Industrial and Manufacturing Engineering Lunch Box Activity

Objectives

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- Understand how industrial engineers take part in making production systems more efficient
- Understand how industrial and manufacturing engineers take part in creating assembly lines
- Be able to identify problems in assembly line production
- Be able to apply creative thinking to explore and design solutions
- Understand how an assembly line works
- Understand the concept of process improvement

Skill Level: Targeted to middle school students with extension for high school students.	**Prep time:** 15 Minutes **Class time:** 45 minutes

Materials

- (2) boxes of small Ziploc bags per team of 4-5 students (100 bags or more per team)
- (1) large batch of one type of candy per team (M&M's etc.)
- (1) box of small crackers (Goldfish, Mini Oreos, Cheez-Its, Animal Crackers, etc.) per team
- (1) large batch of a second type of candy (Skittles, Sour Patch Kids, Jelly beans, etc.)
- (40) plain cookies per team (Vanilla wafers, Chips Ahoy, store brand cookies, etc.)

Note: The cookies must be able to fit in the Ziploc bags that are being used

- (1) batch of sprinkles per team
- (1) small bowl of frosting per team
- (2) Plastic knife for frosting cookies per team
- (3) Plastic containers per team (or foam/paper bowls)
- (1) Notebook or paper for recording
- (1) Pen or pencil
- (1) Stopwatch or timer (for the teacher)

NOTE: Alternative items can be used for this activity. For example, instead of candy you can use two different types of erasers or two different colored paper clips. Cookies may also be replaced.

Standards

Disciplinary Core Idea:

ETS1.C: Optimizing Design Solution

Performance Expectations:

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design

solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Practices	**Crosscutting Concepts**
☒ Asking questions / defining problems	☐ Patterns
☒ Developing / using models	☐ Cause and effect: Mechanism / explanation
☒ Planning / carrying out investigations	☐ Scale, proportion, and quantity
☒ Analyzing / interpreting data	☒ Systems and system models
☐ Math / computational thinking	☐ Energy / matter: Flows, cycles, conservation
☒ Constructing explanations / design solutions	☐ Structure and function
☒ Engaging in argument from evidence	☐ Stability and change
☒ Obtaining / evaluate / communicate	

Background Information

Introduction:

Industrial and manufacturing engineering (IME) focuses on the development and improvement of processes through various engineering methodologies. **Process improvement** is a task completed by an industrial engineers (IEs) to identify, analyze and improve an existing manufacturing or business process within a company to meet new goals and objectives. These new goals and objectives often have to do with increasing the profit of the business, eliminating waste, increasing worker performance, or accelerating the quantity of products produced. Because all businesses have processes, industrial engineers can often have jobs outside of typical manufacturing environments and work for financial institutions, like banks or insurance companies, or health care organizations such as hospitals.

In addition to improving a process, both Industrial and Manufacturing engineers are often involved in creating entirely new **assembly lines**. Have you ever wondered who designed the process for making an Oreo cookie? Or the assembly process for an iPhone? Most likely an IME was involved in creating the manufacturing assembly line.

This lesson plan will focus on the **process improvement** of **assembly lines**. Students will learn about the engineering process behind the creation of an assembly line by creating their own assembly line to create as many complete lunch box sets as they can in a given amount of time. They will then explore process improvements by applying creative thinking on ways to increase the number of lunch sets they can make.

Background information:

The assembly line

Industrial and Manufacturing engineers (IMEs) are behind the creation of **assembly lines**. They breakdown the assembly process of a product and split it into tasks which are contained in **workstations**. **Assembly lines** are considered to be a type of production system in which parts are added to a semi-finished assembly as it moves down a series of **workstations**. These **workstations** can be machines or operators that contribute to the assembly of the final product. An example of an assembly line with 4 workstations can be seen in the figure below.

Figure 1 *Assembly Line Diagram*

In an assembly line, each **workstation** has an operator or machine that performs one singular task or multiple tasks for the same product. For example, workstation 1 may be involved in gluing piece A and B together, this is one singular task. Workstation 2 may be involved in connecting wires to the A-B assembly and then testing the wires by walking to a nearby tester, this is an example of multiple tasks at one workstation.

Since multiple products can be on an assembly line at any given time, the number of finished products made can be dramatically increased compared to other type of assembly methods. Additionally, workers commonly only have to do one task (or a set of tasks) on an assembly line. This means the required skills of the workers on assembly lines are low and therefore cost less. This allows for mass production of products in a quick and efficient manner. Henry Ford was among one of the first to implement and demonstrate the manufacturing capacities of an assembly line by integrating it into his automobile manufacturing process. Today, assembly lines are also used to make other things such as battery packs, computers, food products and even toys.

