PROUD PARTNER

Grade 9-12 STEM Challenge

Build It Better

Inspired by Sarah, a Production Technician in the Indiana Uplands.

Published by Regional Opportunity Initiatives

GRADE 9-12 STEM CHALLENGE

Build It Better

Inspired by Sarah, a Production Technician in the Indiana Uplands.

Students will learn how streamlining and lean manufacturing create better products in less time.

CAREER CONNECTION AND LESSON OVERVIEW

Sarah is a production technician and assembler for COOK Medical in Bloomington, Indiana. Sarah hand-makes stents for patients who have a potentially life-threatening weakening of large arteries. She also trains the next generation of production technicians, teaching them how to carefully stitch and assemble these life-saving devices. COOK depends on production technicians like Sarah to ensure that the products they manufacture are free of defects and safe for use in people. Having the instructions to make an object is only part of the challenge—how people work together to follow those instructions is a necessary part of production.

In this activity, students will make a papercraft model of a stent, very similar to those manufactured by COOK and by technicians like Sarah. They will use a model assembly line to explore the differences between traditional and lean manufacturing and identify bottlenecks and waste in the production process.

LESSON TIMELINE

DAY 1

- Show the inspiration video, "Sarah - Team Assembler Trainer" (5 minutes)
- Introduce the challenge (5 minutes)
- Group students, manufacturing practice (10 minutes)
- Set up and run assembly lines (30 minutes)

DAY 2

- Finish assembly line runs (if not done on day 1, 20 minutes)
- Discussion (15 minutes)

Recommended Supplies

Supplies (per group of 4-5):

- Stent model template paper, at least 12 copies per group. Blank paper will work if you wish to give written instructions on how to cut.
- Zip-top bags (quart size)
- Scissors
- Tape (clear)
- Tape (colored) OR colored sheets of paper for marking "Work" and "Storage" areas on each assembly line
- Stopwatch or timer
- Pen or pencil

IN THIS CHALLENGE, STUDENTS WILL:

- Understand how processes are improved over time.
- Learn about the differences between traditional ("push") and lean ("pull") manufacturing.
- Learn how to identify bottlenecks in production and how they can limit efficiency.
- Learn about the strengths and weaknesses of Just-in-Time manufacturing.

Standards

Science & Engineering Process Standards
SEPS.1 Posing Questions (for science) and defining problems (for engineering)
SEPS.2 Developing and using models and tools
SEPS.4 Analyzing and interpreting data
SEPS.6 Constructing explanations (for science) and designing solutions (for engineering)
SEPS.7 Engaging in argument from evidence
SEPS.8 Obtaining, evaluating, and communicating information

Preparing for College and Careers
PCC-2.1 Determine roles, functions, education, and training requirements of various career options within one or more career clusters and pathways
PCC-2.2 Analyze career trends, options and opportunities for employment and entrepreneurial endeavors for selected career clusters and pathways
PCC-2.3 Evaluate selected careers and pathways for education requirements, working conditions, benefits, and opportunities for growth and change
PCC-2.4 Use appropriate technology and resources to research and organize information about careers

Grade 9-10 Employability Skills
9-10.M.2 Able to view feedback as data' that helps the learning process
9-10.M.3 Demonstrate an awareness of strengths and weaknesses while accepting constructive criticism from others to improve results.
9-10.WE.4 Demonstrate organizational skills while completing project-based learning experiences and activities
9-10.LS.7 Predict outcomes to problems based on data and evidence
9-10.LS.10 Able to approach problems with reasoning and logic to hypothesize results

Planning and Implementation

BUILD IT BETTER

Essential Vocabulary

- LEAN MANUFACTURING: A method of producing objects and products that focuses on minimizing waste and maximizing efficiency of the system.
- PUSH MANUFACTURING: A manufacturing strategy in which production is driven by projected or expected demand.
- PULL MANUFACTURING: A manufacturing strategy in which production is driven by actual demand. Also known as Just-in-Time manufacturing.
- BOTTLENECK: One part of a production chain that has a limited capacity or speed. This is the step that most directly influences how quickly the entire system can make a product.
- WASTE: Anything that reduces the efficiency of a production line, including excess work-in-progress, overproduction, and errors.

Guiding Questions

1. What does it mean to have a "process" for doing a job?
2. How could you improve a process?
3. What is the difference between traditional “push” manufacturing and lean “pull” manufacturing?
4. How can manufacturers minimize waste in their production lines?

In this challenge, students will:

- Understand how processes are improved over time
- Learn about the differences between traditional (“push”) and lean (“pull”) manufacturing
- Learn how to identify bottlenecks in production and how they can limit efficiency
- Learn about the strengths and weaknesses of Just-in-Time manufacturing

Before Class:

- Read the activity outline sheet and leader notes to become familiar with the activity.
- Gather necessary materials. In this activity, students will be cutting and taping paper to create a model of a stent. We have provided a template that will allow two stents to be made from a sheet of 8.5” by 11” paper.
- Pre-make a version of the papercraft stent to show students what the finished product should look like.

Build It Better

Introduction

> "Continuous improvement is better than delayed perfection." – Mark Twain

Show students Sarah's career shadow video, available at http://www.regionalopportunityinc.org/sarah/. Using this video as an entry point, discuss how medical devices are manufactured. Sarah is not only an assembler but also a trainer: she builds life-saving stents by hand and trains others how to do it as well. In this activity, students will be building a papercraft model of a stent. However, the instructions and the processes are not efficient. They will be testing and refining their process to be able to create consistent models efficiently and without wasting material.

In manufacturing, there are two main types of production strategies:

- Traditional "PUSH" model, where there is a large number of finished goods waiting for the customer to purchase them.
- Lean "PULL" model, where products are made after someone orders it.

