Teaching High School Students Design Process and 3-D Printing: Lessons Learned

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As an external evaluator, Gwen has conducted over 70 evaluations in various areas with an emphasis in STEM-H related curriculum experiences at various colleges and universities across the U.S. Gwen's work with NSF, USDOE, DOE, DOD, HRSA, and DOJ helps in providing the evaluative needs and expectations of federally funded grants with regard to accountability and compliance. In addition, she has served as a panel reviewer for NSF proposals for S-STEM and other EHR programs, GAANN, SIP, and EOC with the USDOE, and is currently an AQIP Reviewer and Peer Reviewer for the NCA Higher Learning Commission.

As an administrator, Gwen has served Director of Assessment for 6 years and Executive Assistant to the President for one year at Rose-Hulman Institute of Technology. She has also served as Assistant to the President and Provost for Special Projects at a Old Dominion University. Her experience as a Commissioner on the Indiana Commission for Higher Education has allowed her to embrace a broader perspective of the nuances of higher education and business & industry. In addition, Gwen has served as the board chair for the Indiana Minority Health Coalition—a grassroots legislated non-profit organization that promoted advocacy and education across the state with 19 local coalitions. As a full-time tenure track assistant professor and an adjunct faculty, Gwen has helped Master and PhD students understand and navigate the subtleties of organizational culture to negotiate their professional success.

Gwen received her bachelor's degree from Southeastern Louisiana University in 1984, her Master's Degree in Curriculum and Instruction in 1996, and a PhD in Education Administration in 1999 from Indiana State University.

Teaching High-school 3-D-Printing and Advanced Manufacturing Using Autodesk Inventor – lesson Learned

Dr. Ahmed Cherif Megri
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Abstract:

We conducted a summer teaching class about advanced manufacturing and 3D printing (project financed by National Nuclear Security Administration (NISA) & Department of Energy DOE).
3D printing is considered to be one of the most innovative technologies of the current century, with diverse applications in education, engineering, art, and design. With our summer program, our objective is to serve advanced manufacturing, as evolving technology and to improve STEM education and prepare the new generation of high-school students (future engineers) by the use of the existing tools.

Through the use of programs, such as Autodesk Inventor and CREO, as well as 3D printing concepts, we include both technology and basic traditional STEM topics, such as math and science. These tools allow the students to reach their objectives without going through complex mathematics and engineering concepts and methods. This way, these projects will mostly focus on critical thinking and the development of creative solutions to problems.

Without deep mathematics knowledge, students were able to conceptualize, customize and prototype their design. The visual nature of these tools (Inventor and CREO) and the 3D printing technology enabled high-school students to grasp the technology and concepts very quickly.

The purpose of this paper is to demonstrate the design and implementation of an experiment, from basic parts. In particular, we will discuss the lesson learned, such as:

- Instead of going through the program chapter by chapter, we are encouraging collaboration and integrated work, through a set of projects that students need to select only five of them that fit their need and curiosity.

- Going through the design process, step-by-step: define the problem, background research, specify the requirements, brainstorm solutions, development work, prepare the prototype and finally assessment and analysis. Students have the ability to create their own designs using tools to reach creative design and concrete outcomes.

Most importantly, the project methodology will be discussed. We discuss the project design program from students' point of view, and the experience earned in design, integration, and also in written and oral communication skills. The methodology used to evaluate the effectiveness of this design program in term of learning outcomes is also described. In this paper, we focus only on the third year of the summer camp.

Introduction:

To invite high school students into a college setting to learn about engineering design, and 3D printing to spark interest in STEM related programs, thirteen high school students (10th and 11th grade) were invited to participate in a two-week summer camp at North Carolina A&T State University (NCAT) campus. The team that conducted the workshop is composed of two NCAT faculty members, one undergraduate student and a high school teacher. The workshop took place between July 9 and 20th, and started at 9 AM, and ended at 5 PM. The lunch break was at 12 noon (lunch was provided). The main objective of the workshop was to prepare a pipeline of students in the area of advanced manufacturing and 3D-printing.

In particular the objective of this summer camp is to teach the students how to use Autodesk Inventor™ 3D CAD software which is a computer-aided design application for creating 3D digital prototypes that are used in the design, visualization and simulation of parts and assemblies. During the first three days, the students did learn the basic tools and utilities of the program. Each student then worked on four projects that they chose from twelve projects suggested by the instructors.

The lectures aimed to inform the students about the great interest that the Department of Energy (DOE) has in advancing engineering graphic design and advanced manufacturing (AM) in its facilities (Shahi, 2016), **(**Tibbits, 2017)**.** The lectures also exposed the students to the specific applications of AM that DOE is using in these facilities. The camp also included a half-day visit to a facility on campus that uses computer graphics designs and 3D-printing. The afternoon of the last day of the workshop was dedicated to students' presentations where each student gave a twenty to thirty minute presentation about his/her design. The presentations are aimed to improve students' communication skills. Also, parents were invited to attend the presentations.

Workshop Objectives and General Description:

The two-week summer camp was part of an outreach program that includes lectures, activities and presentations. Specifically, this program has multiple goals:

1) Train the students to use Inventor™ 3D CAD computer program to design objects and teach them how to 3D print parts created.
2) Improve students' STEM skills.
3) Introduce the students to advanced manufacturing (AM), solar energy, and materials science and engineering.
4) Improve students' communication skills.

