D printing during these weeks such as print orientation, infill density, print pattern, print speed, and many other useful tools. I have also found myself discussing 3D printing related issues with other students. Through these discussions we have gained and

exchanged knowledge on the optimum print parameters that should be adopted for specific print materials. These, and many other research related challenges that we faced just in this first semester of the work, and how each problem was solved, have allowed me to learn and grow in knowledge and confidence to continue work in this research.

David Fernandez (Mechanical Engineering Junior)

I am an immigrant, first generation student at UVU. I am 35 years old, a father of five children, am self-employed outside of university, and have been trying to finish my education for over ten years. Before beginning my undergraduate studies, I decided to work in the engineering industry as an engineering technician where I conducted research under the supervision of a professional engineer. I fell into the idea that going to school was not necessary if I was already in industry. However, the longer I worked as an engineering technician I began to see the large gap in knowledge and pay. When the company I was working for was bought out I searched for another job as an engineering technician but could not find one. That is when I decided to go back to school. Since then, I still left school and came back a few times. I became a business owner, lost the business during COVID, and went back to school. I left because of the need for money, but then had double-hip surgery from a work accident. This resulted in me deciding to go back to school. I left school one last time because I found an opportunity to build another company as a contractor, but that did not go as planned either. I decided to go back to school again for the last time in 2021 and have been in school since then.

In the Summer of 2023, I was contacted by Dr. Jaafar, with the opportunity of undertaking undergraduate research with his mentorship. I was given the grant proposal to go over to find out if I would be interested. The proposal also provided an idea of what would be expected from me, and what the research goals were. I accepted the offer since I felt that it would be beneficial to me, especially since I intend to further my studies after graduation. I also felt that my experience doing research in industry would help me in this regard. I was excited to start work on the project.

We were first advised to conduct a thorough literature review related to our project's topic and to then present to our mentor what we learned. During the initial meetings we discussed how to conduct the research, establish weekly meeting plans, and were told that we (the students) would mostly work independently. We were also taught how to create a chart showing project milestones with targeted dates for achieving them. At first, working independently was difficult since we did not have a full understanding of what it meant to be a researcher in this field. However, after the first few weeks, we gradually grew into our roles and found our way with the help of our mentor.

In our classes we are typically given projects and opportunities to work in a group where our grades depend on the output of others. Sometimes, a student from the group does not complete his/her tasks. The other students in the group must then cover for them to complete the work. I

observe that this, in some ways, is how it works while doing research as well. The only difference is the setting. One is in a structured classroom setting where grades are involved. The other is where research outputs are required.

I had taken a CAD modeling class in the past and have done 3D printing before, but I had never been involved to this extent in the process. In the past when I wanted to use a 3D printer, I would send my file to the person in charge of the printer. Now I was the one handling every aspect of the work. I could feel the pressure of responsibility and felt a lot depended on my output. However, being able to consistently meet the outputs and deadlines outlined in the research gave me confidence and self-belief in my capability. Solving problems as we conducted research made me realize I can do much more than I thought.

I find that being a student, under my current situation, is difficult. Having a family, responsibilities outside of school, work, and health factors make going to school a sacrifice. Oftentimes, I cannot be in two places at the same time. When I must sacrifice being with family or not working to earn money because that time must be allocated to do homework, it helps put into perspective how important and valuable getting an education is. It helps to know that I am sacrificing all of this now to secure a better future for my family.

I have five sons and all of them look up to me as their role model in every aspect of their lives. My oldest asked me for an anatomy book when he was 5 years old. That was during the second year I was back in school. Now he can understand a little more of what I do and asks for presents related to the STEM field. I observe and hope that my being involved in the STEM field will rub off on them. Another great challenge that I had to face was when my wife had to deliver our fifth baby during the middle of the Fall 2023 semester. Taking parental leave was not an option. Even after contacting all my professors, some did not give me more than an extra day to finish my homework and prepare for a midterm test scheduled for that week. Having a young family and going through school is not easy. When my fifth son was born, less than 24 hours later there was a fire next to the nursery in the hospital. My wife and I were the last ones to be evacuated. Less than 2 years ago I had double hip surgery, and now I have a tough time sitting and walking, even though I was an athlete and worked in manual labor most of my life. I lost a business and with it our life savings and equity when COVID hit. Even through all that, and more, I consider education and experience in school to be priceless and worth going for.

