ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022

Paper ID #37388

Work in Progress: Motivation and Interest on the Design and Optimization of 3D-Printed ABS and PLA Scaffolds

Nabila Shamim (Dr)

Anh Nguyen

Sheena M. Reeves

Sheena M. Reeves is an Associate Professor in the Chemical Engineering Department at Prairie View A&M University and has been a faculty member for over 10 years. Her research background is in nanoparticles and other particulate systems including pharmaceuticals and catalysts. She is an avid supporter of undergraduate research and mentorship.

Ariful Bhuiyan (Assistant Professor)

Dr. Bhuiyan received his Ph.D. in Mechanical Engineering from Texas Tech University in 2013. His thesis was titled "Anterior Cruciate Ligament Response Due to Forces Resulting from Quadriceps Muscle and Ground Reaction." He received his M.Sc. in Mechanical Engineering from the National University of Singapore in 2005 and earned B.Sc. in Mechanical Engineering from Bangladesh University of Engineering and Technology in 2002. He has more than 10 years of industrial experience, playing different roles like lead project engineer, system engineer, principle mechanical engineer, and finite element analyst. Currently, he is conducting research on engineering education.

© American Society for Engineering Education, 2022
Powered by www.slayte.com

Work in Progress: Motivation and Interest on the Design and Optimization of 3D-Printed ABS and PLA Scaffolds

Nabila Shamim[1] Anh Nuguyen[1], Sheena Reeves[1], Ariful Bhuiyan[2],

[1]Department of Chemical Engineering, Prairie View A & M University, TX 77446

[2] Mechanical Engineering Program, University of Houston, Clear Lake, TX

Abstract

Educators are constantly challenged to give a new pedagogical approach to instill a love of learning. However, providing academic content alone may not provide the problem-solving skills necessary for practically solving complex problems in the real world. Technology-integrated learning environments include developing critical thinking, solving complex problems, collaborating, and engaging deeply in the learning process. 3D printing technology allows students to combine these learning processes to create their dream product. In this report, large-pore acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) scaffolds are printed using a simplistic 3D printer as a preliminary class project. Due to the different structural properties, the varying responses make scaffold design optimization very challenging. The work in progress report **aims** to determine students' interest and skills with 3D printing using project-based learning opportunities, which are critical to developing successful student learning methodologies. Students from the CHEG 4310 Polymer Science and Engineering, a senior-level special topic course in chemical engineering, will conduct a class project printing models using different polymers to gain hands-on experience in 3D printing. This leading-edge technology will enable our minority engineering students to learn in the same environment as industry counterparts, increasing the value of the student experience and interest. In addition, our students can use this platform to design novel materials with the best properties and facilitate the path for finding solutions to industrial problems.

Keywords: 3D Printing, Complex problem solving, PLA, ABS.

Introduction:

The world is constantly changing; therefore, it is vital to embrace and grow with the change. Additive manufacturing (AM), broadly known as 3D printing, transforms how products are designed, produced, and serviced. 3D printing is one of the key future technologies that will produce design solutions based on specifications and constraints defined by engineers [1-3]. This emerging technology can be used in numerous automotive, aerospace, and medical industries. Implementing 3D printing projects in the classroom will encourage critical thinking, solving complex problmes, collaborating , and engaging deeply in the learning process [4-6]. Cognitive skills can help students to observe and reflect on the complex design problems and optimize the process of 3D printing because the visual images of the finished product increase students' understanding and remembering in an interactive and fun way [7, 8].

The College of Engineering at PVAMU currently ranks as the top 3 African American engineers' producers with Bachelor's Degrees [9] among HBCUs. The Bachelor of Science in Chemical Engineering is an ABET-accredited program, and it is proliferating. However, despite AM's increasing importance to the U.S. economy, the chemical engineering degree program does not offer any course related to 3D printing to equip students with comprehensive knowledge in AM. A recent analysis conducted by the Pew Research Center reported that the minority groups have made small gains into STEM positions over the years and found that African American students accounted for only 9% of the STEM workforce in 2019 [10], suggesting a lack of progress at a time when many companies and universities had pledged to promote diversity. However, According to Diversity in Higher Education, in May 2021, Roy G. Perry College of Engineering ranked first in producing African American males and third in producing African American females with bachelor's degrees in engineering. However, the 4th-year graduation rate for engineering students is only 12%. One way to promote student success and persistence through graduation is by introducing hands-on experiences through project-based learning and involvement in class. Solving applied challenges with group engagement will encourage student interaction and team building through the development of critical thinking skills. These key strategies will enhance student 4^{th} -year graduate rate to our expected goal of 20%. Therefore, there is a need for systematic training in the current curriculum to equip students with comprehensive knowledge in cutting-edge topics such as 3D printing. The impact of 3D printing is steadily increasing in the world including the chemical engineering profession. 3D printing, or additive manufacturing, has become an enabling technology in traditional chemical engineering processes (developing internals for process plant equipment) and emerging areas such as bioengineering (tissue scaffolding). The need for modern, low cost and durable printing materials also extends to material science, where advances will lead to more advanced plastics for use in products. It is anticipated that advances in 3D printing and chemical processes will lead to molecule-level printers that can print drugs on-demand in the health industry [11].

