Research Experiences for Teachers
Enhancing Teacher Knowledge and Skills in Modern Manufacturing

Additive Manufacturing and Material Extrusion

By: Chip Brown

Supported by:
Richard Hoard
Vice Principal
Andy Dekaney High School
22351 Imperial Valley Drive
Houston, Texas 77073
Date: 07/15/2022

TEXAS A&M
UNIVERSITY.

Research Experiences for Teachers
Enhancing Teacher Knowledge and Skills in Modern Manufacturing

Additive Manufacturing and Material Extrusion

By: Chip Brown

Supported by:
Richard Hoard
Vice Principal
Andy Dekaney High School
22351 Imperial Valley Drive
Houston, Texas 77073
Date: 07/15/2022

Issue, Motivation, and Goals

Current State: The Project Lead the Way (PLTW) curriculum taught at Andy Dekaney High School does not currently include a unit that introduces the students to Additive Manufacturing, also known as, 3D Printing.

Current Enrollment: The program at Andy Dekaney High School currently has:

- There are approximately 250 students in the Engineering Pathway program
- Two teachers teaching 4 Engineering Preps in addition to teaching transportation and electronics courses
- Approximately 98% of those 250 students in the Engineering Pathway program are African American or Hispanic with the remainder being "other"
- Approximately 12% of those 250 students are female

Desired State: To enhance the PLTW Engineering Design Process (EDP) Curriculum and Technical/Engineering drawing curriculum with a unit on Additive Manufacturing and 3D Printing techniques. The students will then put into practice the specific 3D printing technique known as Material Extrusion.

Purpose: The goal of the Engineering program at Andy Dekaney High School is to ensure that all populations of students are exposed to the concepts and vocabulary they will see in their freshman and sophomore years of college, university, or trade school. **Since Additive manufacturing is now a widespread topic in colleges, universities, and trade schools, the goal of my engineering program and this curriculum enhancement is to ensure students have been exposed to the topic of 3D Printing prior to entering their freshmen year at a college, university, or trade school.**

Modification Summary	Content Knowledge (Input)	Conceptual Difficulty (Input)	Intended Goals (output)	Methods of Instruction
Accommodation	Same	Enhanced	Enhanced	Enhanced
Adaptation	Enhanced	Same	Enhanced	Enhanced
Parallel Curriculum Outcomes	Enhanced	Enhanced	Enhanced	Enhanced
Overlapping topics	Enhanced	Enhanced	Enhanced	Enhanced

Higher goals

Engineering Design Process
Technical Drawing, Fusion 360
Material Extrusion Printing

Desired State and Unit Description

Future State: Students will be introduced to Additive Manufacturing through a Unit on Additive Manufacturing. The unit will include:

A. Using the EDP, students will create a first version of phone stand.

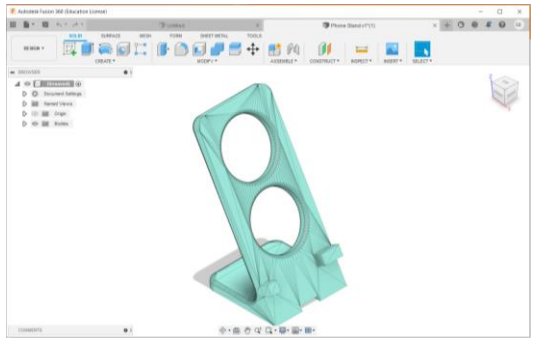
Class discussion will include:

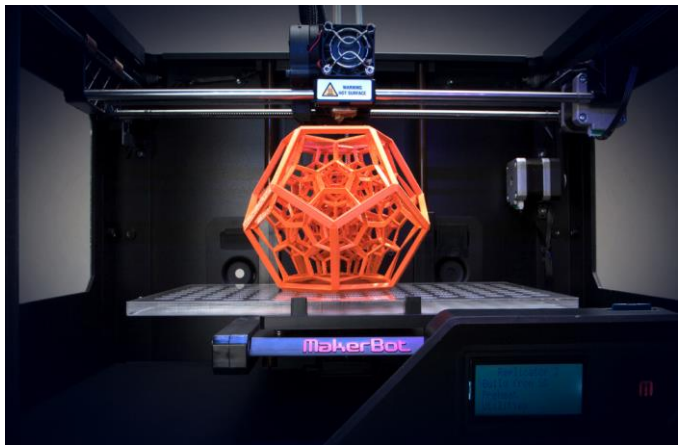
1. Steps of the EDP
2. Brainstorming techniques
3. Designing for Manufacturing
4. Innovation

