Multi-Institutional Collaboration in Additive Manufacturing

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Professor Wooldridge is a Registered Architect, a Professional Engineer in multiple disciplines including Architectural, Mechanical, and Manufacturing systems, and holds multiple patents related to consumer cooler technology. A fourth generation cattle farmer, he also owns two private engineering and design firms and has designed buildings and systems all across the central and southern regions of Kentucky. Wooldridge is also licensed by the ATF for explosives, their handling, and detonation, as well as providing consulting design and engineering services for weapons manufacturers. He teaches courses in additive manufacturing, pre-engineering, parametric design, and workforce leadership at Somerset Community College, where he serves as faculty and PI on various NSF, KCTCS TRAINS, and USDA grant projects. Professor Wooldridge created KCTCS' first technical, state wide, 3D printing certificate program, and is the director of SCC's Additive Manufacturing Center of Excellence, developing a variety of new applications and techniques to help KY businesses integrate additive manufacturing into their production and business models.

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Tom is a Professor of Mechanical Engineering Technology at Sinclair Community College. His areas of focus are design and manufacturing of products in the MET program curriculum. Tom serves as a Co-PI for the NSF funded AM-WATCH project. He provides guidance on design and curriculum development on additive manufacturing. Tom also serves as the Principal Investigator on the NSF funded STEM Guitar Project. He also manages the guitar manufacturing lab @ Sinclair which produces over 1700+ guitar kits a year for the STEM guitar project distributed across the United States. A PLTW affiliate professor for IED, NISOD Teaching Excellence award winner, Certified Autodesk instructor and ETAC-ABET Commissioner, and text book author, Tom has taught both at the high school and collegiate levels.

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Abstract

During the Fall 2018 semester, two community colleges and one university shared their design and additive manufacturing (AM) facilities and capabilities. While student teams learn the depth of technical drafting in one community college's design course, the other two institutions have opened the doors of their AM labs so that students can solidify the knowledge they acquire which is largely limited to the computer screen in their design course. As the design files are received by the AM labs of the other two institutions, the files are evaluated for AM related issues and modifications are suggested. Following any revisions, the AM labs begin production of the files, both in single version and batch production for potential, larger volume applications while demonstrating to the students and stakeholders the versatility and cloud manufacturing capabilities that AM has to offer on a variety of levels, as well as helping to improve the student's design competencies that are necessary for AM. This current paper will report the nature of the current AM coalition and share a sample student project designed and produced during the Fall 2018 semester. The feedback received from the students will also be shared.

Background

AM, also known as 3D Printing, is one of the most commonly used fabrication technologies used in design, STEM, art, and healthcare lately to solidify students' learning and success [1]. It has been proven that students who gain the skill sets of today's industry have a better chance in getting a competitive job in their future careers [2]. So, it is clear that the impact of AM on several fields is growing widely [3], [4]. However, several institutions do not have the resources to learn and practice the capabilities of this cutting-edge technology, especially when it comes to rapid transition from design to scalable, volume level production.

As part of a current National Science Foundation (NSF) Project [5], several AM innovations have been developed and implemented in this project [6]-[13]. Throughout its execution, two community colleges and one university have established an AM coalition and set of best practices so that other higher education institutions could adapt and implement the similar best practices.

The combined efforts of intellectual designs by students from two community college professors' classes with professional design aid and prototyping from a university professor and his student made this project concept a reality. The project team had the task of creating a reliable design that can help people with weaker muscle tissue perform the ordinary and everyday task of opening plastic caps and soda bottles or cans, and this would be accomplished through a design solution that was a simple and repeatable part model.

Furthermore, the team had to address the initial problem that not all bottle caps are made with the same dimensions, which required the need for a universal design that could accommodate a variety of commercial sizes. Water bottles, sports drinks, and soda bottles tend to be in containers with caps that differ from the other two respectively. These three sizes seemed to be the constant variable; at least for the US standard plastic bottles along with the universal metal can tabs and the glass bottle caps that must also be able to be opened easily through the use of the cumulative design.