I have also learned to adapt and continue moving forward even through my personal struggles and the struggles faced during this research. I had never used Fusion 360 and I taught myself how to use it and designed some dog bones according to the ASTM standard that we identified for the tensile test. I have never learned how to manually adjust the printing settings on a 3D printer. I have learned how to do that now and observed how changing the settings can help ensure successful prints. I have also learned how to use the tensile testing machine, collect data, and generate plots to investigate the mechanical properties of the samples. I find that the plots that are generated from these tests were similar to those we learned about in a course I took on Materials Science and Engineering. It was great to see how I could apply what I learned in that

class on obtaining the mechanical properties of a material from a stress-strain plot directly to the plots that we generate from our test data.

There has been a learning curve getting used to the dynamics of doing research on campus, with another student, and being supervised by faculty. I have observed that when work is not clearly divided between my partner and I, it is hard to understand what each person's responsibility is. Each person tends to gravitate towards the least resistant path, and we must learn the new dynamic of working together. Some issues that have arisen were the delegation of responsibilities, working with other students not involved in the research, and unclear communication. I feel that getting these issues resolved is important.

Another issue we ran into was presenting our research findings. In our weekly meetings, we present what was achieved and the work we have done for that week. Sometimes only one of us would present because of time, and assumptions were made that the other student had not conducted any work. This begs the questions, "should professors be involved in every aspect of research?" For example, micromanage, and "how can the supervising faculty assure that the students are truthfully conducting their research?" There needs to be a sense of understanding, trust, and respect between faculty and student throughout the work, and being able to talk about it helps us resolve the issue.

As a group, we have learned that clear communication between all members is key and that is how we have resolved our issues. From my experience I have learned that in industry these issues also exist within a research group, and we must learn how to navigate the issues to achieve our end goal. Friction between co-workers will always arise. We just must keep an open mind and a willingness to listen and work together. As a non-traditional student I make time when and where I can to accomplish tasks assigned to me. Even after all this, I would say that I have enjoyed the journey of getting my education at UVU. I have also enjoyed my experience doing research with my faculty mentors and my partner Walker Eads. I have also enjoyed extending my relationships with the supervising faculty, Drs. Seibi and Amin. Friendship and mentorship have extended outside of the classroom, and it shows how much professors can care about their students' lives and education.

Research Activities and Experiential Learning (Fall 2023-Mid Spring 2023)

Throughout this period, we had weekly meetings with our mechanical engineering faculty advisors. During the initial meetings, our advisors provided a general overview of the research, and direction on how investigative research is conducted. We were informed that a semester plan is imperative. It was said that if one "fails to plan" then one "plans to fail." As the semester progressed, these weekly meetings were also used to provide an update on work that has been completed, and work that is planned for the coming week.

Early in the Fall 2023 semester, we were advised to do a lot of literature reviews of journal publications related to our study. We learned about the *Google Scholar* search tool and how it

can lead us to past work in our field of research. We learned that part of research is continuing what others have done, and in this way, contributing to scientific knowledge. At first, we found it difficult to find an article that was closely related to the work we would undertake. After going through more than 10 articles we found that the one source that could be used was a reference from one of the papers. This experience showed that an effective way for finding related articles is not only by looking at articles that have been looked up through different search engines, but to also see the references that those papers cited.

We felt empowered that our advisors gave us the opportunity to determine the materials and equipment for purchase, based on the scope of study and a given budget. We also learned about the equipment available on campus that can be used to gather data. This was a valuable experience because it taught us how to look up and find certain tools and equipment that the work requires. Knowing what tools to get and how to effectively use them helped push the research further.

An initial challenge was that we have never used a 3D printer before. Neither did we know that there were many different types of plastics that could be used with 3D printers. It took us a while to successfully print using these different plastic materials as each had their own optimum extruding temperature and plate adhesion temperature. We also learned about ASTM standards for tensile specimens and that different material types require different ASTM standards for the specimen geometry and the test parameters to be used.

The work initially involved planning on what plastic filament type to print into the required test sample. The printer has a lot of different pre-set printing temperatures; however, some of the plastic materials used were not listed in its database. In such cases we had to do some literature research to find adequate temperatures of the nozzle and printing bed.

