Exploring Advanced

Manufacturing on Cape Cod

Engineering Grades 9-12

This mini-unit is designed to provide high school students with opportunities to learn about the advanced manufacturing processes used at Sencorp White as well as to expand their understanding of local career opportunities available to them. Students will learn about the differences between an Engineer and an Engineering Technician and relate the various jobs in these categories to opportunities at Sencorp White. In addition they will have the chance to learn about both degree and certificate programs available at Cape Cod Community College in these fields. At the end of the unit students will have completed both pre-visit and post-visit lessons, visited Cape Cod Community College and Sencorp White and explored advanced manufacturing right in "their own backyard."

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Background information on the unit development

1. Who helped to create this unit?

Names	School (Grade/course taught)
Kim Fogarty	Park School/Grades K-8
Susan West	Barnstable High School/Grades 9-12
Alex Russo	Cape Cod Community College STEM Career Counselor

2. What were some sources of inspiration for this unit?
   The two weeks spent at Sencorp White were rich with engagement. We toured the facilities multiple times, spoke with as many different employees as we could, had long discussions that connected STEM education from Kindergarten through employment. Having TiRs from K-8, High School and Community College background provided us with multiple perspectives and we were able to make connections between education and employment opportunities. Keith Morrison set up tours and meetings with employees from all areas of Sencorp White and this provided us access to both Engineering and Technician opportunities. We felt fortunate to be welcomed at all of our meetings.

3. In your own words, what are you hoping students learn—big picture—through this unit?
   The big picture we want to paint is that there is a huge variety of STEM opportunities right on Cape Cod, some require a 4 year degree but many more can be started with a high school degree, a certificate, or an associate degree. We want to emphasize the connections between school and employment in the area of Advanced Manufacturing.

4. What might students find exciting in this unit? Most students and teachers have never heard of Sencorp White. We think students will find it exciting to see what happens in this manufacturing facility and how many of the topics we will learn about in their class are evident on their tour. The vertical manufacturing process is visible during a tour and they will see the engineering design process on an industrial scale.

5. What science standards or real-world content did you strive to emphasize? We looked at both the newly adopted Massachusetts Engineering/Technology Standards for High School, as well as the Project Lead the Way Standards for the Introduction to Engineering Design Curriculum. We emphasized manufacturing processes, technical drawing and the Engineering Design Process.

6. How would you say that this unit “matters” to the STEM community? Or to our community on Cape Cod? Or to the larger community?

This unit matters a great deal to the Engineering Program at Barnstable High School, the Engineering and Advanced Manufacturing Programs at CCCC and the leaders of Sencorp White. Right now there is a major lack of employable applicants at Sencorp White and other technical companies on Cape Cod. We worked to start aligning our goals and understanding the major connections between Curriculum that is already written and what is happening at Sencorp White. Other schools may be interested in bringing their students to visit the facility, whether as whole class tours or individual student interns.

7. What's the most important lesson you learned as you created this?
   We learned that the connections just keep multiplying the more we explored. We mostly had time to focus on high school and CCCC engineering/technology curricula but there are many more areas for exploration in math, computer science, elementary and middle school science and math.

8. Anything else you would like fellow teachers or others to know about this unit?
   There was a steep learning curve for us to get accustomed to the vocabulary, divisions and manufacturing processes at Sencorp White. It might be helpful to visit the facility before bringing students in order for teachers to feel prepared for their field trip. The lessons and field trip plans are intended for students who are currently taking a high school introductory engineering course. The plans could be adapted for other students but the activities may/may not go as smoothly if students do not have the prerequisite knowledge about technical drawings, dimensional analysis and manufacturing processes.

Table of Contents

Introductory Lesson	Constructing Lesson	Practice Lesson	Assessment Lesson
Lesson that introduces the content. More teacher directed	Lessons that engage students in building and linking together understanding. Guided/collaborative. Student/teacher or partners/small group	Lessons or activities that students can complete relatively independently	Formative: Check-ins along the way to see if students "get it" Summative: Students showing what they know, when you feel they are ready