The PUSH system means that a lot of finished objects are sitting around waiting for a customer to buy them. Usually, the number made is based on market forecasts or estimates of how many of something customers will want to buy. Unfortunately, this means that too many products might be made or too few. This results in either wasted product or unmet demand.

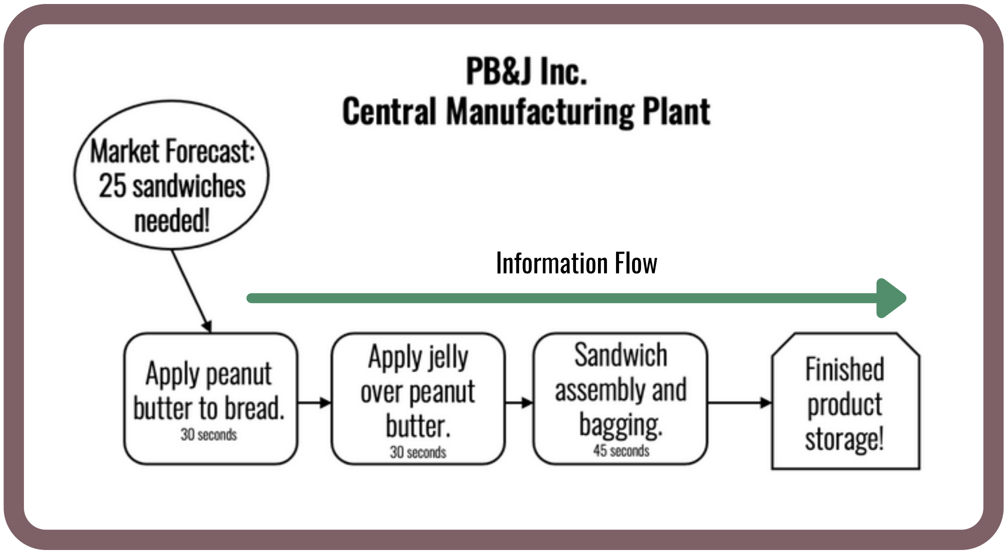
Almost all products are made using a series of process steps, with each step adding a component or refinement to the design. In push models, the product is completed and stored until purchased. This approach is called a "push" system because the estimated need pushes the factory to build as many products as they think they can sell as fast as possible. This can lead to bottlenecks at each stage of production, as each step in the process takes different amounts of time. If one step runs as fast as it can, it can get ahead of other, slower steps. This leads to excess unfinished product that has to be stored until the next step catches up, wasting time and space.

In lean systems, the number of products made is directly tied to the orders from the customer, not the estimate of future need. Whatever product the factory makes is only being made when it is wanted. Industrial engineers call this a "PULL" system. Production is initiated by a need for the final product, but each step in production is ALSO governed by whether or not the step after needs it—each step in the process is also operating under the Pull system.

Pushing and Pulling Sandwiches: An Example...

Imagine you're a factory that makes and sells peanut butter and jelly sandwiches: PB&J Inc. This month's issue of PB&J Insider predicts that demand for sandwiches is good and you will be able to sell 25 sandwiches this month. Your factory has three production steps:

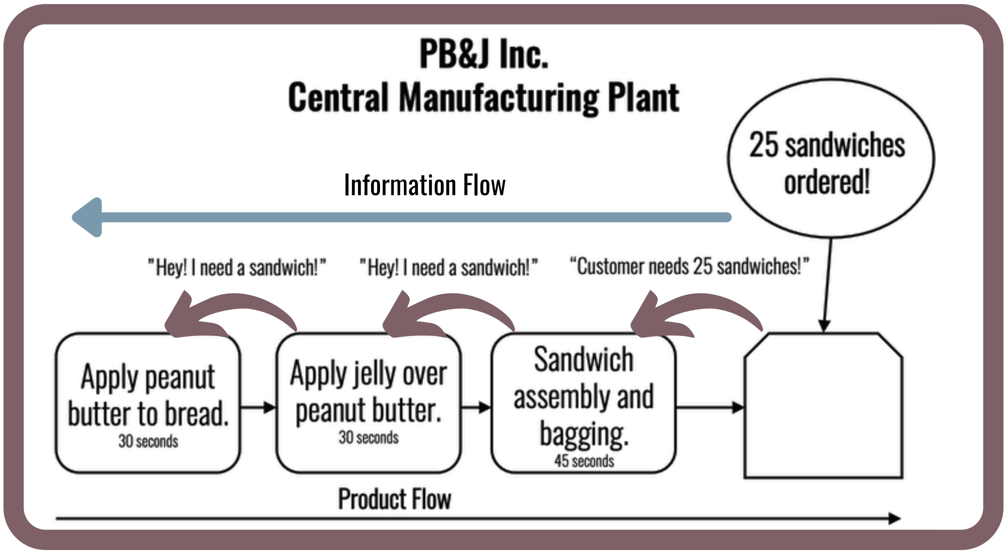
- Putting peanut butter on the bread (takes 30 seconds)
- Putting Jelly on top of the peanut butter (takes 30 seconds)
- Assembling the sandwich and putting it in a little baggie (takes 45 seconds.)



A factory using a "Push" process.

In a Push system, you would take your 25 sandwich forecast and get your team to work making sandwiches. Each step would do their part 25 times and you'd end up with 25 sandwiches that you would need to store until they were purchased (hopefully.) Production here starts at the first operation (peanut-buttering the bread.) This operator will continue to apply peanut butter to bread until the quota is reached—25 sandwiches.