In summary, the benefits of an assembly line include:

1) Continuous flow of products
2) Less skilled workers are required
3) Low cost for manufacturing
4) High volume product manufacturing

Process Improvement

Once a production system formed by manufacturing processes has been designed, an Industrial or Manufacturing engineer is often involved in **process improvement**. **Process improvement** activities often include reducing product defects, increasing the number of products a process can output, increasing worker safety or saving costs. These are achieved by making incremental changes to a processes or breakthrough improvements. IMEs often engage in process improvement by using the engineering design process.

The Engineering Design Process

1) Identify the problem
2) Explore
3) Design
4) Create
5) Try it out
6) Make it better

Engineers use this process to examine every part of a manufacturing process. Once the process has been examined, IMEs explore and design ways to make the manufacturing work easier, the output larger, or the costs lower. The cycle often repeats itself in an effort to continuously improve manufacturing and achieve new goals and objectives.

Below are some examples of processes an IME might improve and the types of improvement they might make.

1) A chip packaging line
    a. Reducing the number of defective chips that make it into a bag
    b. Finding how much less oil can be used to cook a batch of chips without sacrificing taste
2) An iPhone manufacturing assembly line
    a. Increasing the number of iPhones that can be made to keep up with demand
    b. Finding a new type of adhesive that takes less time to dry for gluing components
3) A bank loan process
    a. Reducing the amount of time it takes for an application to get processed
    b. Increasing security verification standards in a loan process

Example:

Let's assume the manufacturing process for an Oreo cookie does not exist yet. An engineer is tasked with having to create an assembly line for the making of Oreo cookies so that they can be sold in large quantities. An Oreo cookie consists of the following:

- 2 chocolate flavored cookies stamped with the Oreo logo
- 1 layer of Oreo frosting

For this example we will assume the engineer has the following material and equipment to work with:

- Pre-made chocolate Oreo batter
- 1 high speed cooking oven
- Oreo frosting
- Cookie trays that have 12 cookie bays, with each bay having the Oreo imprint at the bottom

Now, the engineer must go through the Engineering Design Process to design an assembly line.

Identify the problem

Oreo cookies need to be manufactured at a high rate

Explore

In this phase, the engineer would explore different manufacturing methods to achieve the desired goal. For this example, the engineer will choose an assembly line method.

Design

To begin designing an assembly line, the engineer must first identify the steps required to make an Oreo cookie. These steps must be broken down into the simplest form possible so that they can be grouped into workstations later on. Below is a list of steps that the engineer generates:

Oreo process

1) Grab the pre-made chocolate Oreo batter
2) Pour the batter into the cookie tray bays
3) Place the tray into the high speed oven
4) Turn on and set the oven
5) Take out the cookie tray
6) Remove the cookies from the cookie bays
7) Grab the Oreo frosting
8) Place frosting on one Oreo cookie
9) Place a second Oreo cookie on top of the frosting
10) Set the finished Oreo in a container for packaging

Now that the engineer has identified the steps to make an Oreo, he must group these tasks into workstations. IMEs use methodologies to create the optimal amount of workstations. However, for this simple example the engineer will simply group the tasks by whatever makes sense first (trial and error method). This is the same methodology students will be expected to use in the activity contained in this lesson plan. Below is the initial grouping of tasks.

Oreo process

Workstation 1

1) Grab the pre-made chocolate Oreo batter
2) Pour the batter into the cookie tray bays

Workstation 2

3) Place the tray into the high speed oven
4) Turn on and set the oven
5) Take out the cookie tray
6) Remove the cookies from the cookie bays

Workstation 3

7) Grab the Oreo frosting
8) Place frosting on one Oreo cookie

Workstation 4

9) Place a second Oreo cookie on top of the frosting
10) Set the finished Oreo in a container and package

Create

Based on these workstations, the engineer creates the assembly line and positions one worker in each workstation.

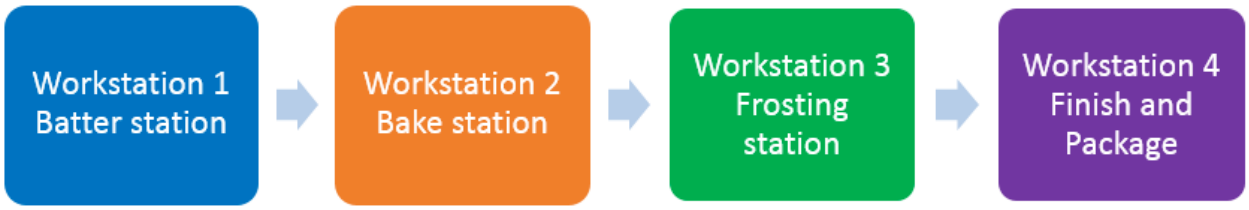

Figure 2 *Oreo Assembly Line*

Try it out

The next step is to test the assembly line. Let's say during the first couple of runs of the assembly line, the engineer notices two issues:
1. Some of the chocolate cookies coming out of the cookie tray have defective logos from sticking to the tray. These cookies are going un-noticed by workers and consequently are being packaged.