On average, each of us spent about 10-12 hours per week working on printing and testing with different plastics. Tensile testing was conducted on a Universal Tensile Tester (*Instron 3369 ID 3369B13598*) to gather data. This data was exported into an *MS-Excel* worksheet categorizing the different plastics into Stress-Strain plots. We learned from our mentor that testing a single sample is not sufficient, and that at least 5 were required whereby an average was then used to generate the plots. The raw data from the tests were then exported into an Excel worksheet. The average value from the 5 samples of each material were then used for plotting the corresponding stress strain curves. Figure 1 shows the stress-strain curves for the different 3D printed plastics, with and without CF. We used the theory covered in a course that we took on Materials Science and Engineering to obtain the material and mechanical properties of our samples based on the data and plot that is generated. As an example, we learned how the material's Young Modulus increases with addition of CF for PP and PA-6, and how ductility is significantly reduced. It was exciting to see how concepts that we learned about in class helped us understand the observed data, and thus derive information about mechanical property and behavior of materials in our study.

We look forward to continuing the work. As of Spring 2024, we have started extruding our own filaments from plastics in the pellets format and subsequently using these filaments for 3D printing into test samples. After discussion with our mentor, we agreed that it would be best if weekly goals were made in the form of a memo which shows clearly what we are tasked to do for the week as well as a chart that shows where we are in terms of the overall research goals. We have noted that the memo also helps us to keep track of past progress. A snapshot of one of these memos is provided. Currently we have also started investigating how different CF content (as a percentage of weight) will influence the mechanical property of the 3D prints. Going forward, our mentor aims to have us publish our findings in a peer-reviewed technical journal.

## Conclusion

This undergraduate research project has had several significant learning outcomes for both students involved. These outcomes have impacted them positively in two ways 1) made their educational experience more enjoyable and meaningful and 2) expanded their technical knowledge and skills by gaining hands-on experience in research and becoming familiar with the required process. Students learned how to conduct literature review, plan, and develop experiments, determine and purchase the needed equipment, design, and fabricate samples, test samples, brainstorm and make practical decisions, analyze, and compare data, and finally draw meaningful conclusions. The technical aspects of this research project have broadened students' understanding and knowledge of advanced manufacturing, especially in the areas of carbon fiber reinforced plastic extrusion and fused filament fabrication.