The camp involved twelve high school students (mainly 10th and 11th grade) and a high school teacher in a two-week workshop. The aim of the camp was to provide the students hands-on experience in modeling and generating engineering designs using Autodesk Inventor™ 3D CAD computer program which is one of the programs used for solid modeling. The program is similar to PTC CREO that is used in Honeywell at the Kansas City Plant, and many other industries. One major advantage of the program is that interested students can download a one-month trial copy of the program to their own computers free of charge.

The workshop took place between July 9 and 20th (schedule is shown in Table 1), high schools principals and guidance counselors in Guilford County were contacted so that the teachers in their schools assisted in choosing the participating students. Students included both genders and at least 70% minority students (these criteria are requested from the sponsor).

Table 1: summer camp schedule

Day	Lectures	Projects
Friday, July 6th	Meet-and-greet: students and parents meet with the instructors, visited the computer lab, and informed about the main activities of the camp.	
Monday, July 9th	-Introduction to Engineering Design Process. Examples are provided. -Introduction to 3D-printing & 3D-printers -Introduction to Advanced Manufacturing	Inventor Software: Project folders and settings, Screen Layout, Additional Information
Tuesday, July 10th	Basic tools and utilities of the program (Part Models): Extrude (Join and Cut), Sketches – Dimensions and Constraints (Horizontal, Vertical, Tangent)	Projects 1 & 2
Wednesday, July 11th	Basic tools and utilities of the program (Part Models): Extrude (Join and Cut), Sketches – Dimensions and Constraints (Horizontal, Vertical, Tangent)	Projects 3 & 4
Thursday, July 12th	-External presenter: introduction of material science, solar energy -Effective Spooling for 3D Printing Filament. The use of the tensile strength machine (TSM)	Project5
Friday, July 13th	Assembly Models	Project 6
Monday, July 16th	-The specific applications of AM that DOE is using in his facilities -3D-printers presentation and demonstration: Fortus 400mc 3D printer -The students express themselves through poems	Project 7 3D-printing of selected projects

Tuesday, July 17th	-Half-day visit to a facility on campus that uses computer graphics designs and 3D-printing	Project 8 3D-printing of selected projects
Wednesday, July 18th	Assembly Models	Project 9 3D-printing of selected projects
Thursday, July 19th	Presentation Models: Templates, Creating Views, Tweaks, Animation	Project 10 (the use of stress analysis) 3D-printing of selected projects
Friday, July 20th	-Students learn to make an oral presentation & ppt -Students' presentations where (twenty to thirty minute presentation) about his/her design	3D-printing of selected projects

Requests were provided to local high schools in Guilford County. Of the applications submitted, 12 students were selected. The selected students are mainly high school sophomores and juniors. The focus was mainly on three local high schools (Page, Northern, Eastern), since they include a large number of minority students. The selection criteria are the GPA, student interest and the recommendation of their teachers. The parents' income is not taken into account. Each Student was paid $200 to participate in this summer camp. The total number of students who applied was about 20 students.

Our goal when recruiting a high school teacher is to have competent and involved instructor, who is qualified and interested in drafting, with deep knowledge of Autodesk Inventor and 3D printing. After a few contacts with drafting and architectural drafting teachers in high school, our selection was very easy, since a teacher with all these qualifications was emerged.

The day before starting the workshop, the students and their parents were invited to a meet-and-greet where they met the instructors, visited the computer lab, and were informed about the main activities of the camp. During the first three days of the camp, students learned hands-on the basic tools of the Inventor program. The students have access to ErinScan-Pro 3D scanner, tensile strength machine (TSM).

Mark-10 manual ES-30 Tensile Test is used and available for the students. TSM force gauge is used for obtaining the mechanical characteristics of isotropic materials, by pulling plastic sealed pieces to breakage. During the last morning, students learn to make an oral presentation. At the afternoon, each student gave a twenty-minute Power Point presentation about his/her design followed by a ten minute discussion during which the student was expected to defend his/her design. Parents were also invited to the presentations.

Summer Camp and Learning Process:

The students learned two primary components that are interlinked in the AM course content: the engineering design process, and manufacturing skills. The course is comprised of several project units, scattered with some 3D-printing skills. Most projects in the course require the use of the design process which we did introduce to the students in one lecture. This course focused on using the process in practice and understanding its systematic, iterative nature. Iterative design is a design methodology in which the process is cyclical and involves sketching, testing, analyzing and improving the product design or features (Nielsen, 1993).

Students are required to carefully and document their ideas, using sketches, and data collected throughout the design process, which is assessed after each project. In addition, students must verbally communicate with their peers and teachers in both formal and informal presentations to justify their design decisions and pitch their final design solutions. The manufacturing and engineering aspects of the course require the students to draw their ideas, through sketches, in two dimensions and, later to build them in three dimensions using a computer program, and 3D-printers. Specifically, they learn to communicate their ideas using both pencil and computer technologies including 3D printers. The sequence of projects is such that there is a consistent progression from 2D to 3D, as well as a progression of sophistication in using the technology. Early in the course, students learned to use 2D drawing sketch. As projects progressed, students moved to 3D CAD packages (Autodesk Inventor) to create blueprints for 3D objects and assemblies or to 3D print their prototypes.