Research Question

Educators in professional programs continuously use pedagogical approaches to prepare students with knowledge, values, and skills to meet the emerging challenges for practices in their respective fields. These pedagogies create bridges between theoretical knowledge and the demands of uncertain situations [1, 12, 13]. In this work in progress report, hands-on projects on 3D printing will be given to students enrolled in CHEG 4310 Polymer Science and Engineering elective course. Students will build knowledge through actively making some artifacts. The project aims to teach students scaffolds' design and operation techniques and other creative models with various 3D printing platforms. The primary goal is to find the impact and effectiveness of 3D printing on student interest, motivation, and engagement. The evaluation will be carried out through pre- and post-surveys from the students.

Elective Course: Introducing 3D Printing

Polymer Science and Engineering is a new elective course offered in Chemical Engineering. This course aims to provide a broad overview of polymer science and engineering. The emphasis is on the structure-property relationship of polymeric materials. The course is a lecture course with laboratory sessions to help students understand the fundamental concepts in which will be applied in the laboratory with 3D printing. The course is offered in the spring semester serving approximately 15 chemical engineering students. By introducing 3D printing as a class project, students will be able to

1. Think critically and analyze the literature in the 3D printing area.
2. Identify 3D model files, such as, STL files.
3. Modify 3D model files and understand design parameters regarding part quality.
4. Gain skillset to create new objects using the aid of computers, for example, TinkerCAD.
5. Compare finished products using different 3D printing and the dependence of various materials.

Laboratory Sessions:

Fused Deposition Modeling (FDM) Flash Forge Guider II and MakerBot Replicate Plus 3D printers with various capabilities of printing polymeric materials, for example, ABS, PLA, etc. are available in the chemical engineering laboratory to use during the laboratory sessions. The lab also has a reliable, affordable, and productive precision F170 3D printer from Stratasys.

Students will use Flash Forge Guider II and MakerBot Replicate Plus 3D printers in this project. This activity aims to familiarize the students with the steps of the rapid prototyping process and software. First, students will download available models from online repository websites such as Thing verse and Grab CAD, which have existing 3D model files in STL file format. Additionally, the course instructor will provide the scaffold designs. Then students are required to download the file, scale the model, adjust position and orientation, and finally follow the given instructions to 3D print the selected file using a Fused Deposition Modeling (FDM) printer. Figure 1 shows the MakerBot build plate with scaling.

In the second laboratory session, students will compare the design between Flash Forge Guider II and MakerBot Replicate Plus and understand the process of extrusion and the dependence on a variety of materials such as PLA and ABS.

Finally, two students will be assigned a final project with a report submission and presentation. In the project, students will create and print a 3-dimensional object from scratch. For creating the model, students will use TinkerCAD. TinkerCAD is a free-of-charge, online 3D modeling program that runs in a web browser. Students are provided with basic instructions and tutorials to design a 3D model step by step.

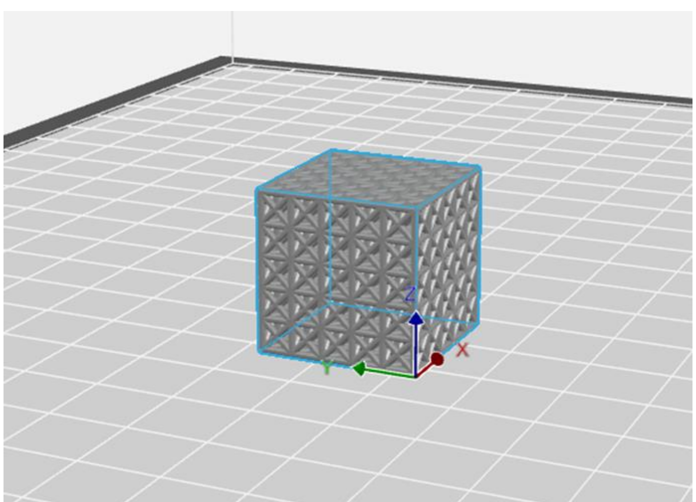

Figure 1: MakerBot build plate with scaling

Methodology

Students enrolled in the CHEG 4310 Polymer Science and Engineering course in Spring 2022 will participate in this research. Students will receive a pre-survey and post-survey to measure motivation and interest. The surveys will validate the effectiveness of incorporating AM in the course, with regards to motivating students' interest to accurately translate designs from computer model to physical products. Participants are asked to complete an online structured questionnaire. Student participation in the surveys is voluntary and anonymous. The surveys will be administered by staff or faculty who are not affiliated with the course offering. The nonprobabilistic convenience sampling method is used as a sampling technique to survey underrepresented minority students with minority women. The surveys are voluntary and are administered during exercise sessions. While students are encouraged to complete the surveys, they are also notified that their course grades have no bearing on their participation. The pre-survey will be conducted at the beginning of the semester before giving any theoretical knowledge of AM. Post-survey is distributed at the end of the semester when students have completed the design and fabrication of the model.