Learning Plan

Summary of Key Learning Events and Instruction

Lesson Name	**Type** (Introductory, Constructing, Practice, and Assessment)	**Content Addressed**	**Standards Included (by number)**
1. Career Opportunities in STEM/ Advanced Manufacturing	Introductory/Constructing	Career Opportunities in STEM Comparing and Contrasting Engineering and Technology Fields	Unit 1 PLTW: U3, U5 K5, K6 S5
2. Visit to Sencorp White: Introductory Powerpoint Factory Tour Quality Control Activity	Constructing/Practice	Manufacturing Processes used at Sencorp White Quality Control Practice Activity Practice reading Multi-view Drawings and using tools to measure dimensions and tolerances.	HS-ETS2.1-1.4(MA) HS-ETS1.5(MA) HS-ETS1.6(MA) Unit 3 PLTW: U4 K1, K3 S1, S5, S6
3. Follow up to Field Trip: "How Many Up?" Manufacturing Processes Activity	Practice/Assessment	Determine amount of products that can be produced given certain constraints. Practice dimensional analysis to convert units and solve problems quantitatively.	HS-ETS1.3(MA) Unit 3 PLTW: U2 S2, S3, S4

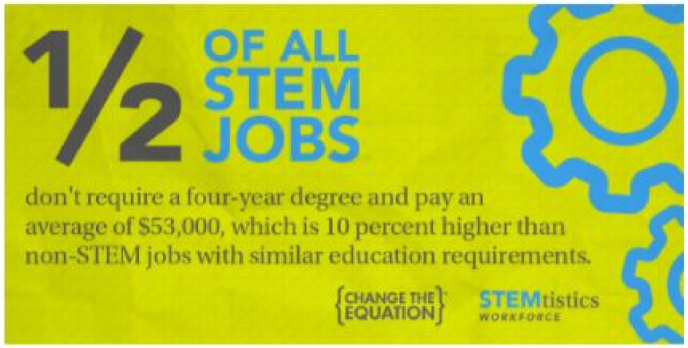
Lesson 1: Career Opportunities in Advanced Manufacturing

Overview of the Lesson: What will students be doing? Through direct instruction, short video clips and internet research, students will explore a variety of STEM careers. They will learn about the education required for various jobs and explore the skills, knowledge and working style related to each career. **Time (minutes):** 60 MINUTES
Standard(s): What standards (s) will be the focus of the lesson? • U3. Technical professionals clearly and accurately document and report their work using technical writing practice in multiple forms. • U5. Engineering consists of a variety of specialist subfields, with each contributing in different ways to the design and development of solutions to different types of problems. • S5. Explain the contributions of engineers from different engineering fields in the design and development of a product, system, or technology.
Essential Question(s): What essential questions will be addressed in this lesson? • How do the knowledge and skills I am learning in engineering class relate to my future? • What career opportunities are available in engineering and technology? What education is required? • What is the purpose of visiting CCCC and Sencorp White with my engineering class?
Instructional Materials/Resources/Tools • Internet access, Infographic relating Engineering to Engineering Technician • Change the Equation Website Statistics and Resources about STEM Opportunities http://changetheequation.org/ • O*Net Online STEM Career Information https://www.onetonline.org/ • CCCC Department of Engineering Sciences and Applied Technology https://www.capecod.edu/web/engineering
Assessment: How will you know that the students got it? Repeat the sorting activity after the field trip and see if students are able to identify correct category to place careers under: Engineering/Engineering Technician/Other
Science and Engineering Practices included (put the included ones in bold): **1. Asking questions (for science) and defining problems (for engineering)** 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data

5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. **Obtaining, evaluating, and communicating information**

Lesson Overview:

10 percent higher



Half of all STEM jobs don't require a four-year degree and pay an average of $53,000, which is 10 percent higher than non-STEM jobs with similar education requirements.

Source: Brookings Institution, The Hidden STEM Economy, 2013.

Opening/Engagement:

Video clip: STEM is Cool! Videos **http://changetheequation.org/stem-cool**

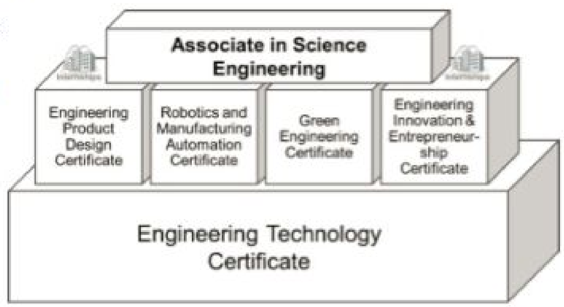
From CCCC website(to be updated Fall 2017): https://www.capecod.edu/web/engineering