The sandwiches will go to the jelly applicator, who will put jelly on 25 sandwiches. The problem arises when the sandwiches get to finishing and packing. This step takes a little longer, which means partially assembled sandwiches (or "work-in-process", or WiP) will begin to pile up. This is a bottleneck and the finisher/packer is unable to keep up. In the push system, the peanut butter operator and the jelly operator are blissfully unaware that the finisher is falling behind because they're "pushed" to make their part of the 25 sandwiches. The partially completed sandwiches then have to be stored somewhere until the finisher can get to them, wasting time and space. Uneven production is a real problem: manufacturing can only go as fast as its slowest step.

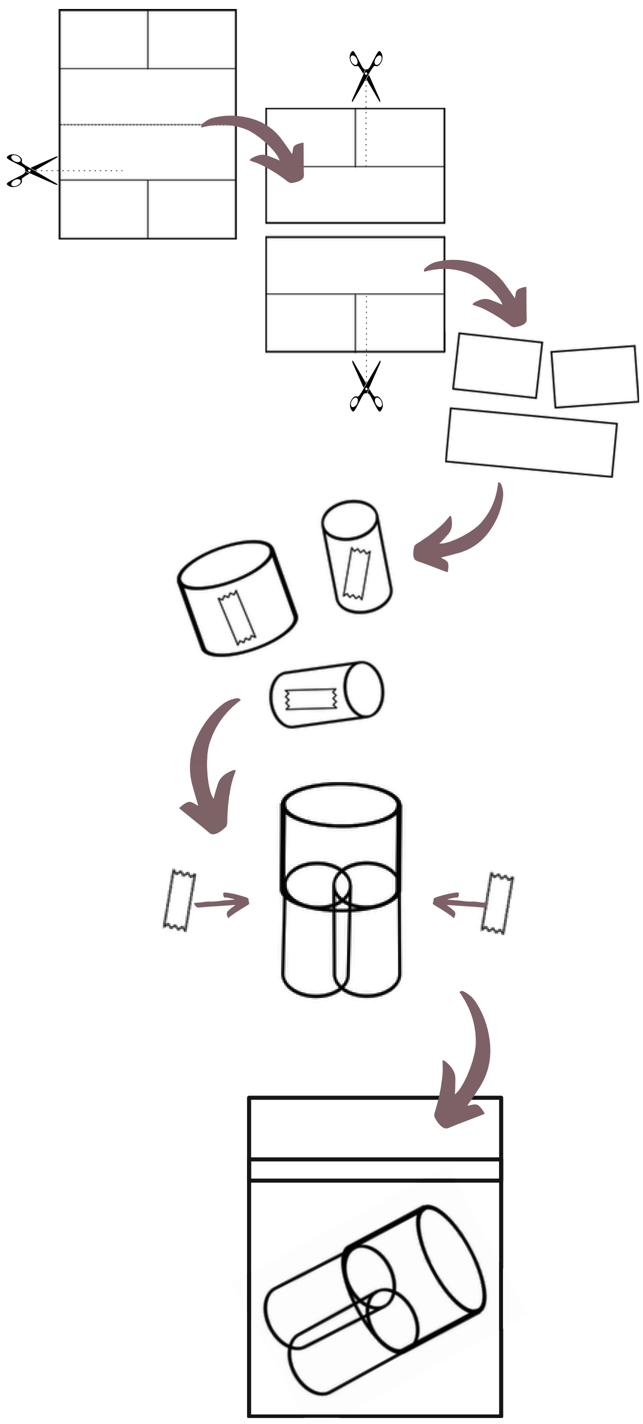


A factory using a "Pull" process.

If your PB&J Inc factory follows a lean Pull system, things work very differently. Here, manufacturing will only begin when someone places an order for 25 sandwiches. In some ways, this production line processes information backward. Instead of saying "We need to make 25 sandwiches to sell" it phrases it as "We have sold 25 sandwiches and we don't have any sandwiches in stock." This "sandwich needed!" message goes to the finisher step (the last step), who has no product to assemble. So the finisher requests 25 sandwiches from the jelly assembler, who passes the request to the peanut butter applicator, who starts production. This is called a "Pull" system because the information starts at the end and flows backwards through the facility, pulling product through the factory. The peanut butter applicator only starts sandwiches based on the requests from the jelly team. Production stops when there are no more requests and the order has been filled.

The Activity

Today the students are making stents—or, rather, papercraft models of the types of stents Sarah makes. Show students the finished papercraft model and explain that they will be using an assembly line to put these together. There will be four stations in this assembly line:



Workstation 1: Cutting out the paper parts.
A stent is made from 3 pieces of paper and each 8.5” by 11” sheet of paper can be cut into parts for two stents (6 total pieces). This employee will need to cut up and separate out the parts into groups of three (one larger piece and two smaller pieces of paper) to be passed on to workstation 2.

Workstation 2: Rolling and taping the paper component parts.
Each stent will need to have its paper parts rolled up and taped together into tubes. One large tube and two smaller tubes will be passed on to workstation 3.

Workstation 3: Assembling the three paper rolls together into one stent.
The two smaller tubes will be taped next to each other inside one end of the larger tube.

Workstation 4: Quality assurance and packaging finished stents into a zippered bag.
This station will take the completed stent and place it into a sandwich bag and seal it. If there is a fifth student in the group, this person will be responsible for quality assurance (making sure the stent is assembled correctly, making sure the bag is sealed, etc.)

Running the Simulation

Practice: Give students a chance to practice manufacturing a stent (about 10 minutes). Each student should make at least one paper stent on their own. Once they understand how to put them together, reiterate what part of the process happens at each workstation. They may notice that there is some variability in their products at first—this is okay!