The course survey is an effective form of analysis to evaluate how the learning objectives are fulfilled [14]. The surveys are designed to measure students' interest and perceived value for a 3D printing task through empirical studies. The first part of the research investigates whether students can create computer models, print, and then optimize based on design criteria. The second question is whether this design exercise increases students' interest in 3D printing. The pre- and post-surveys are rated on a 5 level Likert scale. Therefore, students are going to rate the survey questions as strongly agree (5), agree (4), neutral (3), disagree (2) and strongly disagree (1). Both pre and post-surveys will begin with similar questions. Table 1 shows the design concept questions for this research.

Table 1 The Pre-Survey Questions on 3D Printing

Focus Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Aware of the topics on 3D printing					
Aware of the skillsets for digital modeling through the aid of computers. Such as, AutoCad, TinkerCad					
Aware of performance and functional constraints of 3D printing					
Understand the process of slicing STL files for 3d print, and the interdependence of design parameters on part quality					
Understand the extrusion process and the dependence on a variety of filament materials?					
Understand the potential of using designing/ modeling objects on a computer for work					
Understand the potential of using design thinking in work					
Learning 3D printing could improve education					
Interest in working in STEM fields					
Interest in working in art and design fields using 3D printing					

Along with consent design questions, motivational questions will be added to the post-survey to address the research question that adding a project on 3D printing has altered students' motivation.

1. After finishing this project, I was motivated to learn new materials.
2. After finishing this project, I have an interest in 3D printing.
3. After finishing this 3D printing project, I feel comfortable enough with the topic of 3D printing to teach to someone else.
4. After finishing this 3D printing project, I have more enthusiasm towards learning.

5. After finishing this 3D printing project, I learned real-life skills.
6. After finishing this 3D printing project, I am confident in 3D-printing sequence of designing, fabricating, and measuring models.

Developing the Design for the Class Project

An undergraduate research assistant working with the principal investigator uses the Fused Deposition Modeling (FDM) technology to conduct a preliminary study on the repeatability performance using PLA and ABS plastic filaments for two types of 3D printers. ABS and PLA filaments are widely used today in both education and industry. However, each filament has its strength and weakness, including stiffness, durability, chemical resistance, and heat resistance. Although PLA filament is one of the most accessible materials, it only fits into hobbyist applications due to its poor heat and chemical resistance. On the other hand, ABS filament is lighter and more durable [15]. It is used in more practical applications.

A research student used the 3D printing technique for both ABS and PLA filaments to print different scaffolds design and understand the differences between those two filaments. At the same time, optimize the design position during the printing process. The designs were received from the University of Houston, Clear Lake (UHCL), where the designers had optimized the structure angles for actual scaffolds. There were five designs printed for this work: 3x3 bc, 5x5 bc, 5x5 fx, 5x5 fxbc, and a hollow design bc. PLA parts were printed using the MakerBot Replicate Plus printers, while ABS filament was used with the Flash Forge Guider II. The print setting for MakerBot is set as default; however, the number of external brims was eight, and the raft to model vertical shell offset was 0.33m. MakerBot printer requires the MakerBot print app to model, or the STL file can be loaded into the 3D platform to adjust position, orientation, and scaling with the print setting. The Flash Forge printer was set to print at high resolution with an enabled raft and default settings for layer heigh, number of shells, and infill density. The extruder temperature was 220 °C and the platform temperature was 100 °C. The printing speed was 40mm/s. Figure 2 shows the different scaffold designs printed with PLA and ABS filaments using MakerBot and Flash Forge printers, respectively. The particular printing process influences the implementation of the design project to the class as the conducted research gives primary design constraints such as minimum dimensions, spacing and angles. Since this is a one-semester course with time constraints, the logical sequence of information from these preliminary results will guide students throughout the project. This tutorial will give them a step-by-step instruction. A similar set of exercises will be given to the students as a final project where they will follow the steps and use their creativity to model and print a structure with optimized properties.