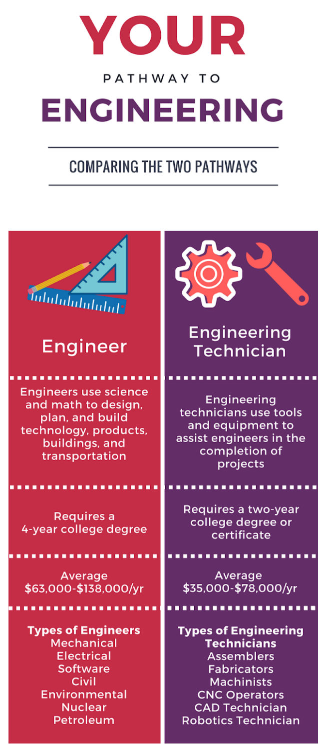
There is a documented need for skilled engineering and manufacturing workers nationally and regionally (*National Strategic Plan for Advanced Manufacturing, 2011, Staying Power II 2012, Building Bridges to Growth, 2011*). Engineering and manufacturing executives, in general, and local industry partners, in particular, continually cite difficulty in finding high quality, skilled employees as the largest threat to their competitiveness. The skill shortage is evident at all levels of employment with over 600,000 manufacturing jobs open nationwide (*STEM Summit, The Demand Side – Industry and Jobs Today 2012*).

In response to this identified need, Cape Cod Community College has established an up to date engineering and manufacturing certificate program with support and involvement from regional manufacturing business partners. The program's focus is on the development of fundamental engineering skills, especially electrical, mechanical, computer science, and robotics engineering, along with the manufacturing workforce skills required by today's technical product development and manufacturing industries.

The program is designed around a stackable certificate concept that can lead to an Associate in Science degree with appropriate transferability into Bachelor's or Master's programs. The certificates have been developed in a collaborative model with industry to ensure that all students have command of the theoretical and applied skills required by today's engineering and manufacturing environments.

The Engineering Technology certificate is the core or base certificate, which can be followed by certificates in Engineering Product Design, Robotics and Manufacturing Automation, Green Engineering, and or Engineering Innovation & Entrepreneurship.





During the Lesson:

Have students either research separate careers and share their information with the class through short presentations or have students work individually to research the following career options on the O Net Online website. This site allows them to look at a large amount of information about each job, including education needed, median payscale, typical daily tasks and environment, projected job growth, job skills(both technical and "soft skills."

Electrical Engineer https://www.onetonline.org/link/summary/17-2071.00
Mechanical Engineer https://www.onetonline.org/link/summary/17-2141.00
Electrical and Electronic Assemblers https://www.onetonline.org/link/summary/51-2022.00
Electrical Engineering Technician https://www.onetonline.org/link/summary/17-3023.03
Mechanical Engineering Technician https://www.onetonline.org/link/summary/17-3027.00
Electro-Mechanical Technician https://www.onetonline.org/link/summary/17-3024.00
Mechanical Drafter https://www.onetonline.org/link/summary/17-3013.00
Computer Controlled Machine Operators https://www.onetonline.org/link/summary/51-4011.00
Machinist https://www.onetonline.org/link/summary/51-4041.00

Lesson Closing Sorting Activity: Have each table group take turns pulling a job at Sencorp White out of the envelope and choose which title to place the career under: Engineering/Engineering Technician/Other Area (a short description of the job could be added to the job title.) Mechanical Assemblers Electrical Assemblers Electro/mechanical Assemblers CNC machinists Laser operators (laser cutter/CNC machine) CNC Sheet metal operators Painters Tool makers (dies and molds) Inventory control (stock room) Maintenance (maintain the machines & facility in general) Shipping/Receiving Production Control Finance Purchasing Sales Field Service Technicians Electrical Engineer Mechanical Engineer Application Engineer Quality Control Engineer CAD Technician Engineering Technician Control Engineer
Instructional Tips/Strategies/Suggestions for Teacher: What other ideas would you like to highlight? What grouping strategies are important? What are adjustments for struggling learners, enrichment, or for students who are English Learners? It might be helpful to customize the information for each job(a choice on the website) and then print out informational handouts for ELL students and others who struggle with large amounts of information.

Lesson 2: Field Trip to Sencorp White

Overview of the Lesson: What will students be doing?

Student visitors to SencorpWhite will participate in a 3-part experience. First, they will learn a little about the company and its products through a brief introductory slide show. Second, they will tour the facility and lastly engage in this onsite activity to culminate the experience. This lesson requires students to closely examine factory artifacts and compare to design specifications. They need to ascertain whether the part passes or fails Quality Control.