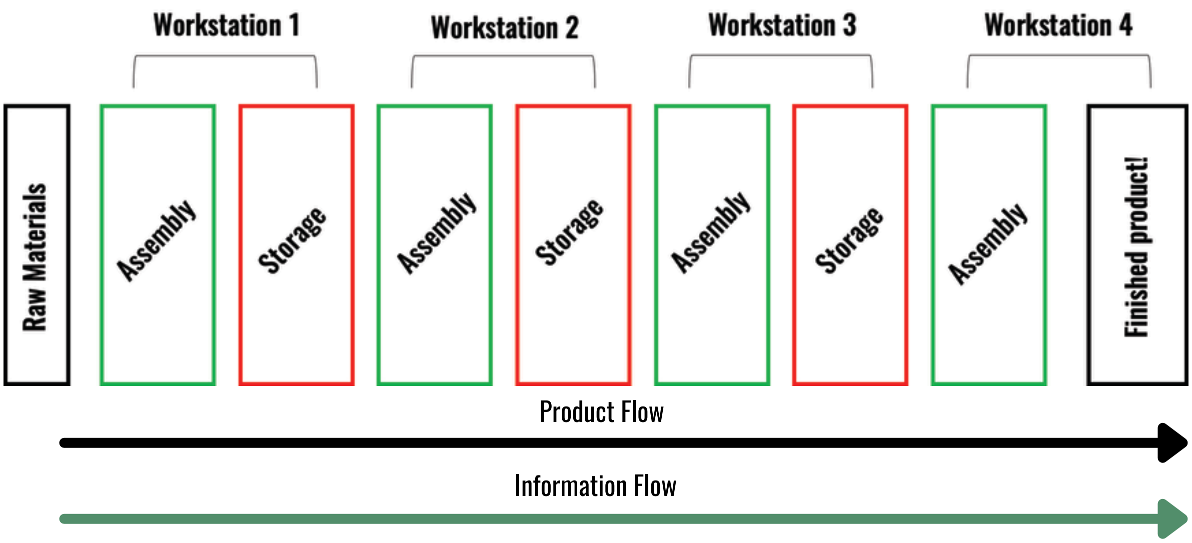
Each group should set up a production line. There will be two areas for each workstation: an area to work in and an area to store their finished parts. The RAW MATERIALS or STORAGE area of the upstream workstation is their "inbox."

The PUSH Run

For the push-style model, each student is to make their part as fast as they can while still meeting quality expectations. They will complete their work and then “push” to the next workstation. To run the Push scenario:

1. Each workstation must work with the incoming product that has been waiting the longest (first in, first out—or “FIFO”.)
2. Begin the push run and have the student designated as Quality Assurance start a timer.
3. Each group should continue their push run for all work centers until 5 stents have been completed.

Once five stents have been completed, stop the timer and count up the amount of work-in-progress (unfinished stents) in the line. Record this information on the STUDENT DATA SHEET.

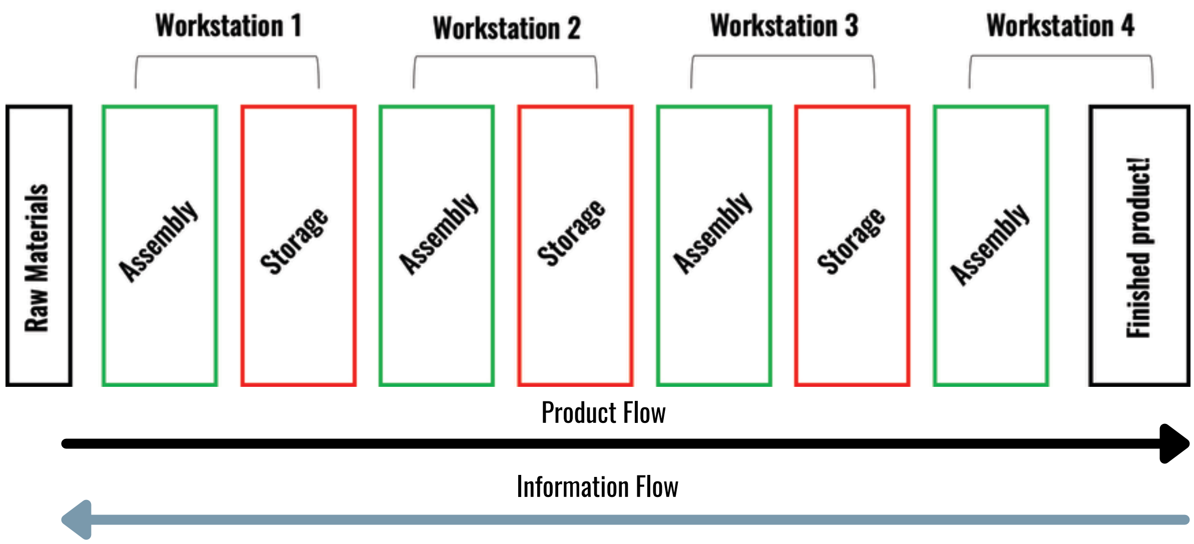


Prompt students for feedback on how this round of production went.

- What worked well during the run? What did not? Students will probably identify that step 2 or 3 are slow steps. WiP piled up here causing a bottleneck.
- Did it seem like everyone was working equally hard? How did each of you feel about your jobs? Workstation 2 should probably feel the busiest as the cutting step is very fast but the rolling and taping can be time consuming.
- What pros and cons do you see for the push system?
  - Pro: it's easy. The idea is straightforward.
  - Con: A lot of WiP backup that has to be put somewhere until the next production step can get to it. First in, first out slows things down.

The PULL Run

For this run, we need to do a little prep work. In lean manufacturing, it's not that there isn't ANY WiP in the system, it's just a much smaller amount. Before this round begins, have students create one work-in-progress piece at each workstation. Students should also move to a different area of the production line to prevent their expertise from making them artificially quicker. This time, each workstation's outbox will be the inbox for the next workstation.



Explain to students that in this run, a worker can only start work if:

- There is one WIP unit in the inbox (except workstation 1—they're pulling from the raw materials.)
- When their outbox is empty. If the outbox still has product in it, their production should stop until it is picked up by the next workstation. Here, an empty outbox is a signal that they should be working.