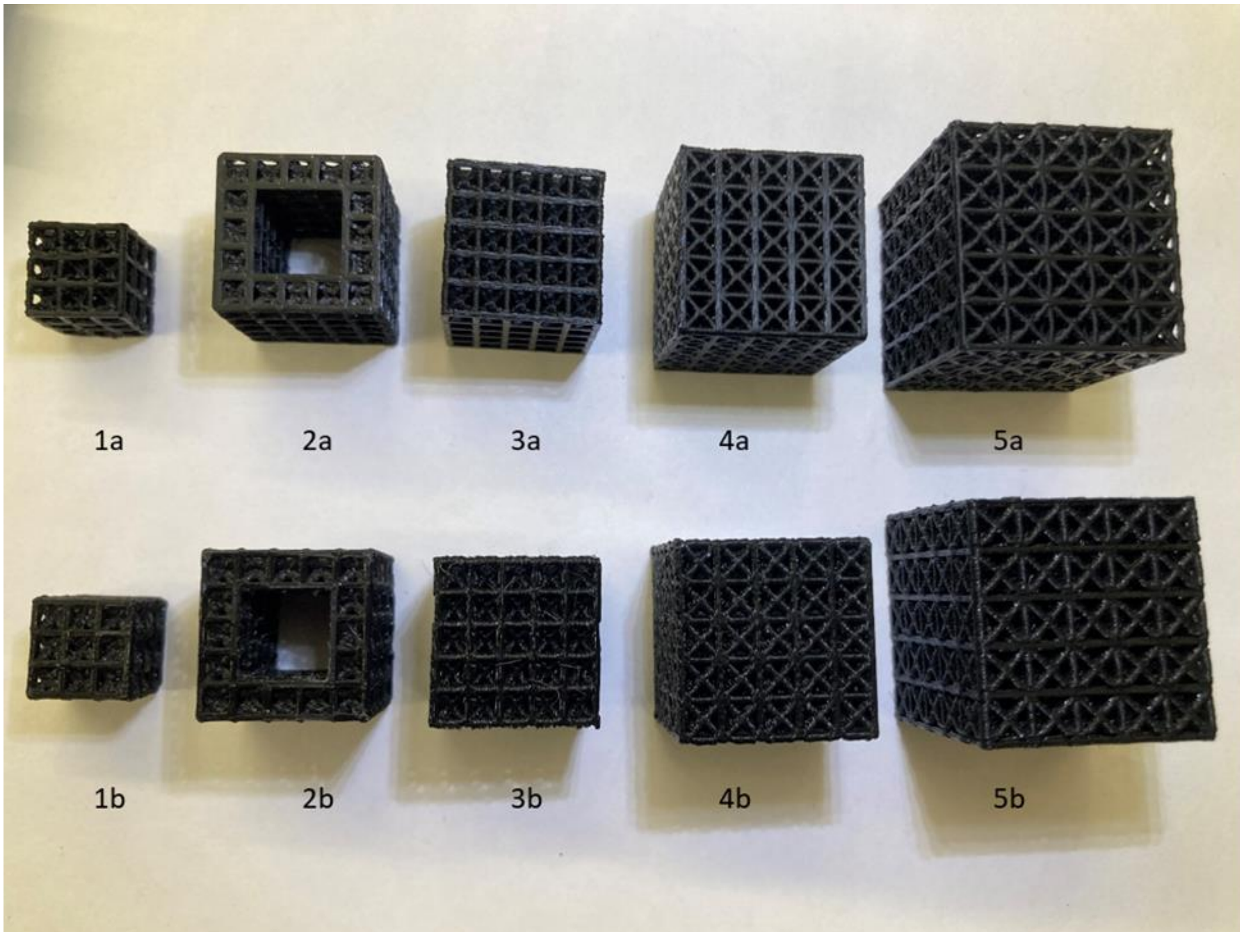

Figure 2: Parts from MakerBot and Flash forge. Top: ABS filament using Flash forge. Bottom: PLA filament using MakerBot. Left to right: 1. 3x3-bc, 2. hollow-5x5-bc, 3. 5x5-bc, 4. 5x5-fx, 5. 5x5-fxbc.

Preliminary Data

A Qualtrics survey was offered to the polymer science and engineering course during the spring 2022 semester. Ten responses were gathered from the pre-survey, and nine were collected (post-survey) after the first project was completed. The pre-exposure surveys measured the participants' fundamental knowledge, and interest in 3D printing. The survey also captures participants' curiosity about 3D printing aiming to evaluate how participants are involved in learning about 3D printing. Students took the same survey questions after completing project 1. The results from the first ten survey questions of pre and post survey are reported in Table 3 with the mean and standard deviations of each survey question. Results are obtained by averaging the Likert scale values reported on the pre-and post-survey for each question, while the standard deviation is indicative of the distribution of scores for each response. The statistics are conducted with paired T-tests, and the p values are reported to show statistical significance; p values below 0.05 are generally accepted as indications of statistical significance.