B. Students will use Fusion 360 to create the "first" model of the phone stand.

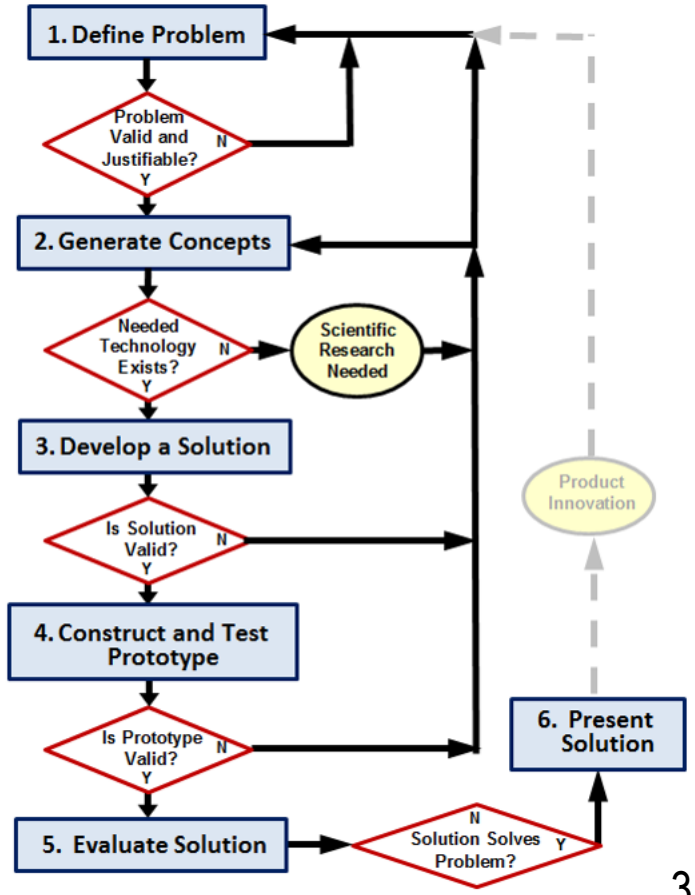
Class discussion will include

1. Layer thickness
2. Fill pattern
3. Fill percentage
4. Manufacturing orientation





3D Printing – CNN.com



PLTW.org

Equipment and Budget Considerations

Equipment Requirements:

- Eight (8) 3D Printers
  - Justification
    - Eight units will be required to accommodate two classes of 30 students each being able to print their version 1 samples within 24 hours of designing them. Each print will take 4-8 hours dependent upon fill %, layering, and fill pattern.
      (30 prints per class) / (2 parts per print session) x (8 hours per print) = 120 print hours
      120 print hours / 8 printers = 15 hours per printer to print 30 prints

- PLA spools, assorted colors
  - 24 spools per year
    - 1 spool will print 10 phone stands
    - 3 spools to print 30 phone stands
    - 2 -3 phone stands per student = 90 phone stands = 9 spools with 2 spools as spare. The additional spools will also provide color variations for any outside projects requested by the school or district.
    - Additional spools will be used for Capstone projects and competition projects.

Equipment and Budget Justification

Item	Quan	Unit	Total
3D Printer	8	$ 2,000.00	$ 16,000.00
Shelving	2	$ 375.00	$ 750.00
PLA Spools	24	$ 40.00	$ 960.00
Dehumidifier, PLA Storage	1	$ 550.00	$ 550.00
Surge Protector	1	$ 50.00	$ 50.00
		Total	**$ 18,310.00**

Equipment Requirements:

- Dehumidifier for PLA storage
  - Humidity is detrimental to the lifespan and performance of PLA material. The dehumidifier cabinet will increase the lifespan of our investment in PLA

- Four – Tier Welded Steel Garage Shelving 77” wide, 72” high, 24” deep
  - This will act as the storage system for the printers and will keep them neat, organized, and off the floor. Additionally, the “wall” of printers will look impressive for potential donors to the program.

Assessment and Impact

Goal of Unit:

- Is to familiarize students with the Engineering Design Process and concepts related to material extrusion, additive manufacturing material extrusion.

Assessing the effectiveness of the student's work within the unit:

- Intermediate success will be measured:
  - Daily through class discussion and guiding questions
    - Ex) What are some of the considerations when orienting the part on the surface of the material extrusion printer?
    - Ex) What was your biggest obstacle to brainstorming your solution to the problem?
  - Weekly through the observation of student results
    - Student efficiency of the use of Fusion 360
    - Student understanding of each of the steps in the Engineering Design Process
    - Student efficiency of the use of the Engineering Design Process
  - Weekly through the use of quizzes and activities

- Overall success of the unit will be measured by:
  - Individual student results

Assessment and Impact

Goal of Unit (cont.):