To run the Pull System:

1. Have the Quality Assurance student start the timer and begin the production run.
2. Each workstation must work on the materials that have been waiting the longest (again: first in, first out.)
3. Continue the pull run until five stents are complete.

Once five stents have been completed, stop the timer and count up the amount of work-in-progress (unfinished stents) in the line. Record this information on the data sheet.

Prompt students for feedback on how this round of production went.

- *What worked well during the run? What did not?*
  Students will probably identify the slower steps and bottlenecks as being the same as the first run. However, their waste WIP numbers will be much lower. They may have also completed their stents in a shorter time period.
- *Did it seem like everyone was working equally hard? How did each of you feel about your jobs this time?*
  Those students at slower stations were still very busy but probably felt much less harried without product piling up. The students at faster stations may have found themselves with more downtime.
- *What pros and cons do you see for the push system?*
  - Pro: Consistent production speed, less waste/WIP, faster time from order to delivery. Easier to see where the work isn't balanced (people working constantly vs. people having downtime.)
  - Con: Lean pull is a little more complex and requires more coordination.

Discuss and Report

Prompt student discussion about both production techniques.

- *What might switching from a push-style system to a pull-style lean system do to improve a factory?*
  Less wasted space storing work-in-progress. Easier to be flexible in how much is made because everything is made as it is ordered. No excess are made that might be thrown out or sold at a loss.
- *How would a lean manufacturing system help a company save money?*
  Less WIP means less wasted money storing in-process materials. No extra product laying around that has to be put somewhere until it is bought.
- *What is a limit to both of these systems?*
  There is always a bottleneck if the processes aren't balanced in the amount of time they take. The process is only as fast as its slowest part.
- *Which approach would be best for products that are made in low volume, ie, not a lot of demand at once?*
  The Pull system is going to be better because low volume usually means that each product is expensive. Companies aren't going to want to waste money storing WIP.
- *Do you think lean systems need more, fewer, or the same number of workers than a traditional push system?*
  The same number of workers can be used but some workers may have more free time to allow them to do other jobs (free up bottlenecks, etc)
- *What are the main differences between a Push system and a Lean pull system?*
  In the push system, each person does their part of making the product as fast as possible, no matter what other workstations are doing. In a pull system, signals are sent from the end of the process to each workstation to begin working.
- *What products might be manufactured using a pull system? A push system? Why might one be better for some things than others?*
  A Pull system is going to be a better fit for expensive or highly customizable products like custom cars. Push systems will be a better fit for high volume products with little customization, like cell phones.
- *If every worker is working at their fastest and most efficient, does that mean that the production line will always be producing quickly?*
  No! Products can only be made as fast as the slowest or longest step (the bottleneck) will allow. If every person is working as fast as possible, they may be creating WIP that will stack up at the slowest step in the process.

Career Exploration and Extension

Prompt students to think about and research what a career as a production technician might entail.

- What does a production technician do all day? What does Sarah do?
- What kind of training would a student need to become a production technician? What other types of technicians are there?
- Are jobs like Sarah's in high demand? Will more people be hired to manufacture medical devices by hand in the future?
- What kind of education is needed to be a production technician? Where could a student be trained locally for this career? What types of classes are important?

Name: ______________

Build It Better

Student Data Sheet

Today you and your team will be producing a papercraft model of a stent. Stents like this, which looks a little bit like a pair of paper trousers, are used to treat people with defects in their circulatory system and prevent life-threatening hemorrhages. Your stent company is going to try out two different ways to produce your stents and determine which is more efficient.

First, you will need to set up your workstations. There will be four stations:

- **Workstation 1: Cutting out the paper parts.**
  A stent is made from 3 pieces of paper and each 8.5" by 11" sheet of paper can be cut into parts for two stents (6 total pieces). This employee will need to cut up and separate out the parts into groups of three (one larger piece and two smaller pieces of paper) to be passed on to workstation 2.
- **Workstation 2: Rolling and taping the paper component parts.**
  Each stent will need to have its parts rolled up and taped together to form a tube. One large tube and two smaller tubes will need to be passed on to workstation 3.
- **Workstation 3: Assembling the three paper rolls together into one stent.**
  The two smaller tubes will be taped next to each other inside one end of the larger tube.
- **Workstation 4: Quality assurance and packaging finished stents into a zippered bag.**
  This station will take the completed stent and seal it inside a sandwich bag. If there is a fifth student in the group, this person will be responsible for quality assurance (making sure the stent is assembled correctly, making sure the bag is sealed, etc.)