Table 2: Results of Pre and Post Survey questions mean and standard deviation

Questions	Mean	Std Deviation	Mean	Std Deviation	p
	Pre Survey		Post Survey		
Self-efficacy					
Aware of the topics on 3D printing	3.00	1.10	1.22	0.42	0.002
Aware of the skillsets for digital modeling through the aid of computers. Such as, AutoCad, TinkerCad	3.10	1.22	1.44	0.50	
Aware of performance and functional constraints of 3D printing	3.30	1.42	1.33	0.47	
Motivation					
Understand the process of slicing STL files for 3d print, and the interdependence of design parameters on part quality	3.90	1.14	1.67	0.47	0.034
Understand the extrusion process and the dependence on a variety of filament materials?	3.60	1.36	1.67	0.67	
Understand the potential of using designing/ modeling objects on a computer for work	2.50	1.02	1.33	0.47	
Understand the potential of using design thinking in work	1.70	0.46	1.22	0.42	
Interest					
Learning 3D printing could improve education	1.50	0.67	1.00	0.00	0.19
Interest in working in STEM fields	1.10	0.30	1.11	0.31	
Interest in working in design fields using 3D printing	1.90	0.94	1.44	0.68	

Although the number of the participants are small, the result shows that self-efficacy ($p< 0.002$) and motivation ($p< 0.034$) have statistically significant differences between pre and post survey. However, when the pre and post-survey results were compared, interest was not statistically different. As students already have an interest in learning and working in the STEM field. The qualitative observation of the pre and post survey are shown in the donut charts.

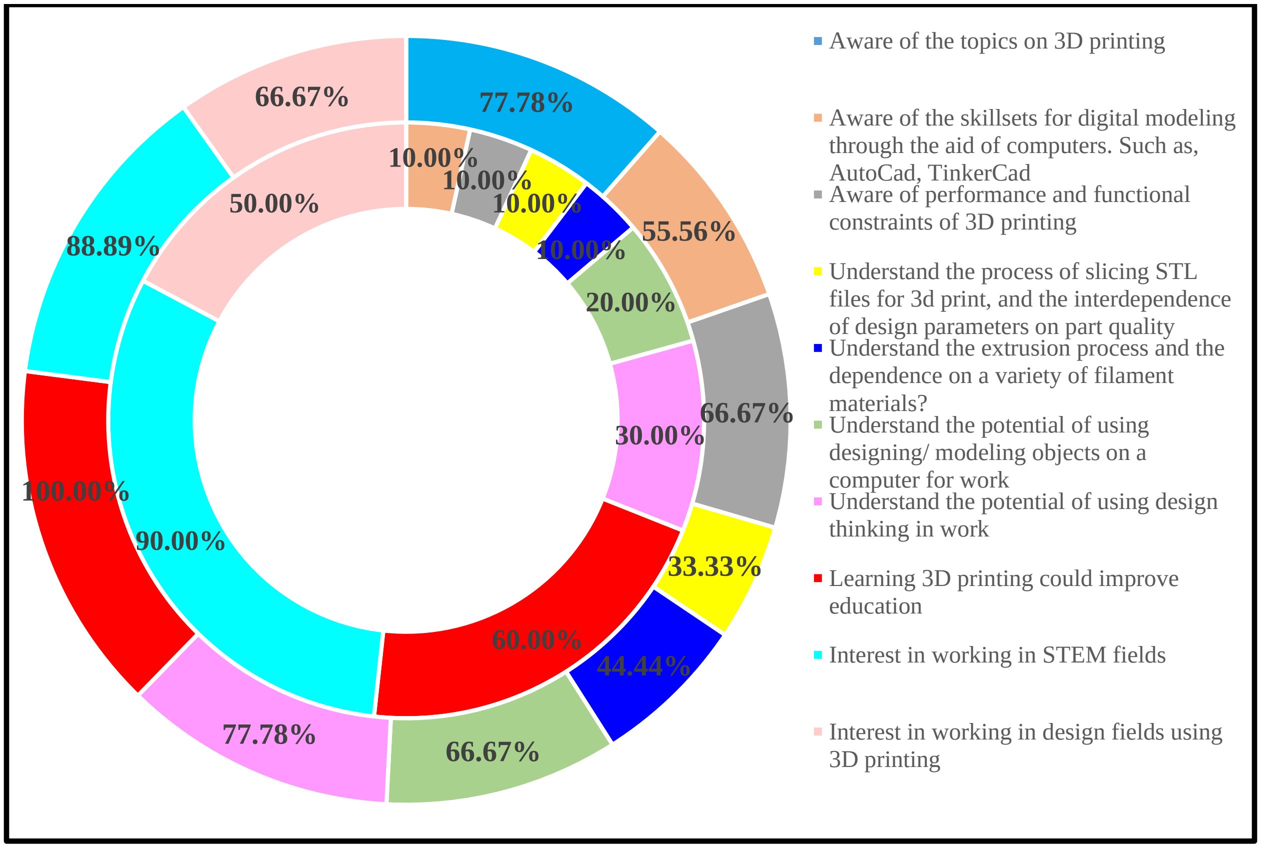

Figure 3 Pre and post-survey results of the percent of students who strongly agreed with the survey questions. Each color represents the survey questions.

Results show students have increased confidence with 3D printing in the post compared to the pre-survey. After completing project one on 3D printing, 100 % of students agreed that learning 3D printing could improve education in STEM. Recent work by Alexandria et al. [16] shows that adding 3D printing in biology courses can increase engagement and build confidence among students. General interest or excitement about 3D printing was the most similar theme mentioned by students for both surveys.