We have multiple levels of 3D-printers, the basic ones and the most advanced ones. The basic ones are easy to use and can be used by the students. The advanced ones need a special training and require advance knowledge. At NCAT University, we have an instructor and a technician responsible for such sophisticated printers and they are always available to give information and help different students regarding the use of such printers.

Each of the projects is considered a design problem, and the projects are presented in order of increasing complexity thus, improving the understanding of the use of the software functionality.

The importance of understanding the criteria, the requirements of the design, details, and innovation before designing a product is emphasized. In a progressive manner, the students learn how to make investigation, and fulfill the design process, and built the models that meet the defined requirements and constraints (see appendix, figures 1 to 8). As the projects grew more sophisticated, students were paired with other students for whom they will collaborate to reach a final product.

When working on the design, the students began from sketching the design and discussing it with one of the instructors. The discussion included the math skills that the students utilized in making such designs. At least one of every student's designs were be 3D-printed. This year, we used Fortus 400mc 3D printer, which is a professional grade fused deposition modeling (FDM) printer, to print the students' designs.

In conjunction with the main objective of learning the design process and some elements of Advanced Manufacturing, math and fundamental science skills are also considered and used to improve the quality of the project. For example, overall heat transfer coefficient of the wall designed is calculated, starting from the simplest calculation, such as calculating the areas of the house walls, floor and other components. Later, the basic of heat transfer, such as conduction, convection, and radiation and their simplified equations are introduced and used to predict the overall heat transfer coefficient of the walls, floor, and roof. Tolerance, criteria, and time constraints are proposed to the students. Tolerance in engineering is the allowable limit or limits of variation into a physical dimension, a physical property of a material (thermal conductivity, density, and specific heat), and of the design object developed.

Thus, students are required to use measurement tools, calculators, and estimation in order to satisfy all the criteria and constraints imposed on them by the instructors at the beginning of each project and also to show that their design is feasible, within the time constraints and fulfill the criteria. The integration between the design and the STEM discipline qualify this course to be considered in the future as a STEM course, since the students apply skills from science and math to engineer solutions and apply different technologies to build their models.

The same course content could be offered using any number of different project ideas, leaving room for instructor creativity. The course is about using tools to solve problems with the understanding that flexibility and innovation are key attributes in the work force. The intent of the course is the same as the consortium for advanced manufacturing (CAM), which is to raise innovation, communication, teamwork, foundational math skills, and other skills needed in the case of high-school students, before they join the workforce or higher-level education. The funds of this outreach program are part of CAM financed by the Department of Energy (DOE).

At the end of the summer camp are oral presentations of all projects, describing the ideas, process, and the criteria used. Two types of oral presentations were made: one where the students express themselves through poems and the second is a final oral presentation describing every step of each project developed, in presence of the parents, family, and friends. Examples of project (designs from the summer camp) are shown in the figures 1 to 8 (Appendix).

Lessons learned from summer camp:

The activities of the camp and the degree of their success will be shared with other CAM members to determine the possibility that some of the activities would be implemented on other campuses. Knowing that other campuses in CAM plan to have similar summer camps, we also plan to learn from the success of activities from these camps.

1) During the summer, twelve high school students and a teacher participated in the summer camp. A number of lessons were learned from that program among which were: The use of an external competent and involved presenter to demonstrate various activities related to materials science, solar energy and even some extra summer camp activities was essential to the success of the camp, as well as to stimulate the mood and spirit of the

students.

2) The alternation of activities such as short lectures, software use, manual activities, as well as the use of 3D printers or STM was essential to the success of the summer camp, as students were focused and dedicated to learning.

3) The selection of the two-week summer camp period during the two summer months is essential. After discussion with the students and the high school teacher, we decided in the next camps to move the two weeks to the beginning of the summer vacation, just after the end of classes, because of the physical and mental availability of the students.
4) The future summer camp includes not only learning how to use Autodesk Inventor software, but also more advanced topics related to 3D printers, and sciences. For example, print a large number of 3D-printed dog-bone samples of different densities, perform tests and conduct further analysis, in connection with “force gauge and travel display”, “data display of load vs. distance”, and statistical calculation (minimum, maximum, average, area under curve), use of Excel and graph manipulation tools, including zoom, scaling and panning.

5) Improve STEM education by correlating "science" with "mathematics" and "software" using realistic examples related to 3D printing, materials science and mechanical analysis. For example, 3D printing of dog-bones, performing tests, using Autodesk Inventor for stress analysis, as well as excel to establish a mathematical relationship between different parameters.

6) Use former students who have completed this program to assist with student supervision, as well as to carry out advanced activities, such as improving existing design to achieve professional-level design, as well as to carry out activities related to fabrication/mounting of a new 3D printer, from purchased components. This will have a positive impact on current students, in terms of visualizing the benefits of this field.

7) Develop multiple versions of this curriculum for high-school science teachers, elementary and secondary students. With 3D printers available in elementary and middle schools, the ideas developed under this program will help science teachers at the primary and secondary levels to use their labs and advance the STEM region.