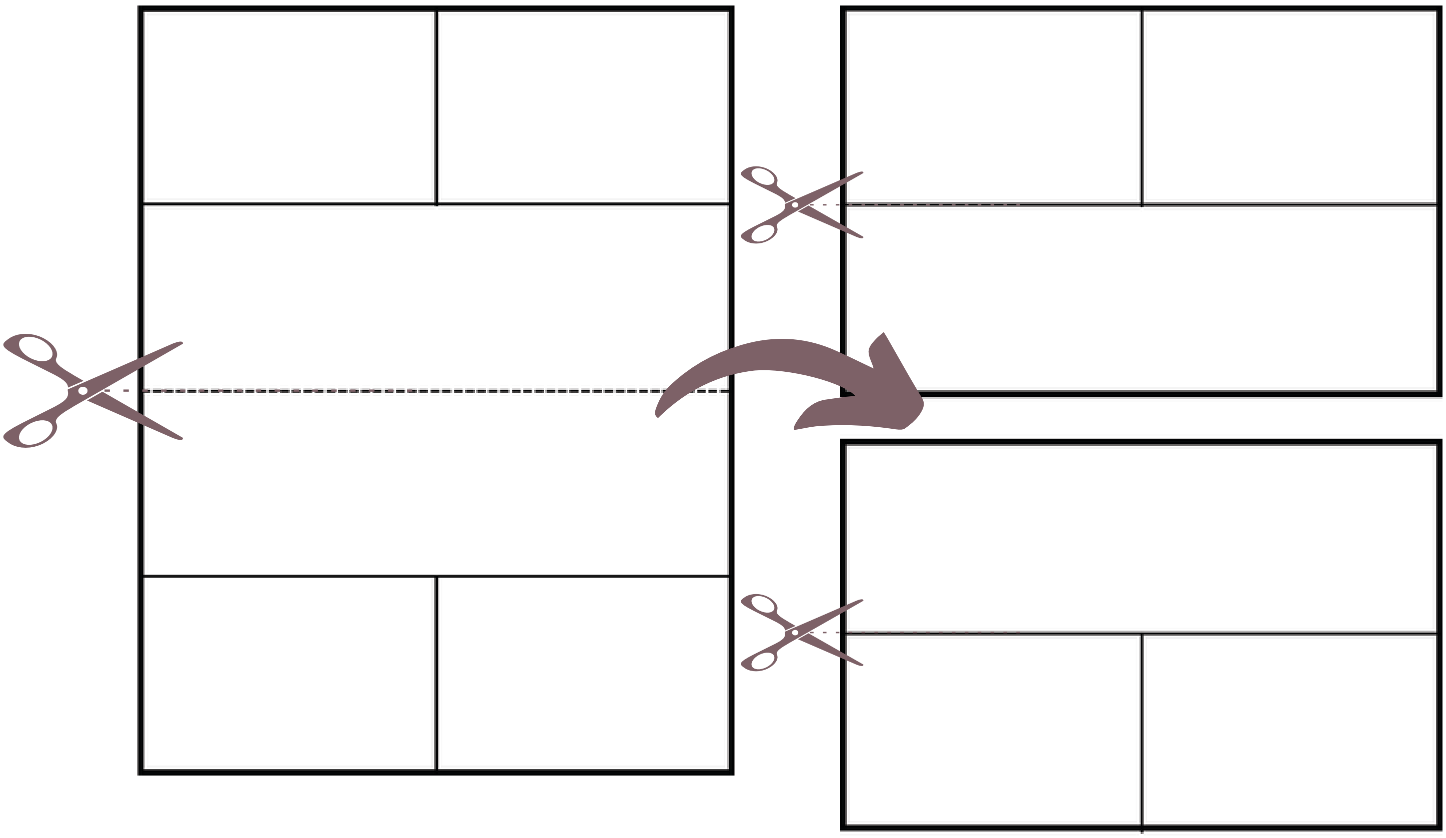
PUSH Run Data

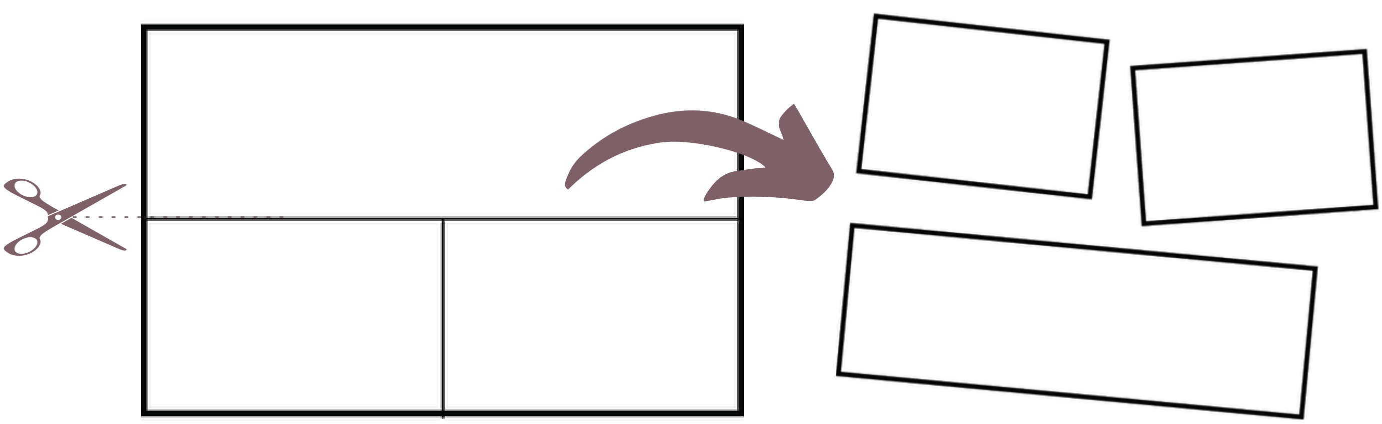
# of stents completed	
Total Time	
Total WiP (waste)	