Motivation is seen as a pre-requisite and a necessary element for student engagement in learning. Figure 4 shows student perception after completing the first project. It shows that 67% of students were highly motivated to learn about new materials. Figure 4 shows that more than

75% of students enjoyed hands-on experiments and printing 3D objects, which increases interest in 3D printing.

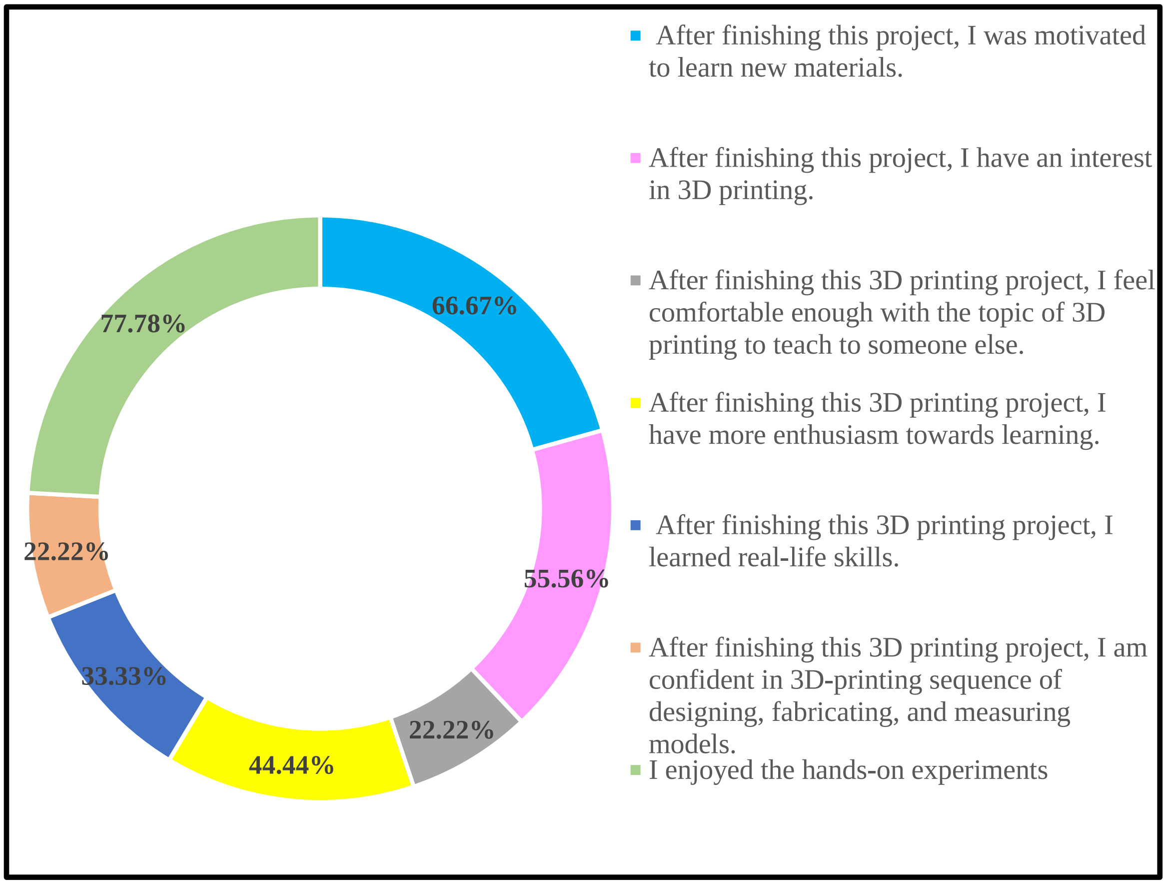

Figure 4. Percent of Student responded strongly agree to post survey questions after completing project 1 on 3D printing.

Even though 90% of students were interested in working in STEM initially, the percentage slightly decreased after the post-survey. This might be because 11% of the students considered it is moderately tricky (Figure 5) to obtain resources and conduct hands-on experiments. In addition, 77% thought the project was moderately challenging (Figure 6), which might be a reason for a decrease in interest in moving to the STEM work field.