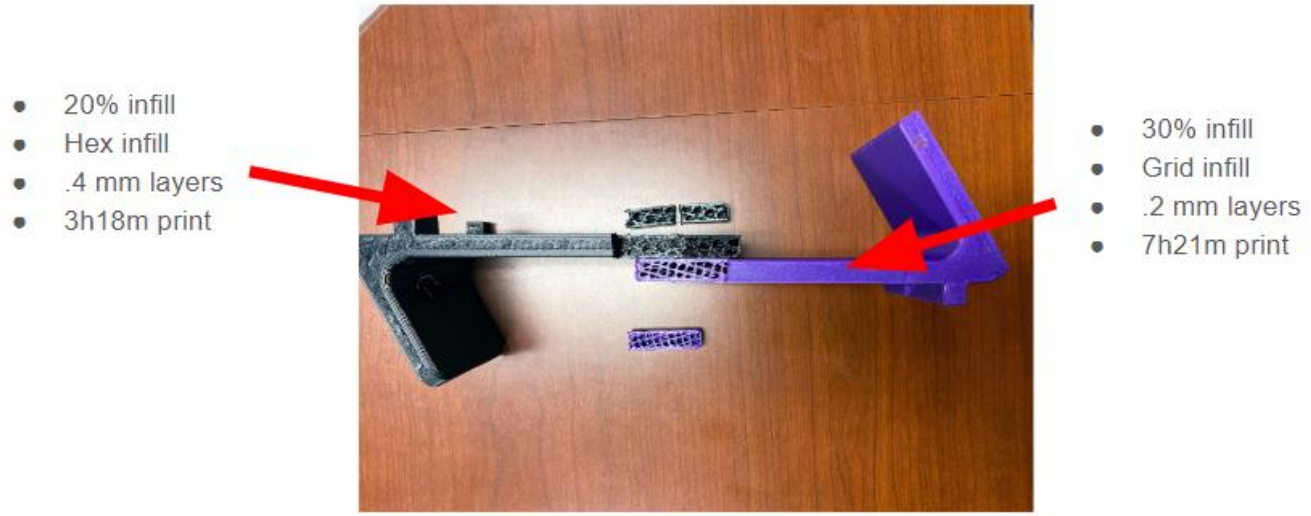
Assessment of the effectiveness of the Unit to the overall program:

- Survey the students upon completion of the Unit
    - What did you enjoy about the unit?
    - What would you change about the unit?
    - What would you change about the way the instructor presented the information?

Tentative Schedule

Schedule for Presentation of the Unit

- The unit will be presented as part of the Engineering Design Process unit. The Engineering Design Process unit is typically presented in Week 2 of the Fall Semester
    - Week 1 (7 hours class time) – Steps of the Engineering Design Process
    - Week 2 (7 hours class time) – Introduction to Fusion 360, specifically file creation, view orientations, 2D sketching, extruding, lofting, dimensioning, and editing. Week two's instruction will also serve as a Warm-Up to the district/TEA required Autodesk Inventor certification using Solid Professor tutorial.
    - Week 3 (7 hours class time) – Additive Manufacturing/Material Extrusion
        - Layer width
        - Fill percentage
        - Fill pattern
        - Supports



Tentative Schedule

Schedule for Presentation of the Unit

- Week 4 (7 hours class time, 4 90 minute block days and 1 45 minute day) –
  - Day 1 – Phone holder design v1
    - Design considerations
      - Balance of the design; will the holder stand up when the user is swiping, pushing buttons, answering calls, etc.
  - Day 2 – Students design phone holder v1 in Fusion 360
  - Day 3 – Instructor discussion on Qualitative and Quantitative observations
    - Students make the Qualitative and Quantitative observations of their/or a classmate's printed part
      - Alternative – Students make Qualitative and Quantitative observations of pre-printed parts by cutting open a section of the part to observe the fill percentage, layer height, and fill pattern
  - Day 4 – Phone holder design v2
    - Focusing on reduction of supports
    - Focusing on stability issues
  - Day 5 – End of Unit Assessment
    - Students submit their final design for printing
    - Students take an exam covering
      - Steps of the Engineering Design Process
      - Variables of the Additive Manufacturing/Material Extrusion process
      - Basic use of Fusion 360
        - Creation of a small, simple, object

Summary

If the goals of this unit are met, through Instructor participation, Campus Support, and Funding, the benefits of this Unit will be several-fold

- Increased interest and participation of the Engineering Pathway students
- Increased district awareness of the Engineering program at Andy Dekaney High School
- Increased awareness of the program from the parents and community

The addition of this unit, and the equipment that accompanies this unit will have the following measurable results:

- Growing the approximately 12% female population to 20% since Engineering will be seen as not only a “hands on” course but also a computer designing and high technology manufacturing course that’s not the “greasy, steel toed, machining” stereotype that many high school students seem to have of the program.
- Since Chip Brown is the head of the Engineering Program, the Seniors and the Engineering teams (including the competition team, Science Olympiad Team, and UIL team), will have access to and be using by the Material Extrusion printers and they will be able to be used by these teams for at least the following purposes:
    - Engineering Robotics team: Creation of parts for their competitive robots
    - Engineering team: Creation of parts for competitions such as the Envision and PLTW Chevron Challenges
    - Engineering team and Science Olympiad team: Creation of parts for specific pre-built design projects
- Additionally, the Material Extrusion printers will be used by the Senior Capstone class (Engineering Design and Development) to create prototypes of their capstone designs.
- Printing support and maintenance will be provided by Chip Brown, Campus Liaison for Technology (CLT) as he is already assigned to providing that support for the existing 3D printers on campus.

https://fortune.com/2015/08/05/ilooklikeanengineer/