PULL Run Data

# of stents completed	
Total Time	
Total WiP (waste)	

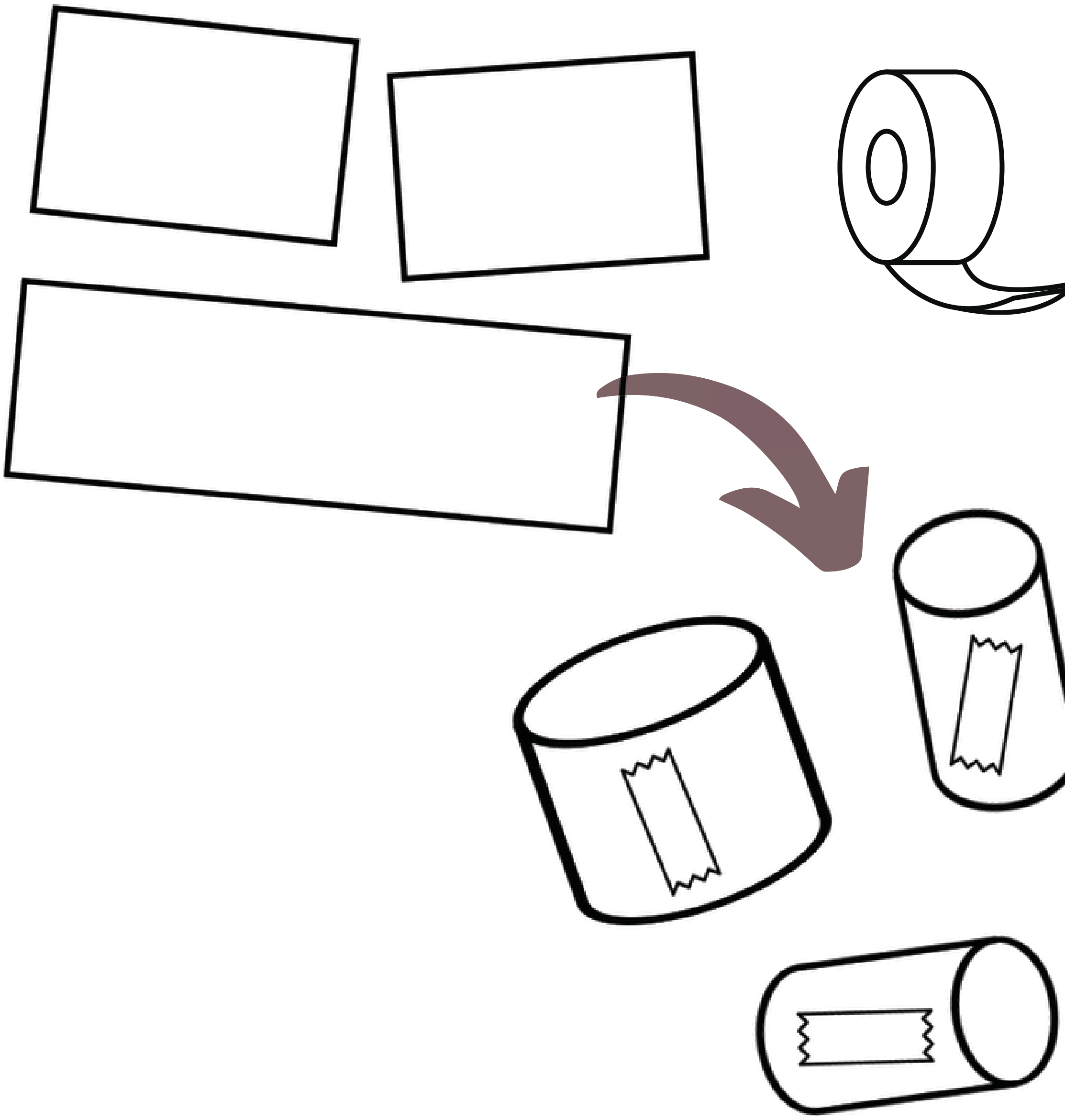
WORKSTATION ONE





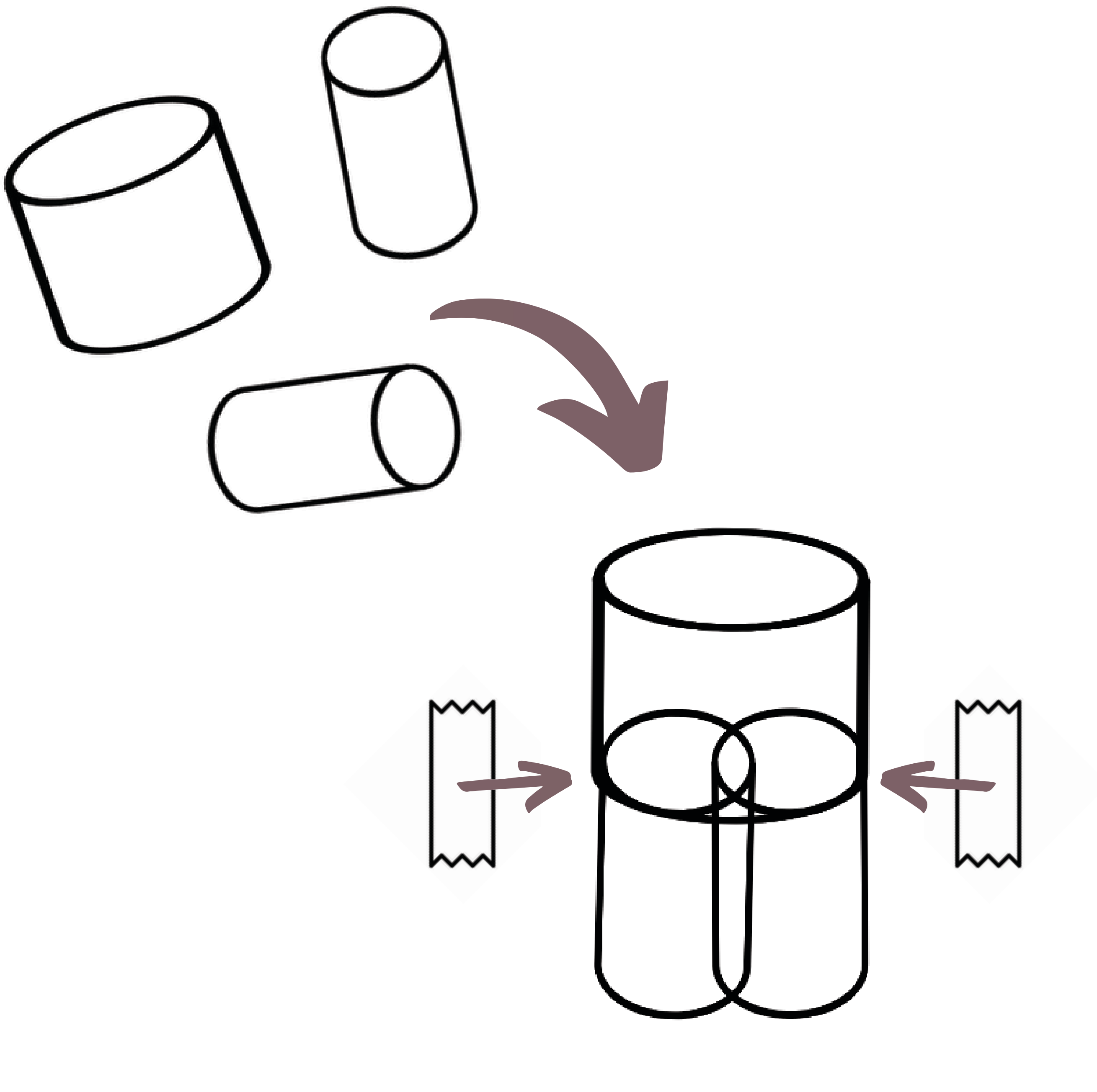
Cut your paper in half.
Cut each half in half again lengthwise.
Cut one of these halves in half again.
Pass to the next station in sets containing two short and one long piece.