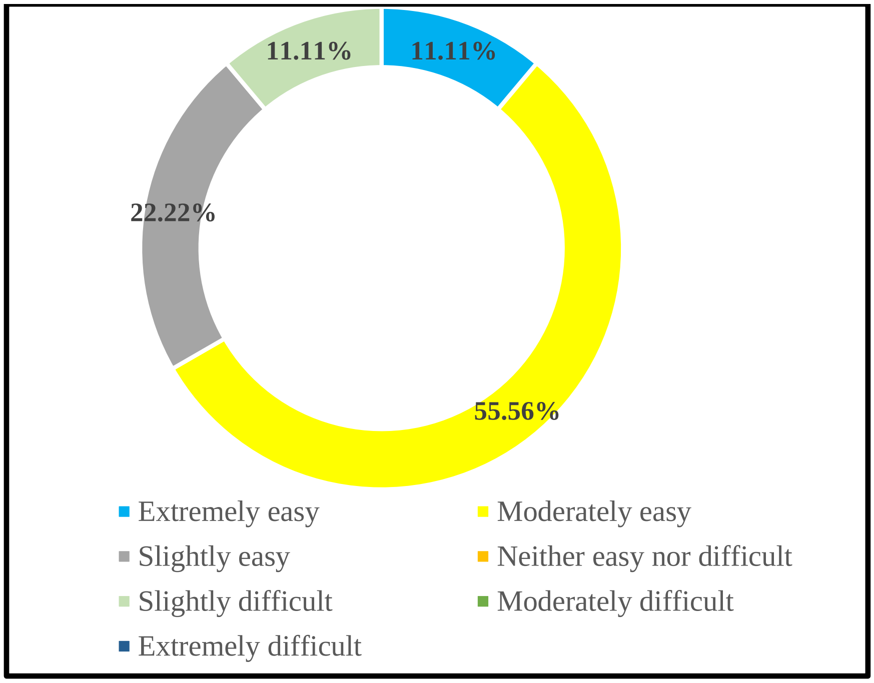

Figure 5: Students responses to how easy or difficult is it to obtain the resources that you need from the university library system?

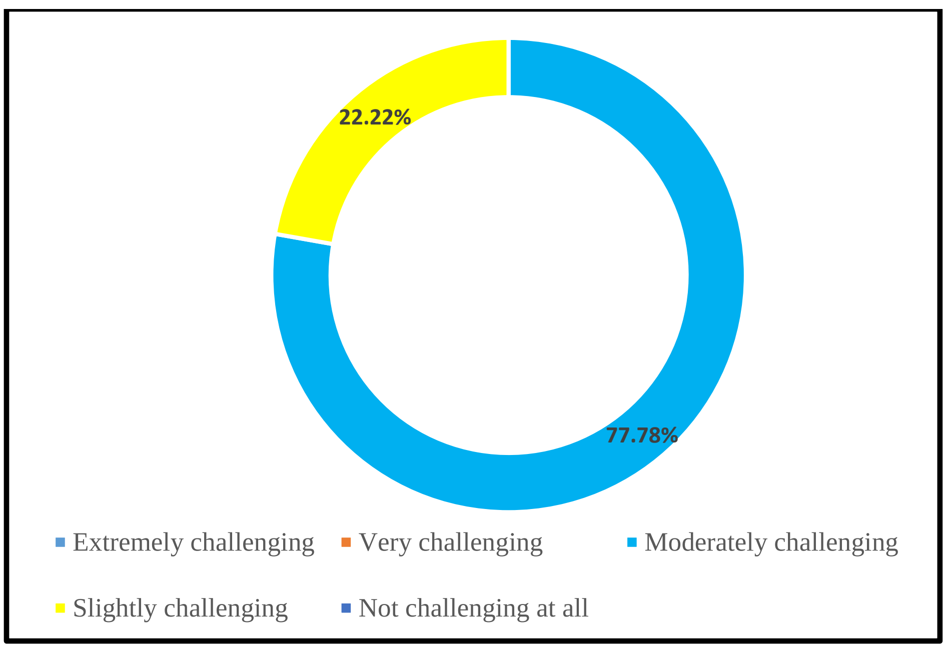

Figure 6: Students responses to how challenging was this project.

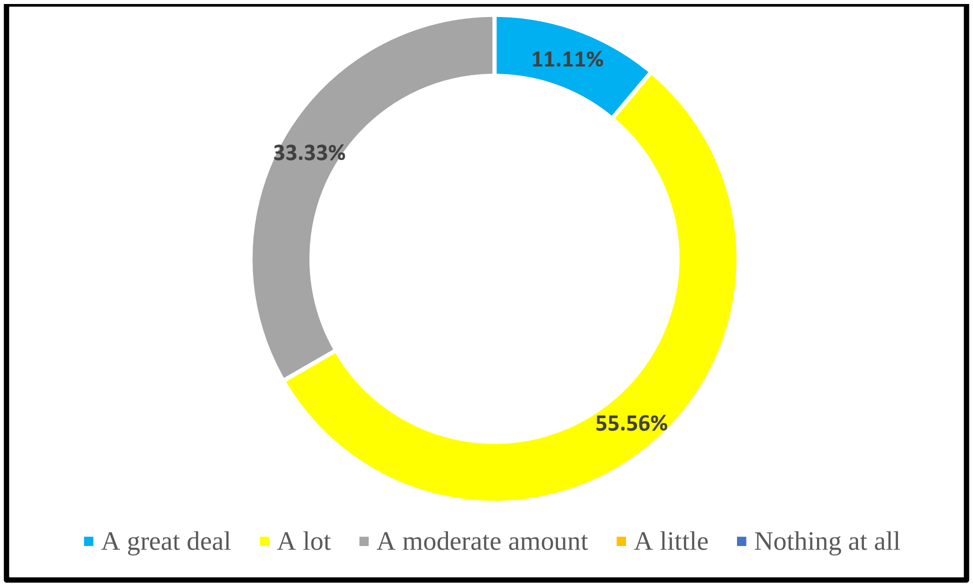

Figure 7: Students responses to how much did they learn from this project.