8) High school teacher participation was essential to the success of the workshop, since they provide knowledge and experience on how to deal with high-school students in different levels: educational and behavioral

9) Students were emailed data and information every night that prepared them for the next-day activity. This contributed to the success of the workshop as the students knew exactly the activities of the day and had the files they needed to start the activity.

10) Parents were kept involved by: a) inviting them to a short presentation about the camp on Friday afternoon before the start of the workshop (the workshop started the next Monday) and b) inviting them to their children’s presentations. One of the success stories of summer

camp is that two of the students who participated in the program were accepted into the Mechanical Engineering program and School of Technology at our University. They started their program in the following fall semester.

Evaluation and Methodology:

The success of the workshop was demonstrated through different outcomes, such as the two of the students who participated in the program and were later accepted in the Mechanical Engineering program and School of Technology at our University. Similarly, camp students participated in at least two different poster competitions (2017 Appalachian Energy summit, and MSIPP Consortium for Advanced Manufacturing 1^{st}, 2^{nd}, and 3^{rd} Annual CAM Scholar Poster Competitors), utilizing the work learned at the summer camp. These competitions are usually designed for undergraduate and graduate university students.

More evaluation research utilizes mixed-methods approach employing both qualitative and quantitative data sources to determine the impact of the workshop on student learning. Mixed methods designs are methodologically superior to simpler designs because of the ability to leverage the strengths of several different methods. Consistent data from both qualitative and quantitative methods increases the trust worthiness of findings.

Using the indirect course evaluation form, students were asked, anonymously, to self-assess their ability in specific areas identified by the instructor in connection with the course learning objectives, as well as the motivations for the program experience. The compilation of the results of the student self-assessment of course learning objectives questions for this short course is presented in Table 2. The students responded with "5" (Extremely Competent) through "1" (Not Very Competent). As well, a consent and approval from the students and their parents have been obtained for taking and publishing personal photos.

In this way, an equivalent class was obtained for each question. The results of the students' assessments show that for all the questions, students generally felt like they were able to perform the tasks requested. The next step is to check if the assignments performed by the students showed the same positive answers.

T test and the test of Kolmogorov-Smirnov (Test of Normality)

The Kolmogorov-Smirnov test are valid when testing whether a set of observations are from a completely-specified continuous distribution (Normal distribution), considering:

- The survey for a group of students before (pre) and after (post)
- The 'null hypothesis' is: H0: The sample data are not different than a normal population.
- And an 'alternative hypothesis' is: H1: The sample data are different than a normal population.

We conducted the test of Kolmogorov-Smirnov for Normality and the p-value shows that the data for all variable are not significant which means the normality of the data by rejecting the Null hypothesis. As conclusion, the 'null hypothesis': there is no difference in mean pre and post. The 'alternative hypothesis': there is a difference in mean pre and post.

Figure 1, as well as Table 3, show the survey (Table 2) results using the t-test (This test used to find the difference between the averages of two populations. The method is comparing the results between the pre and post summer camp. The results show that the majority of the topics are significantly improved.

The results for the t-test are significant for all the variables besides question 3 "Impacts of the Advanced Manufacturing industry into global warming and resource depletion" does not show any difference. From table 3, we observe the p-value all less than 0.05 which means all the questions show a significant result therefore, there is an important improvement in mean pre and post survey.