2. When he subtracts the number of defective Oreos being produced, he notices that this process is not producing enough cookies to keep up with demand

What kind of solutions could the engineer implement in this situation?

> **NOTE**: By making observations and analyzing the assembly line for potential enhancements, the engineer is beginning to engage in **process improvement**.

Make it better

One possible solution the engineer could take to address the issue of defective cookies is adding a "quality inspection/control" step to the process. The engineer would then evaluate the pros and cons of doing this.

Pros	Cons
Potential to significantly reduce the number of defective Oreos	Adds time to the process
Increase in product quality	Adds labor cost

Other solutions include changing the material of the cookie tray so that the cookies do not stick in the first place. Or adding a step where workers add a liner or oil to the tray. The number of solutions available to any given problem in an assembly line can be infinite. It's the process of weighing the pros and cons of each solution that the engineer must consider.

> **NOTE**: If the product being produced was a more technical product, like say a medical device, adding inspection steps may add significant cost if expert knowledge is needed or expensive testing equipment is required. An engineer weighs the costs with the potential benefits.

Once these improvement have been made, engineers often put metrics in place to monitor the progress of the changes made.

Engage

Students will explore the process of creating an assembly line and implement process improvement by designing their own lunch assembly line. Additionally, they will gain critical thinking skills by coming up with alternative solutions to improve their design and justifying their teams decisions. In order to engage students in this activity, the following can provide students with examples of assembly lines.

Example:

Think of Subway and how you order a sandwich. Subway uses assembly lines to build a customer's order. Let's thing about how Subway operates.

What is the order Subway goes by to build a sandwich?
Generally if you are ordering a sandwich you start with the bread. After the bread, you proceed down the line to get your choice of meat and cheese. Next, you can toast your sandwich or go straight to veggies and condiments. Lastly, your sandwich is packaged and you pay.

Why does Subway choose this order?
Subway begins with the bread because without the bread, you cannot continue the process. The meat and cheese is before the veggies because if a customer wants their sandwich toasted, you do not want to heat up vegetables (although some customers may want that). When designing an assembly line it is important to understand how certain tasks impact other steps. In this way you can find the best order to do things in.

What are the workstations at Subway? How many are there?
In general, one could say the workstations are Bread slicing, meat and cheese with oven option, veggies and condiments, and lastly packaging and cashier. This is a total of four workstations. However, often restaurants have more than four workers or split these stations in different ways. What are some other ways you have observed these stations are broken up in?

Can Subway do process improvement? Give some examples.

Subway often adjust the number of workers it has on the "assembly line". This is a form of process improvement. If the restaurant is busy, they may have two workers doing vegetables and condiments to increase the speed at which they make sandwiches. Other examples of improvements Subway makes includes pre-cutting 6-inch slices of bread, putting two sandwiches in the toaster oven at the same time or replacing ovens with faster models.

Explore

Experiment Questions:

Students will be examining the following questions in this activity:

What is an assembly line? What are its components?

Assembly lines are a type of manufacturing system in which parts are added to a semi-finished assembly as it moves down a series of workstations. The main components of assembly lines are workstations.

How can an assembly line be designed? What can it help you to achieve?

An assembly line can be designed using the engineering design process (identify, explore, design, create, try, improve). They can help increase the number of products you finish and decrease costs of manufacturing.

What type of engineers design assembly lines?

Industrial and Manufacturing Engineers.

What is process improvement?

Process improvement is the process of analyzing every part of the manufacturing process and coming up with ways to increase the performance of the process.

