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Get the Skinny on LEAN Manufacturing

Motivation / Engineering Connection

Prior to college, most students do not know what is means to be an engineer. Even for those who plan to major in engineering, most typically think in terms of well-known branches of engineering: mechanical, electrical, civil, chemical, biomedical, aeronautical, and possibly computer or materials science. Newer specialties have evolved such as:

- Environmental Engineering
- Food, Agricultural, and Biological Engineering
- Industrial Systems Engineering

By the very nature of their names, students can gain a sense of understanding of the first two. However, the third one probably stumps them or is not immediately appealing due to the lack of understanding.

Industrial and systems engineering is an interdisciplinary field of engineering and management to solve complex problems that oversee a manufacturing process. The job goes beyond the assembly line but delves into the parts suppliers, the distribution of a product, the employees, the processes, the machines, and even the way a facility is designed. An Industrial Systems Engineer studies, and looks to improve upon, work measurement, methods and operations, ergonomics, and inventory.

Engineers tackle work measurement usually via a time study to determine the capacity of a facility in terms of realistic works orders, delivery dates, and costs. Not only does a facility use this knowledge to determine its work force but also to propose alternative methods or to identify the possibility of underperforming employees. They consider things like repetitive versus non-repetitive tasks and what that means for an employee in terms of productivity and mandatory breaks.

Industrial and systems engineers also take a broader look and perform an operational analysis looking for possible work simplification and ways to make continuous improvements. This analysis looks at tooling and machinery, individual workstations, the overall plant layout, and the workplace environments in general through ergonomics. Ergonomics encompasses both the safety and comfort of the employee as well as the consumer. Industrial Systems Engineers also maintain the proper balance of stock to optimize a company's material handling process.

Although the following activity is primarily concerned with LEAN Manufacturing, a mini-lesson on three common manufacturing buzzwords is in order: *Kaizen*, *Six Sigma*, and *LEAN* Manufacturing. Some companies use all three depending on the situation.

Kaizen is a broad approach to running a company developed by Japanese theorist, Masaaki Imai. It is often described as a business culture, philosophy, or a mindset. It is not a specific tool but a way of operations that rewards ingenuity while practicing to minimize/eliminate waste

(*muda*), find and reduce variation or inconsistency (*mura*), and identify strain on employees and unnecessary burden on equipment (*muri*). All employees are trained to operate with a Kaizen state of mind.

Six Sigma was developed by Motorola and focuses specifically on a company's final product(s). Six Sigma is a tool or set of statistical analysis techniques that are used to minimize defects per opportunity. Instead of an overall mindset like Kaizen, Six Sigma is more like an end goal to minimize variation to strive for near perfection.

LEAN Manufacturing was derived from the Toyota Management System and focuses on a process or a set of processes with a goal of reducing waste and increasing speed and efficiency. LEAN is a management process in which manufacturing efficiency and product quality are equally important. A LEAN facility checks to ensure that each step of a process adds value to efficiency and/or quality. In a LEAN facility, all employees have a voice and each person is valued for their contributions, large or small.

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The Math Behind Six Sigma

Have you ever asked a teacher if a grade would be curved? In your mind, you probably think of it as free or extra credit points being added. But do you know what it really means? Many data sets create a bell curve in which 68% of the data falls within plus or minus one standard deviation from the average, 95% of the data falls within two standard deviations, and 99% falls within three standard deviations. When a teacher curves a test grade, that teacher fits the data into a bell curve. This means students who scored at the top of the class, could potentially lose points or receive a letter grade that is lower than what they equate their numeric grade to be.
It's easier to understand the bell curve and standard deviation using some data.
Suppose you surveyed students in your school about the tail length of their pet cats and collected 100 samples.