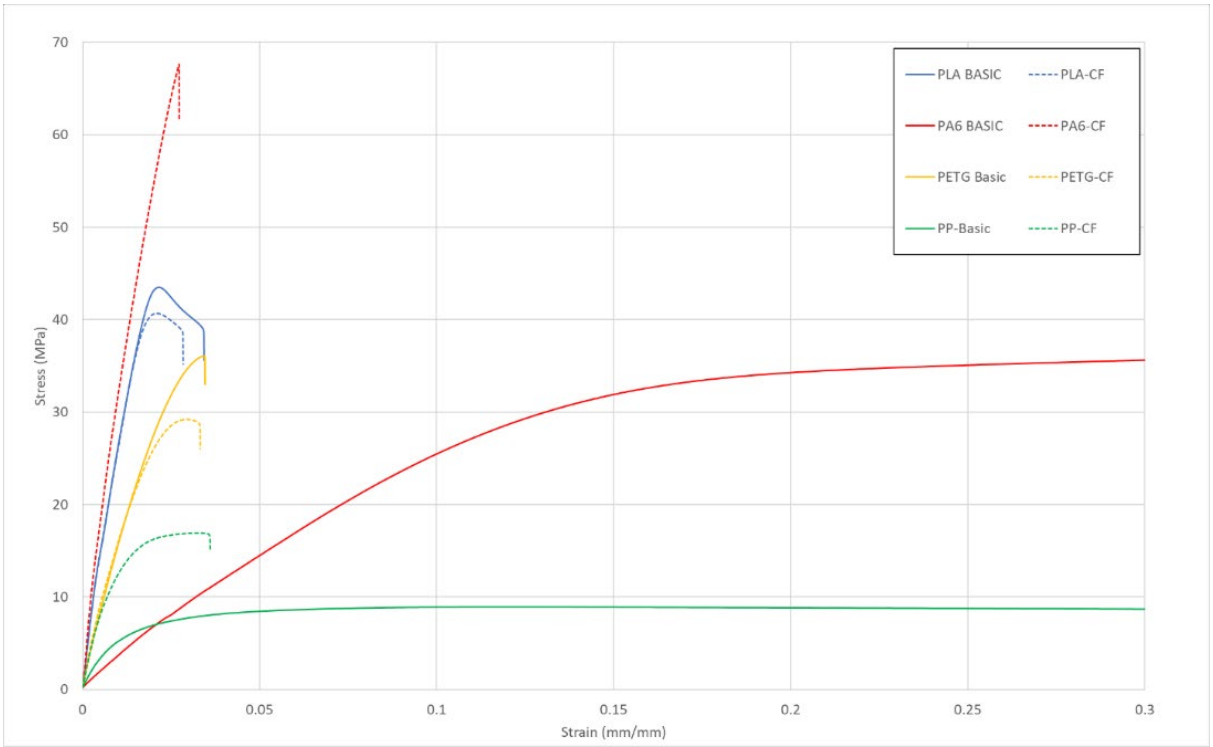

Figure 1. Stress- Strain plots for the different plastics, with and without CF.

**Example Memo:**
**Memo 1/26/2024**
**3D Printing Research with Filament Printing and Extrusion**

**Last week plans recap/reminder.**

| Name | Tasks planned last week |
|---|---|
| W Eads | Clean up extruder and get ready for more pellets<br>Get different spool samples of all extruded pellets we have on hand<br>Do test prints of extruded filament – aim at 100% infill<br>Tensile tests of printed dogbones from extruded filament |
| D Fernandez | Redo the tensile test for one PP-CF and on PP basic<br>Get familiar with extruder and start extruding pellets<br>Create Work order for materials needed for extruding |

**Progress**

| Name | Tasks accomplished during past week |
|---|---|
| W Eads | Extruded PP-CF and tested a dogbone print at 100% infill<br>Extruded PLA and tested a dogbone print at 100% infill<br>Extruded PA-6 with improvements to be made<br>Extruded PP without yet printing a dogbone |
| D Fernandez | Extruded PP-CF<br>Extruded PLA<br>Extruded PA-6<br>Extruded PP<br>Tensile test for Printed dog bones |

**Plans**

| Name | Tasks planned for upcoming week |
|---|---|
| W Eads | Watch videos on how to extrude PA-6<br>Research more into extrusion (especially with Filabot X2)<br>Deep clean extruder<br>Maintenance on 3D printer |
| D Fernandez | Watch videos on how to extrude PA-6<br>Research more into extrusion (especially with Filabot X2)<br>Deep clean extruder<br>Maintenance on 3D printer |

**Hours**

| Student Names | Hours put into research |
|---|---|
| W Eads | 12 |
| D Fernandez | 12 |

| Milestone description | Category | Assigned to | Progress | Start | Days |
|---|---|---|---|---|---|
| **Spring** | | | 32% | | |
| **Extruding** | | | 43% | | |
| Finalze print of PP and PP+CF | | | 100% | 1/16/2024 | 3 |
| Finish PP Basic/PP-CF Plots | | | 100% | | |
| Finalize tensile test of PP and PP+CF | | | 100% | 1/15/2024 | 10 |
| Familiarize with Machine/Process | | | 100% | 1/18/2024 | 2 |
| Start Extruding each Pellet type | | ALL | 30% | 1/19/2024 | 7 |
| Maintenance for Printer | | ALL | 0% | 1/19/2024 | 8 |
| Extrude test filament with (PP-CF) | | ALL | 100% | 1/19/2024 | 1 |
| Research options for other pellets | | | 20% | 1/25/2024 | 5 |
| Complete Memo/Update Gantt | | ALL | 100% | 1/19/2024 | 1 |
| Work order Pellets / equipment | | ALL | 50% | 2/5/2024 | |
| Extrude/test filament | | ALL | 20% | 2/2/2024 | |
| Complete Memo/Update Gantt | | | 100% | 1/26/2024 | 1 |
| Research devices that match Filabot Extruder | | ALL | 0% | 1/29/2024 | 7 |
| Deep clean Filabot X2 Extruder | | ALL | 0% | 1/31/2024 | 3 |
| Watch more videos on extrusion for PA-6 | | ALL | 0% | 1/26/2024 | 10 |
| Extrude/test filament with CF Flakes | | ALL | 0% | 2/9/2024 | |
| Extrude/test filament with different CF %W | | ALL | 0% | 2/16/2024 | |

I have reviewed and approve this memo:

Walker Eads_____

David Fernandez_____

**Supervisor**

Recommendations/Notes:

Supervisor's Signature:

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