Time (minutes): ½ DAY (2 ½ -3 HOURS)

Standard(s): What standards (s) will be the focus of the lesson?

ETS1. Engineering Design

- HS-ETS1-5(MA). Plan a prototype or design solution using orthographic projections and isometric drawings, using proper scales and proportions.*
- HS-ETS1-6(MA). Document and present solutions that include specifications, performance results, successes and remaining issues, and limitations.*

ETS2. Materials, Tools, and Manufacturing

- HS-ETS2-1(MA). Determine the best application of manufacturing processes to create parts of desired shape, size, and finish based on available resources and safety. Clarification Statement: • Examples of processes can include forming (molding of plastics, casting of metals, shaping, rolling, forging, and stamping), machining (cutting and milling), conditioning (thermal, mechanical, and chemical processes), and finishing. State Assessment Boundary: • Specific manufacturing machines are not expected in state assessment.
- HS-ETS2-2(MA). Explain how computers and robots can be used at different stages of a manufacturing system, typically for jobs that are repetitive, very small, or very dangerous. Clarification Statement: • Examples of stages include design, testing, production, and quality control.
- HS-ETS2-3(MA). Compare the costs and benefits of custom versus mass production based on qualities of the desired product, the cost of each unit to produce, and the number of units needed.
- HS-ETS2-4(MA). Explain how manufacturing processes transform material properties to meet a specified purpose or function. Recognize that new materials can be synthesized through chemical and physical processes that are designed to manipulate material properties to meet a

desired performance condition. Clarification Statement: • Examples of material properties can include resistance to force, density hardness, and elasticity.

- U4. Sketches, drawings, and images are used to record and convey specific types of information depending upon the audience and the purpose of the communication.
- K1. Identify general rules for dimensioning on technical drawings used in standard engineering practice.
- K3. Distinguish between precision and accuracy of measurement.
- S1. Measure linear distances (including length, inside diameter, and hole depth) with accuracy using a scale, ruler, or dial caliper and report the measurement using an appropriate level of precision.
- S5. Dimension orthographic projections of simple objects or parts according to a set of dimensioning standards and accepted practices.
- S6. Identify and correct errors and omissions in the dimensions applied in a technical drawing based on accepted practice and a set of dimensioning rules.

Essential Question(s): What essential questions will be addressed in this lesson?
•What specialized tools exist for precise measurement of objects?
•How can I figure measurements when partial information is given?
•Why is precision important in manufacturing?

Instructional Materials/Resources/Tools
•*Metal Rulers*
•*Calipers (teachers should bring any they can spare for the activity)*
•*Shadow Box (?)*
•*Radius measurers*
•*Hole measurers*
•*Worksheet to track findings*
•*Pencils*
•*Sample artifacts numbered 1-6*

Assessment: How will you know that the students got it? The students will be filling out an inspection sheet which will have spaces for measurements and their ultimate Pass/Fail decision. This will be a way to check for their understanding, along with spot checking groups as they complete the activity

Science and Engineering Practices included (put the included ones in bold):

1. **Asking questions (for science) and defining problems (for engineering)**
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. **Constructing explanations (for science) and designing solutions (for engineering)**
7. Engaging in argument from evidence
8. **Obtaining, evaluating, and communicating information**

Lesson Overview:
Students will start in the conference room and watch a PowerPoint Presentation to provide an overview of sections of the tour. Following the tour they will reconvene in the conference room and play a short game where they must work with their group to all touch a piece of white copy paper one at a time as fast as they can. This model will be related to the vertical manufacturing process they observed in the factory. Students will be able to measure the artifacts using the different tools, compare results to the design drawing measurements and make correct recommendations on which items to pass and which to fail based on their results.

Opening/Engagement:
PowerPoint Presentation Overview of Sencorp White (starts with time lapse video of how a thermoformer is made)

During the Lesson: Tour Facility

Lesson Closing
Today you work in SencorpWhite Quality Control. You are a professional (an engineer or technician) who is responsible for making sure the company's products meet expectations. Today you have 4 identical steel components. You must inspect them and determine if the parts are exact to the design specifications and *tolerances* laid out in the technical drawings.

Inspect. Sort into pass or fail.