Length (cm)	Frequency
12	1
16	1
18	1
20	2
21	3
22	7
23	22
24	28
25	23
26	5
27	3
28	2
30	1
44	1

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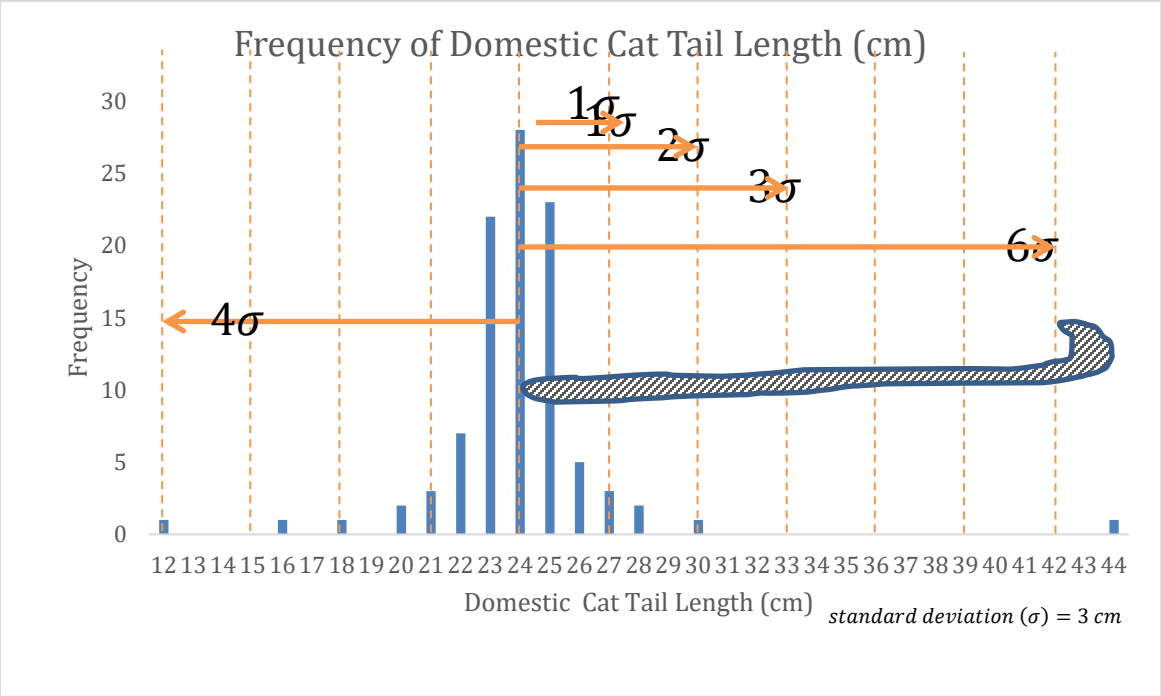
The average tail length from our sample is 23.97 cm, or 24 cm (rounded to nearest cm) which is calculated as follows:

$$\frac{12 + 16 + 18 + 2(20) + 3(21) + 7(22) + 22(23) + 28(24) + 23(25) + 5(26) + 3(27) + 2(28) + 30 + 44}{100} = 23.97 \approx 24$$

The standard deviation is calculated as follows: $\sigma = \sqrt{\frac{\sum(x-\bar{x})^2}{(n-1)}} = 2.99 \approx 3$



Where $x = data\ sample$, $\bar{x} = sample\ mean$, and $n = sample\ size$

So what does this mean? Standard deviation is a measure of spread from the average. If the standard deviation is low, it means the value is close to the average; if the standard deviation is high, it means the data is dispersed over a wide range of values. Note: standard deviation can only be used when the overall data resembles a bell curve. In other words, in a normal distribution, 68% of the data is generally within ±1σ, 95% within ±2σ, and 99% within ±3σ. If a data point falls within a few standard deviations, one can determine that it is standard or typical. If a data point falls outside of a few standard deviations, one can also conclude that it is unusual or atypical. Looking at the histogram and standard deviation markings, you should conclude that a 12 cm cat tail is unusual and a 44 cm cat tail is highly unlikely. According to the 2017 Guinness Book of World Records, the longest recorded cat tail belongs to Cygnus Regulus Powers, a silver Maine Coon cat with a tail length of 44.66 cm!

Practice the Math

At your teacher's direction, you will have one minute to list as many dog breeds as you can. Afterwards, your teacher will list the totals on the board. After all of the data is collected and organized on the board, create a frequency histogram, calculate the mean and standard deviation and then determine how many standard deviations away from the average your own total is. Is anyone outside three sigmas? Why someone may be far below or far above the average in this activity?