Figure 1 presents an image of one of the several initial prototype concept models the Sinclair Community College students developed. This concept is meant for two sized plastic caps using a socket wrench type model with the larger cap fitting the first countersunk cylinder and a smaller bottle fit for the secondary countersunk cylinder with a standard recognizable glass bottle opener on the far end. The long arm of the design allowed for a higher torque at the connection point with the cap so that users would not have to apply as much twisting force. This was a great start to the design process as it still had room for improvement and needed to be more versatile. Specifically, the requirements that this tool had to be usable with every can or bottle anyone may encounter within their daily lives had to also be addressed.

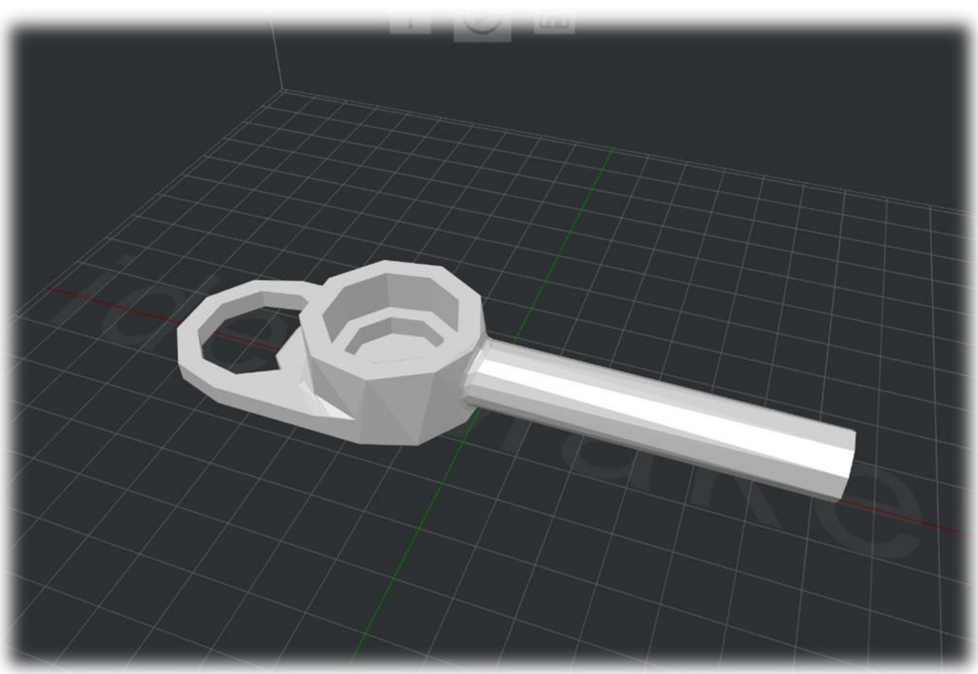

Figure 1: One of the first few student submissions with interesting concept

The student assistant working with the Tennessee Tech University professor proposed an alternative new and innovative design, and students at the Sinclair Community College got to work on the new CAD model. As the greatest ideas always seem to start on a napkin or sticky note, Figure 2 shows the innovative design made by the Tennessee Tech University student assistant.