WORKSTATION TWO



Roll the pieces into tubes and secure them with tape.

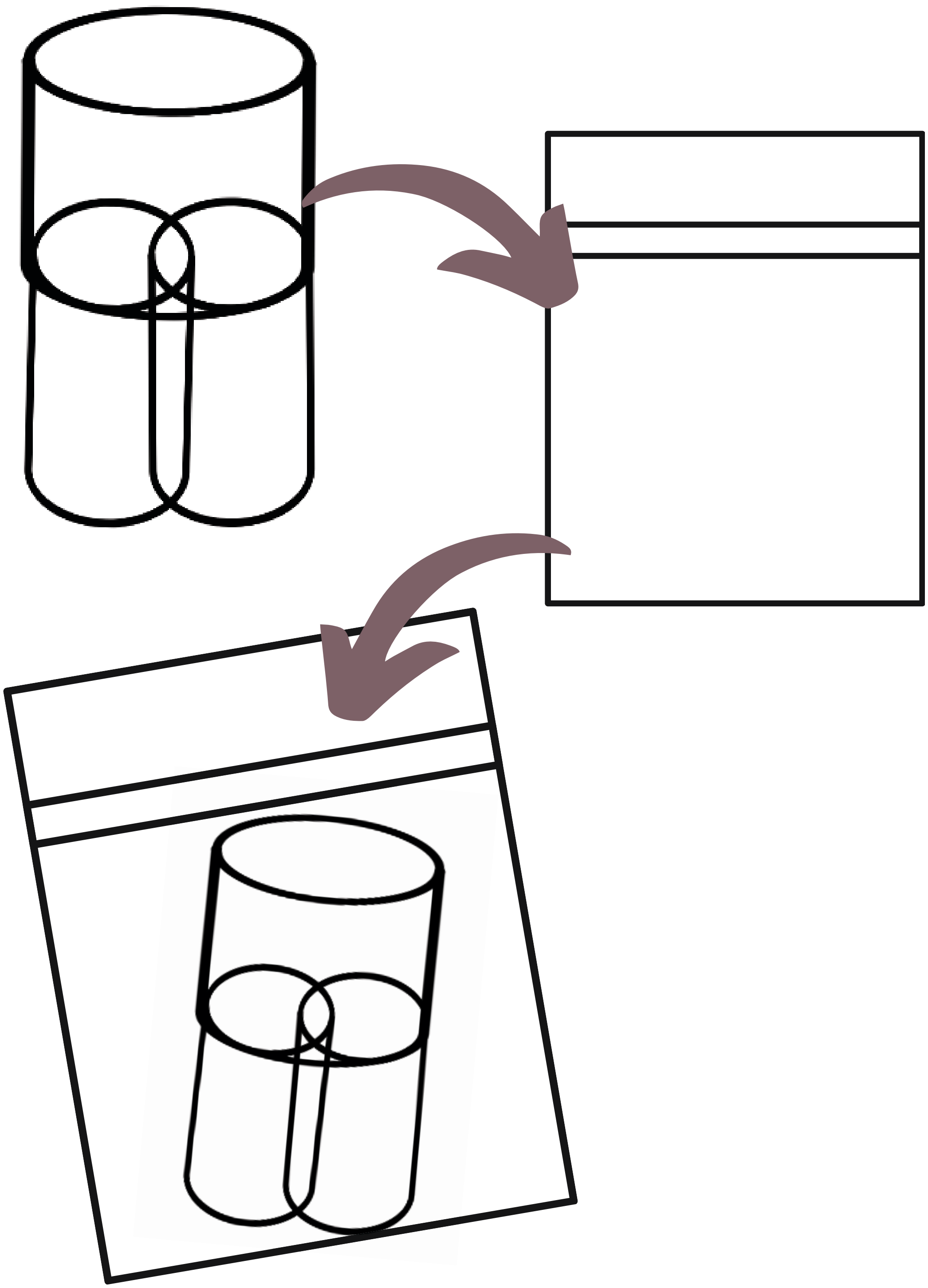
WORKSTATION THREE



Place the two smaller cylinders just inside one end of the larger cylinder.

Secure with tape!

WORKSTATION FOUR



Place your finished stent in the plastic bag and seal.
Your product is finished!

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IMAGE AND CONTENT CREDITS

Images

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- Cylinder by shwepes from the Noun Project
- Adhesive tape piece by Juan Pablo Bravo from the Noun Project

Content

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