Procedure:

Set Up

1) Students should be split into teams of 4-5 depending on the classroom size. Each team should have enough workspace to collaborate.
2) Review the PowerPoint presentation to introduce the topic of assembly lines and process improvement to the students. Cover the examples in the presentation and have students stop and pair share their answers to these examples.
3) The "Let's start out activity" slide on the PowerPoint has the task students will be completing
4) Explain to students that their task is to create an assembly line to pack as many lunch sets in 1 minute as possible.
5) A complete lunch set will consist of the following items:
    a. One small zip lock bag with 4 pieces of one type of candy and 10 pieces of the second type of candy.
    b. One small zip lock bag with two frosted and decorated cookies (sprinkles etc.).
    c. One last zip lock bag with 8 crackers.
6) Each team should now be provided all the materials listed in the materials section.
    IMPORTANT NOTES:
    - If you are using candy and cookies, ensure that students do not have any allergies to the food you will be using.
    - For frosting, obtain one container of frosting and split the container into foam bowls. One foam bowl will be for each team. Let students know that this is ALL the frosting they will get. If they run out and do not use it efficiently, they will be out of production.
    - Note that you do not have to use candy and cookies to do this activity. The two types

of candy can be substituted for two different types of paper clips or erasers. Cookies can be substituted by anything else as well.

- If you choose to substitute material. **Make sure you change the wording on the PowerPoint presentation to reflect the material you are using**.

7) Instruct students to organize and layout there assembly line beforehand within their team. Students should also record the number of stations they create, number of students per station and how many tasks each station is doing. Allow 5-10 minutes for this.
    a. Facilitate this by reminding them to identify the tasks needed to make a lunch set and grouping them into workstations.
    b. Let them know that every workstation must be staffed by one student
8) After time is up, confirm that all teams have finished creating their assembly line and recorded their process.
9) As the teacher, you will be responsible for telling students when to start. All teams should begin assembling at the same time. Stop time after 1 minute has passed.
10) Once time is up, have each group of students share the number of complete lunch sets they were able to make. Do not have teams discuss the details of their assembly lines with the class yet.
    a. Ask students if every lunch set they made meets the conditions of a lunch set. That is, the correct number of items is in each zip lock bag.
    b. Any lunch set that contains a bag with the incorrect number of items is considered to be a defective product and does not count towards the total number of produced lunch sets. This is an example of something that can go wrong in an assembly line process.
11) Now instruct students to improve their process. The goal is to increase the number of lunch sets they produce and decrease the number of defects within the two minute time limit. Let them know that what they are going to be doing is “process improvement”
12) Allow an additional 5-10 minutes to let students make changes to their process. Some teams may choose not to make changes if they believe there process was the best.
13) Confirm all teams have finished making changes and have them record their changes.
14) As the teacher, you will be responsible for telling students when to start. All teams should begin assembling at the same time. Stop time after 1 minute has passed.
15) After the second trial, have each team share the number of lunch sets they were able to produce minus any defective sets. Also have each team share what improvements they made to their original assembly line and why the changes were made.
16) Proceed with the discussion questions provided in the PowerPoint presentation.

Explain

The following questions should be asked to the students once they have had time to completely finish the activity

1. **What worked best in your original assembly line? What didn’t work so well?**
    a. Students should discuss the arrangements of their workstation, the number of tasks

in each workstation and if there were any "defective" lunch sets made.

2. **What improvements did you make to your original assembly line?**
    a. Students should share the details of their changes made to their original assembly line.
3. **Did your improvements work?**
    a. Students should discuss if the number of defects were reduced by the changes. They can also share if the number of lunch sets they finished overall increased.
4. **What are some other improvements you would make if you could run this a third time?**
    a. Students can answer anything that would improve the assembly line.

Elaborate

More advanced students can answer the following application questions after completing the activity.

1) **Create a bar graph or other mathematical representation comparing your assembly lines efficiency between the first and second trial.**
    a. Students should graph the total number of lunch sets produced.
2) **If you had to create a manufacturing facility for these lunch sets, how would you apply what you learned in this activity to the creation of the manufacturing facility?**
    a. Students should focus on the design of the facility.
3) **If you were building a manufacturing facility and had the money to buy new equipment or technology, what would you buy to improve the process? How would you expect this purchase to help your assembly line?**
    a. Students could answer things like a machine that pours the candy automatically or equipment that frosts multiple cookies at one time. Students can get creative here as long as they justify their answer.
4) **Imagine the number of defects in your assembly line is high (i.e. incorrect number of candy or crackers in a bag). What improvements could you make to correct this at a large scale?**
    a. You could add an inspection step to the assembly line.

Resources

Additional Resources:

More on assembly lines
http://www.encyclopedia.com/topic/assembly_line.aspx

Assembly line example
http://www.history.com/this-day-in-history/fords-assembly-line-starts-rolling

Resources Used:

http://www.pbs.org/wgbh/aso/databank/entries/dt13as.html
http://auto.howstuffworks.com/under-the-hood/auto-manufacturing/automotive-production-line.htm

http://www.econedlink.org/lessons/index.php?lid=668&type=educator