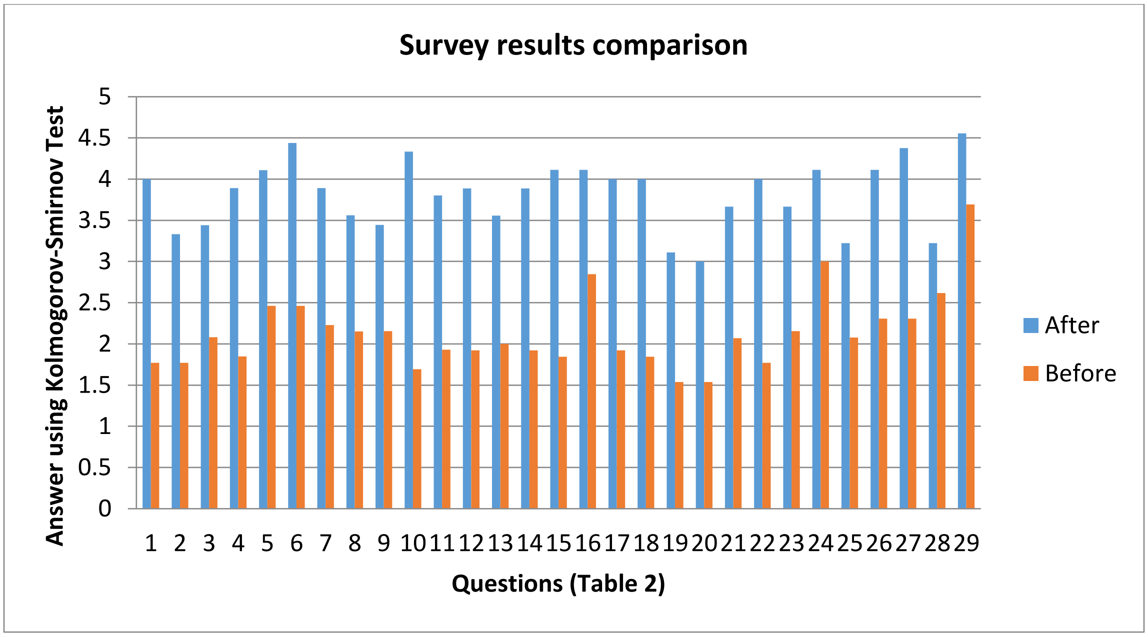

Figure 1: Statistical Results: The test of Kolmogorov-Smirnov

The instructor also conducted an evaluation of the performance of students in the course as part of the Program Objectives (PO) and outcome assessment process. A summary report on the performance of students (to meet the program objectives) and compliance with the program outcomes was prepared and submitted to the funding agency (DOE). A more rigorous process in assessing the learning outcomes of this summer camp course will be implemented, which are in parallel with the program outcomes. The following outlines the process that will be used for this course assessment:

- Individual instructor evaluation of the degree of learning achievement of individual students on a team, which includes consideration of the collective achievements of the team.
- Peer evaluation (optional by instructor)

- Grading of deliverables by the instructors (projects evaluation, oral presentation, team minutes, and web site if applicable)
- Teamwork survey & Self-assessment
- Final presentation judging (with evaluation criteria explicitly indexed to the learning objectives and articulated via rubrics for all measures).

The survey assessment of the competence and motivations before and after the class learning objectives show clearly that improvement in terms of competence of the students' modeling, data collection and analysis, and problem-solving. The improvement touched all aspects.

Table 2: Pre-Survey: Results of Indirect Assessment for this short course (12 students in the course). Please rate the following questions in regards to your current knowledge of the subject, scale of 1 – 5:

(**1**) Poor, (**2**) fair, (**3**) good, (**4**) very good and (**5**) excellent

1.	Scope of the Advanced Manufacturing (AM) industry
2.	Role of the ASTM Specifications on AM
3.	Impacts of the Advanced Manufacturing industry into global warming and resource depletion
4.	Concept of AM technology
5.	AM and 3D visualization
6.	How to select create 3D model
7.	Specifying final geometry of printed products
8.	Understand the basic environmental and economical issues related to the selection of 3D printers
9.	Understand the concepts of the life cycle analysis of parts
10.	I am familiar with AM industry
11.	I am familiar with commonly used 3D printers
12.	I am familiar with the properties of finished parts
13.	I am familiar with 3D scanners
14.	I am familiar with surface finish of parts
15.	I understand the connection between AM manufactured parts and 3D model
16.	I am familiar with connecting 3D model and the engineering graphics
17.	I am familiar with 3D engineering applications
18.	I am familiar with types of powders
19.	I am familiar with the code of specifications
20.	I am familiar properties of manufactured components
21.	I am familiar with plastic materials used in AM
22.	I am familiar with metallic materials used in AM
23.	I am familiar software to create the 3D Model
24.	I am familiar operating the printer to produce the 3D Model
25.	Select proper boundaries and coordinates to create 3D
26.	I am understand the impact of 3D model on the engineering field

27.	I am familiar with producing parts with different colors and various shapes
28.	This class helped me to select a major
29.	This class improve my understanding of engineering

Table 3: T-test and Kolmogorov-Smirnov test

Question	T test	p-value	Significant	KS test	p-value	Normality
1.Scope of the Advanced Manufacturing (AM) industry	-2.2698	0.017215	Yes	0.29908 0.26248	0.15838 0.48593	Yes
2. Role of the ASTM Specifications on AM	-3.5798	0.000937	Yes	0.24694 0.26248	0.34765 0.48593	Yes
3.Impacts of the Advanced Manufacturing industry into global warming and resource depletion	-1.1316	0.135599	No	0.20731 0.27293	0.56228 0.43723	Yes
4.Concept of AM technology	-5.9005	4.51E-06	Yes	0.3532 0.28335	0.06 0.39135	Yes
5. AM and 3D visualization	-2.9178	0.004254	Yes	0.1805 0.3469	0.72705 0.18008	Yes
6.How to select create 3D model	-3.622	0.00085	Yes	0.1889 0.346	0.67554 0.18008	Yes
7.Specifying final geometry of printed products	-2.0042	0.029391	Yes	0.17467 0.37001	0.76185 0.1297	Yes
8.Understand the basic environmental and economical issues related to the selection of 3D printers	-2.3113	0.015799	Yes	0.2581 0.27502	0.29786 0.42781	Yes
9.Understand the concepts of the life cycle analysis of parts	-2.1182	0.02344	Yes	0.28597 0.28335	0.19591 0.39135	Yes
10.I am familiar with AM industry	-3.5575	0.000987	Yes	0.28781 0.27778	0.19025 0.41552	Yes

Conclusions and Future Work:

Teaching the engineering design process to high-school students to encourage them toward a career in this area was a successful story, especially since DOE funded us to repeat this experience in the coming years. Our objective is to include both elementary and middle school students.

The main objective is to familiarize students with both advanced manufacturing, 3D-printing and how we can use these topics to design, and solve the new century challenges. Our objective is to take advantage of all the lessons learned and the experience gained during the first trial to improve the coming camps.

What is most significant about this summer camp is its comprehensiveness, since we developed a learning program around the design process, during which students developed sketches and then used software to design them and print them. After all, they learn to make a clear and professional presentation and to defend their ideas and works.