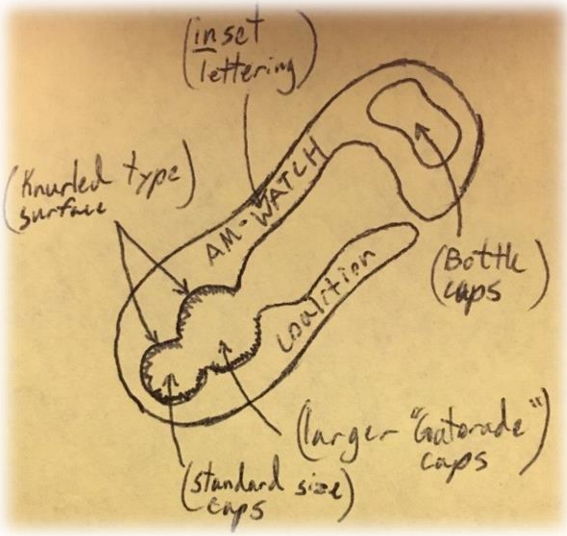

Figure 2: Innovative design changes made by the university student assistant

Eventually, this cutting-edge 3D model was created by the community college student from the concept sketch and printed to test the concept and usability of the design. The solid model of this new design is shown in Figure 3. Most of the team members liked the concept but there was still room for improvement. The main problem was the plastic printed tab snapped off because it was not strong enough to open metal bottle caps. Figure 4 shows a 3D printed model.

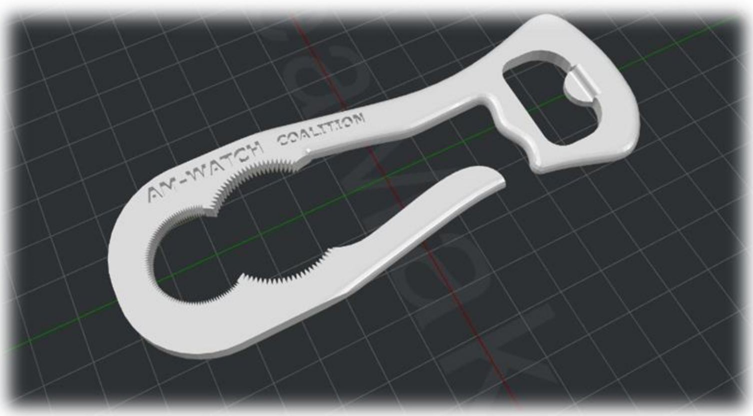

Figure 3: Solid model of the newly designed bottle cap opener

Figure 4: 3D Printed Model

The red circled area shown in Figure 5 was made stronger with the addition of material and final product results in an ergonomic design that makes opening of most bottles very easy due to the extended length of the grip. Now with this final design, anyone can enjoy their favorite beverage without straining their hands or arms!

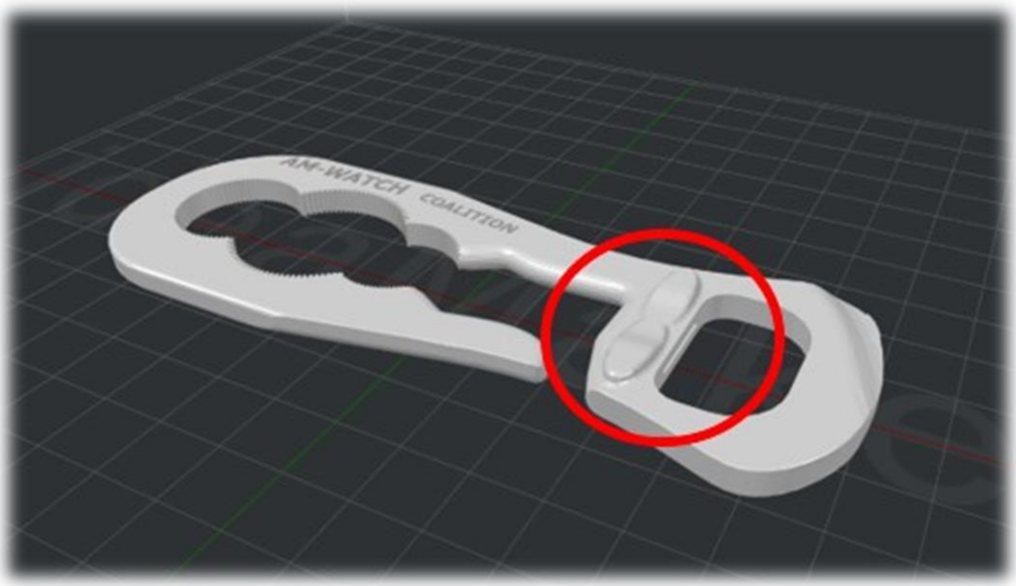

Figure 5: Improvement made to the initial design to make the bottle cap opener stronger