Overall. Students provided positive feedback about the hands on project on 3D printing. All student agreed they learned moderate to a lot in the hands on project. Students showed motivation and interest in learning and made comments on how enjoyable the project was;

1. We enjoyed 3-D printing and understand that this knowledge and experience of FDM printing is a major benefit to us and that we can take this knowledge of a relatively new concept and apply it to future endeavors.
2. This project helped reinforce problem-solving in engineering and helped expand our minds on another software that is possibly applicable to a future career.
3. Through this experiment, we have gained insight on how the design process works, how long we can expect our prints to take, and some of the challenges we can expect to confront.

Students also comment on self-efficacy, we learned from the 3D printing assignment is that to make a successful print you have to understand the structural needs of your design and possible weak points.

As we continue offering this course, we will develop new projects and modules to deliver to the students. We also plan to collect and publish more formal assessment data with a standard grading protocol in future iterations of the lab activities to demonstrate the effectiveness of the course in technology education.

Discussion and Conclusions

A 3D printing project is implemented in the elective course Polymer Science and Engineering at Prairie View A & M University. The laboratory experience will expose students to modeling and printing of a prototype, thus improving the educational quality and experience of minority students. In addition, all the students enrolled in the elective course will develop 3D model assignments and print the prototypes using 3D printers. These integrated research and educational efforts will better prepare minority students for careers in STEM fields, promote opportunities for recruiting minority students through technologically enhanced curricula and increase the flow of minority students into STEM careers. These results suggest that 3D printing projects can be successfully implemented in undergraduate courses and generate positive student outcomes. Engaging underrepresented minority students with 3D printing technology might have significant implications for retention of these students in STEM programs.

References

1. Guo, N. and Leu, M.C., Additive manufacturing: technology, applications and research needs, Frontiers of Mechanical Engineering, 8(3), 215-243, 2013.
2. Thompson, M.K., Moroni, G., Vaneker, T., Fadel, G., Campbell, R.I., Gibson, I., Bernard, A., Schulz, J., Graf, P., Ahuja, B., and Martina, F., Design for Additive Manufacturing: Trends, opportunities, considerations, and constraints, CIRP Annals, 65(2), 737-760, 2016.
3. Vrasidas, C., and Gene V. Glass, Current perspectives on applied information technologies: Preparing teachers to teach with technology, Information Age Pub, 225-240, 2005.
4. Lavin, A., Korte, L., and Davies, T., The impact of classroom technology on student behavior, 2009.
5. Stager, S.L.M.a.G.S., Invent to learn: Making, tinkering, and engineering in the classroom,. 2nd ed. 2019: Constructing Modern Knowledge press.
6. Vanscoder, J. 3D Printing As A Tool For Teaching And Learning In STEAM Education. in Society for Information Technology & Teacher Education International Conference. 2014. Jacksonville, Florida: Association for the Advancement of Computing in Education (AACE).
7. John C. Bean, D.M., Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom. 3rd ed. 2021: Wiley.
8. Oktiawan, W., Hadiwodo, M., and Purwono, P., Enhancement Student Understanding Through The Development Of Lab Module Based On Constructivistic, International Journal of Engineering Education, 2019.
9. Top 100 Producers of Bachelor's Degrees. 2020, Diverse Issues in Higher Education.
10. Woolston, C., Minority representation in US science workforce sees few gains, Nature, 592, 805-807, 2021.

11. How 3D Printing Will Change Your Engineering Degree. Studylink.
12. Serda, T., Educational Challenges in Design for Additive Manufacturing, in 2016 ASEE Annual Conference & Exposition. 2016: New Orleans, Lousiana.
13. Sullivan, W.M. and Rosin, M.S., A Life of the Mind for Practice: Bridging Liberal and Professional Education, Change: The Magazine of Higher Learning, 40, 44 - 47, 2008.
14. Chiu, P.H.P., Lai, K.W.C., Fan, T.K.F., and Cheng, S.H. A pedagogical model for introducing 3D printing technology in a freshman level course based on a classic instructional design theory. in 2015 IEEE Frontiers in Education Conference (FIE). 2015.
15. Grant, A., Regez, B., Kocak, S., Huber, J.D., and Mooers, A., Anisotropic properties of 3-D printed Poly Lactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS) plastics, Results in Materials, 12, 100227, 2021.
16. Alexandria K Hansen, Taylor R Langdon, Lukyon W Mendrin, Kaylin Peters, Jose Ramos, David D Lent, Exploring the Potential of 3D-printing in Biological Education: A Review of the Literature, Integrative and Comparative Biology, Volume 60, Issue 4, Pages 896–905, October 2020.