Our purpose for the coming years is to overcome shortcomings and to use the strengths of diverse outreach programs developed during the last year at NCAT (DOE-sponsored). Our objective is to contribute to improving the performance of the students to match the advanced technology in the US.

Our target this time will be elementary and middle school students and their teachers, since it is known that students' attitudes towards mathematics and science develop at a young age and become embedded by middle school. In order to encourage young students to pursue careers in science, technology, engineering, and mathematics, NCAT will develop a program for K-5 students and their teachers. This engineering outreach program will be implemented in predominately minority elementary schools in the Guilford school area. This work will aim to improve students' attitudes towards mathematics and science at a very young age.

The workshop will include multiple interactive activities (active learning) connected to math and sciences and related to 3D-printing, and advanced manufacturing. However, the students will not be exposed to any lectures. The workshop topics include activities related to the use of elementary functions of Autodesk Inventor Software, Energy, Solar panels, Sustainable Manufacturing, Materials, 3D Printing, Electrical Circuits, and Computer-aided Design/ Engineering. The main instructors will be an Elementary school teacher, and NCAT instructors, and industrial representatives. One or two high school students participating in the previous advanced manufacturing workshops and summer camps will also be involved.

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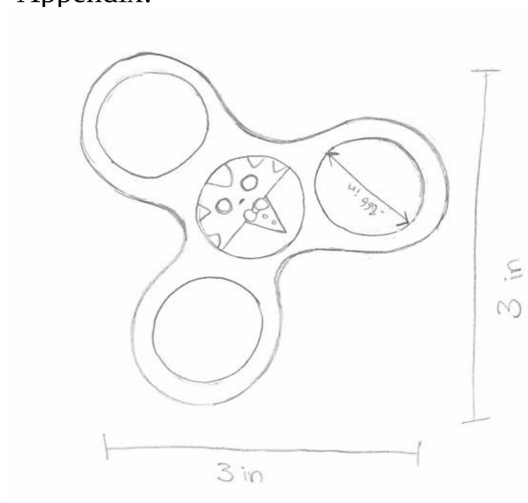
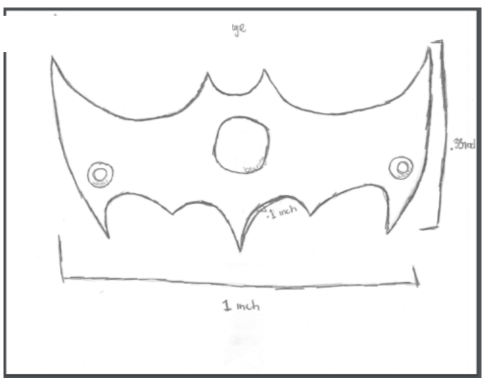
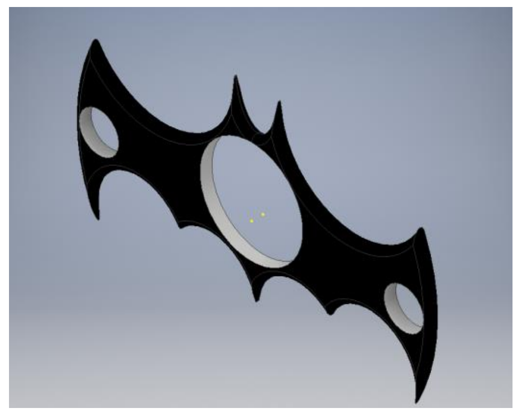
Appendix:

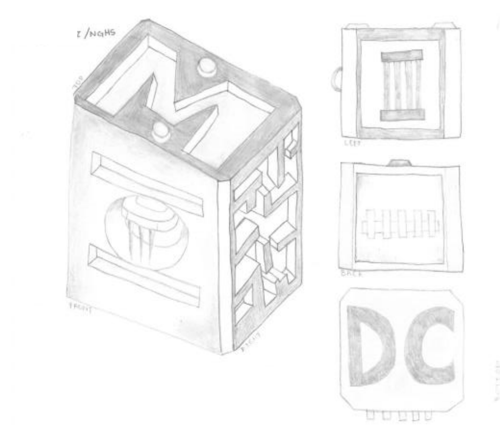


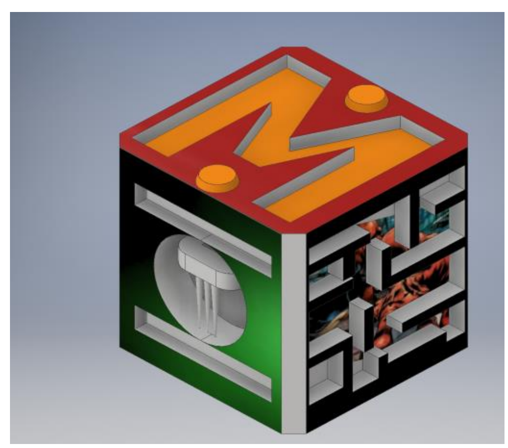
(a) Project 1: The fidget toy/ spinner





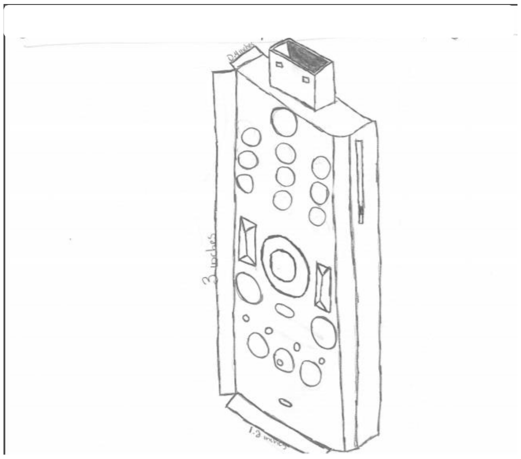
(b) Project 1: The fidget toy/ spinner

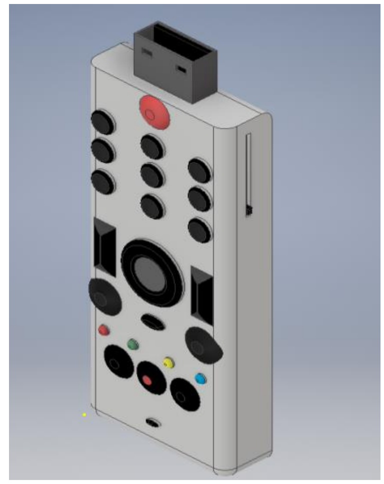




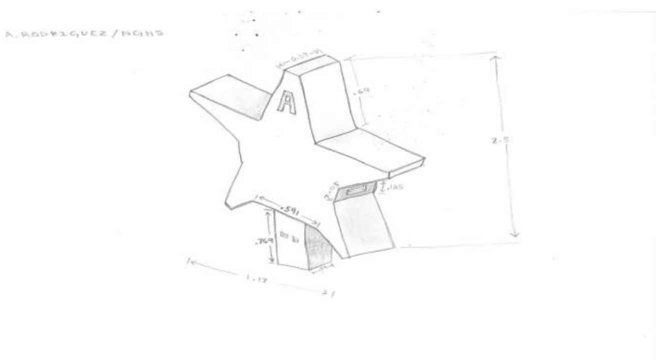
(c) Project 1: The fidget toy/ spinner

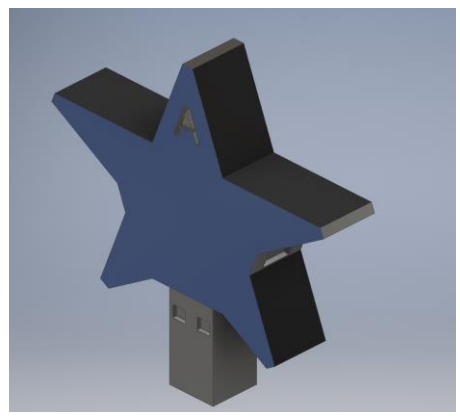
Figure 1: First training design



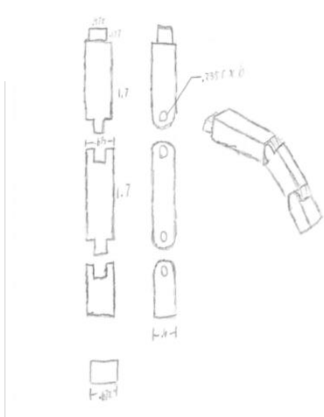


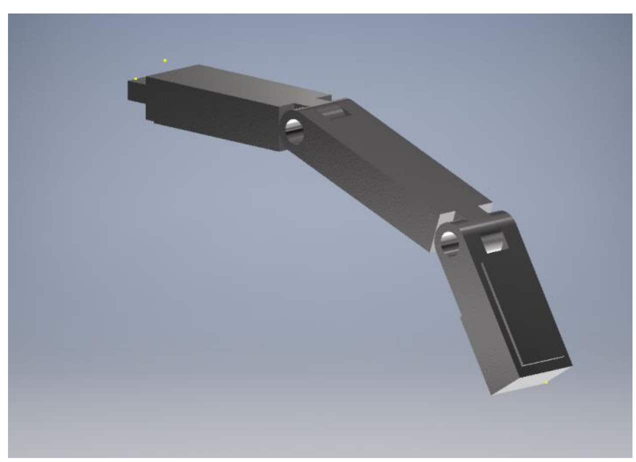
(a) Project 2: Decorative flash drive case