Unique Aspects of the Current Practice

The project has been accomplished by several students and faculty members in Sinclair Community College, Somerset Community College and Tennessee Tech University. The time duration of the project from start to finish was almost four months. Over 6 design changes and

3D Printing tasks have been made in order to continuously improve the bottle cap opener in a more functional way. The following items will provide short summaries of several distinctive features of the current hands-on project.

Student Learning and Success:

Most of the tasks and deliverables of the project have been made possible by the course students. Overall, students' enthusiasm and hard-work was the main factor for the successfully completion of the project.

Teamwork and Communication:

Students and faculty members of the three institutions have continuously communicated and discussed the current standing of the project and ways of constantly improving it. Several phone conversations and emails were exchanged to fully and successfully complete the project. Design and printing tasks of the project were equally distributed to students.

Critical Thinking and Creativity:

This project was an excellent opportunity for the students to increase their soft skills in critical thinking and creativity. Students came up with several design and 3D Printing ideas/solutions to make the project a complete success.

Remote Access Collaboration:

The project provided an opportunity for the students to quickly see tangible results from their work. The remote access network through a smart phone application developed by the project leaders provided an excellent avenue to let the students see their works while they were printed.

Continuous Improvement:

From the brainstorming session of the project to its completion, the entire team was able to review their current works and constantly suggest possible improvements. This way, the team continuously updated their current work to make it better each time. Figure 6 shows sample pictures from the continuous improvement works.

Figure 6: Classroom stages of the product development process from initial design review to proof of concept to product testing

Project Evaluation: Students' Perspectives

Five students were involved in the project, three from Tennessee Tech University, one from Sinclair Community College, and one from Somerset Community College. A brief evaluation survey with both closed-ended and open-ended questions was administered to these five students to get an idea regarding their experiences and their perceptions related to their work on the project. All of them had been working with 3D printers for at least two years. All the students indicated that they had high interest level in the project. The students were involved in the different aspects of the project, including the design phase, optimization, and printing of the parts of the product.

When asked about the part of the project that they enjoyed the most, the students stated the following:

- 3D printing in different machines and materials
- I helped and recommended design changes to optimize the part especially bottle opener side. I recommended to reinforce the area where undergoes more stress concentration
- The redevelopment of the opener was a great aspect because it showed me how a real product would work through the design process and how to change and fix problems
- Testing to see what worked best
- The design phase

From the students' perspective, aspects of the AM-WATCH [5] bottle cap opener project that could be improved in the future included the fact that additional reinforcement could be added and thickness could be decreased. The hand-gripping part of the opener could also be optimized. One student also suggested rotating the penny section so that the working stress was redirected across the grain of the print. Enhancing the durability of the product is also an issue that was mentioned by one of the students.

The students indicated having learned invaluable lessons from the bottle cap opener project. Aspects learned include the following:

- design is not about looks;
- it's about functionality;
- how to efficiently optimize the part with the help of CAD software;
- the redevelopment stage of designing and how the first design will always change;
- iterative designs are great for improvement of the end product, and;
- ergonomic design techniques.

From an evaluative standpoint, overall, the project was a success. Both the faculty and students were satisfied with the process and product. The lessons learned from this project are invaluable.

Conclusions

Collaborative design and production project accomplished by two community colleges and one university faculty and students was highlighted in this paper. Innovative bottle cap opener design and 3D printing was the main task for the students and faculty members in this practice. The entire team has made several design and printing revisions to obtain a functional finished product at the end. Other than the engineering design and production practices, this exercise has also provided several other unique soft skills and opportunities that the students could gain.

Acknowledgements

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