Instructional Tips/Strategies/Suggestions for Teacher: What other ideas would you like to highlight? What grouping strategies are important? What are adjustments for struggling learners, enrichment, or for students who are English Learners?

It will be helpful for students to be familiar with the various manufacturing processes and machines before they arrive, as well as have experience creating technical drawings with standard dimensions and symbols.

Lesson 3: Post-Visit Manufacturing Process Activity—"How Many Up?"

Overview of the Lesson: What will students be doing?
Students will be estimating how many packages can be made on a thermoformer per hour based on the size of the forming and trim presses, which in manufacturing is known as "how many up." They will be able to manipulate templates and make a recommendation of which model thermoformer would be the best match for a potential client.

Time (minutes): 40-80minutes (depending on whether extension activities are assigned)

Standard(s): What standards (s) will be the focus of the lesson?
ETS1. Engineering Design

- HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, aesthetics, and maintenance, as well as social, cultural, and environmental impacts.*
- U2. Hand sketching of multiple representations to fully and accurately detail simple objects or parts of objects is a technique used to convey visual and technical information about an object.
- S2. Use units to guide the solution to multi-step problems through dimensional analysis and choose and interpret units consistently in formulas.
- S3. Convert quantities between units in the SI and the US Customary measurement systems.
- S4. Convert between different units within the same measurement system including the SI and US Customary measurement systems.

Essential Question(s): What essential questions will be addressed in this lesson?

- How does a customer decide which thermoformer model to purchase based on its size, cost and capabilities?
- How can dimensional analysis and mathematical problem-solving be used to guide business decisions?

Instructional Materials/Resources/Tools

- 25 Cardboard Phone templates(made on laser cutter)
- Ruler
- Calculator
- Graph-ruled flip chart paper
- Blank paper
- Pencils
- Timers/phones for assembly line challenge
- 6 handheld single hole punches

Assessment: How will you know that the students got it?
Students will be passing in calculations and sketches that provide evidence for their answers/recommendation of which thermoformer would be the best match for the client. Groups will need to convert units from millimeters to inches and then use dimensional analysis to determine how many products could be made in an hour, day and week. They will also determine how much force would be needed to trim the forms and make a judgement about whether the tonnage of each model is adequate.

Science and Engineering Practices included (put the included ones in bold):

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. **Using mathematics and computational thinking**
6. **Constructing explanations (for science) and designing solutions (for engineering)**
7. **Engaging in argument from evidence**
8. Obtaining, evaluating, and communicating information

Lesson Overview:
Manufacturing Design Activity: "How Many Up?"

Imagine you have been hired by SencorpWhite and have been given the job of presenting options to a cell phone manufacturer who would like to purchase a thermoformer to package their products.

The 2200 Series Thermoformer has a forming press with an area of 19" x 23". The object to be packaged, a cell phone, is 138 x 67 x 7 mm.

1. How many forms could be produced for this object on the machine per cycle, or in other words “How many up?” Assume that each object form must be .5” apart, and all object forms must be at least .75” from each side of the press. *Show your work (sketches and calculations) to support your answer.*
2. If each cycle takes 15 seconds, how many phone packages could be made per hour? *Show your calculations.*
3. If the machine runs 10 hours per day how many phone packages could be made each day? *Again, please show your calculations.*

Extensions:

1. Make sure the trim press can accommodate the number of forms you planned for the forming press in the thermoformer. The 2200 has a cutting force of 60 tons. The plastic used for this packaging requires a force of 350 pounds per linear inch. *Include calculations to support whether you claim the trim press of the 2200 can or cannot handle the output from the forming press.*

2. How would the expected output differ with the 2500 Series Thermoformer, which has a forming press area of 30 x 36” and a cutting force of 110 tons? *Show your work (sketches and calculations) to support your answers.*

Instructional Tips/Strategies/Suggestions for Teacher: What other ideas would you like to highlight? What grouping strategies are important? What are adjustments for struggling learners, enrichment, or for students who are English Learners?

The large gridded flipchart paper and cardboard phone templates should help groups visually determine how many packages can be formed on the given sized press. It might be necessary to help some students set up the unit conversions to make sure they can proceed through the problem-solving process.

Might help to draw a diagram of the thermoformer to identify where the forming press and trim press are located. This would also help ensure they connect the area of the press to the flipchart paper. Could also have students try punching a hole through a single piece of paper and then four sheets of paper to relate to “tonnage” and minimum force needed to cut through materials.

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