(b) Project 2: Decorative flash drive case





(c) Project 2: Decorative flash drive case

Figure 2: Second training design

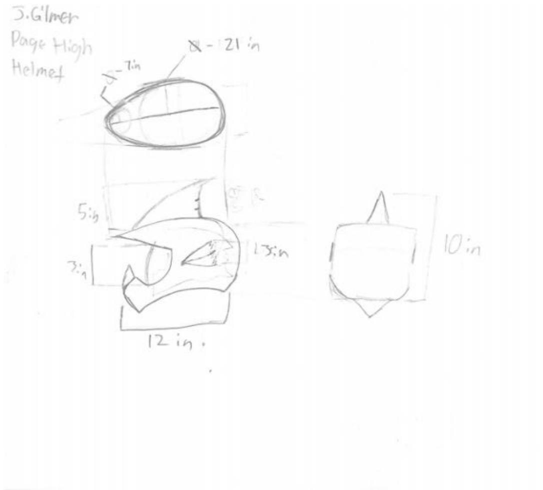


Figure 3: Helmet design

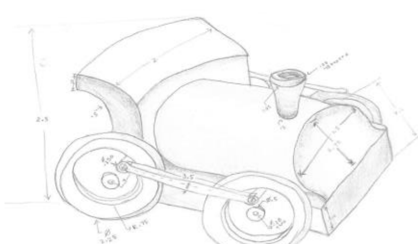



Figure 4: TRAIN

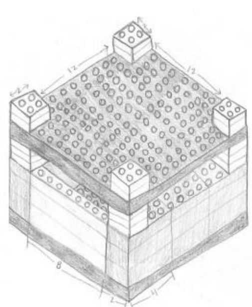
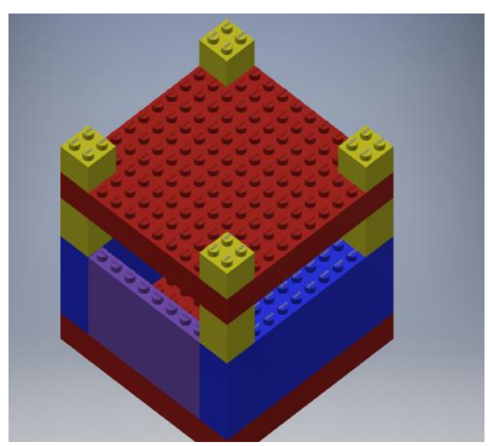



Figure 5: Lego jewelry box/ key holder

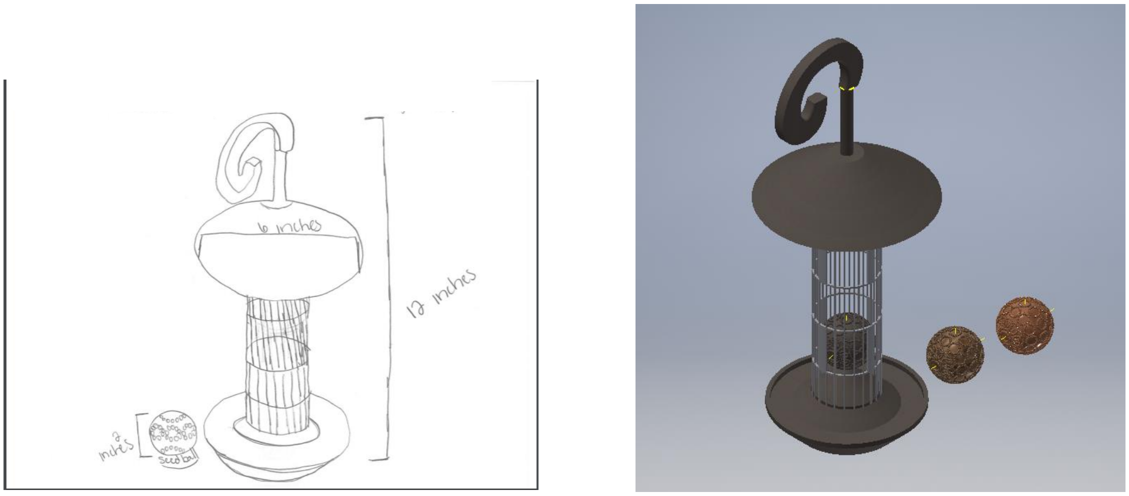


Figure 6: Group project for assembling a bird feeder

Figure 7 (a): CHESS PIECES

Figure 7 (b): CHESS PIECES

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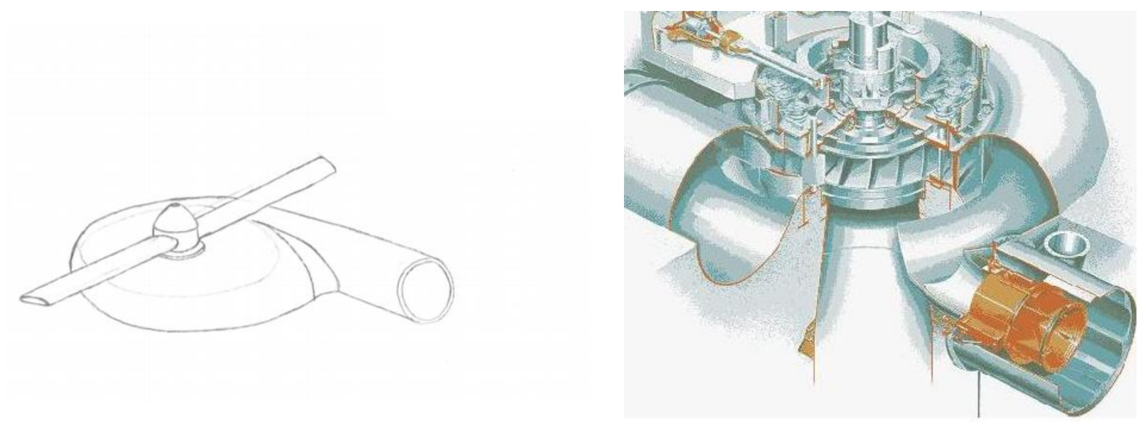

Figure 8: Turbomachinery