Activity Pre-Assessment Questions

Picture a job you are familiar with (either your own or the job of someone you know well):

- Name an action that adds value to a process.
- Name an action that does not add any value and may be considered wasteful.
- Name a step in a process that a customer may consider wasteful but is necessary for a business.

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LEAN Activity

Supplies:

- Extra-large plastic Easter eggs
- Face stickers (eyes, nose, mouth, ears, glasses, mustaches)

In your group, divide yourselves into jobs: line supervisor, supplies handler, assemblers (as many as needed), quality control inspector, and warehouse associate. (You can add, subtract, and combine positions as needed.)

For each system production one (four products), record the time from start to finish, the number of opportunities, and the ratio of defects per total opportunities. Finally, determine any wasteful steps or problems with the process and suggest improvements.

NOTE: All left/right designations are from the assembler's point of view. Do NOT use the large face/body sticker. Instead, use a plastic egg of the designated color for each product.
What is an opportunity? The egg and each sticker procured is an opportunity and the placement of each sticker is another opportunity. Example: Seven stickers and one egg procured, and seven stickers placed results in 15 opportunities.

Group	Product 1	Product 2	Product 3	Product 4
1	Octopus: Purple egg Round eyes Oval mouth Star nose One bubble top of egg Left hook arm Mustache	Octopus: Yellow egg Red eyes Smile mouth One star above left eye Two bubbles right side of mouth Pirate hat	Unicorn: Pink egg Blue eyes Lipstick mouth Rainbow unicorn Crown Three hearts on right cheek Pink hair	Unicorn: Blue egg Pink eyes Plain unicorn White tooth smile Rainbow on forehead Rainbow hair Wand
2	Tiger: Yellow egg Green eyes White mouth Green tie Long bone across forehead Large blue star in middle of bone	Tiger: Blue egg Pink eyes Pink oval mouth Black hat Scars on left cheek RAWR sign right side of mouth	Elephant: Pink egg Green eyes Closed mouth sticking out tongue Hair bow Peanut on tongue Short trunk	Elephant: Purple egg Blue eyes Trunk with branch Black hat Gritted teeth mouth Yellow star centered in each ear

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3	Shark: Blue egg Green eyes Captain's hat Red smiling mouth Two small fish in mouth Three bubbles to the right of mouth	Shark: Pink egg Blue eyes White mouth Seaweed under mouth Purple star on right cheek Three bubble to left of mouth	Monkey: Yellow egg Green eyes Banana hat Nose with round nostrils Mouth with tongue sticking out Banana bubble Mustache	Monkey: Purple egg Blue eyes Red bow in hair Nose with narrow nostrils Open mouth Yellow star in the middle of each ear
4	Clownfish: Yellow egg Blue eyes Circular black mouth Snorkle with bubbles Purple shell on left side Pink shell on right side Pink star for nose	Clownfish: Blue egg Goggles Smiling mouth Orange hat Blue fish facing left on left side Blue fish facing right on right side Three bubbles coming out of the right side of mouth	Lion: Purple egg Golden eyes Mouth without tongue Green bandana Whiskers on both sides One flower on each ear	Lion: Pink egg Blue eyes Mouth with tongue sticking out (no epiglottis) Safari hat One heart as each ear Scar on left cheek

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System 1

System 1 Rules:

- You have three minutes to assign jobs to positions and determine your system.
- The line supervisor cannot touch any materials except the final product.
- Only the supplies handler can obtain materials for the assemblers.
- Record the time it takes assemble your line's four products.
- Only the warehouse associate can move the product to inventory.
- All products must be accompanied by the quality control checklist.

System 1

Time:

Number of opportunities:

Number of defects:

Ratio of defections to total opportunities:

Wasteful steps and suggestions for improvement:

Name: **Date:** **Class:**

System 2

In System 2, the materials handler has an image to assist with procuring the necessary supplies. You should see an improvement in this system which you will discuss at the end. There is a catch: switch product lines!

System 2

Time:

Number of opportunities:

Number of defects:

Ratio of defections to total opportunities:

Wasteful steps and suggestions for improvement:

Name: **Date:** **Class:**

System 3

You will not assemble any products in this system but rather describe what the ideal process would look like.

Post-Activity Assessment Write-Up

Summarize a process at your work or interview a family member about a process at their work. Write a paragraph about how you think the process could be improved or how they can eliminate waste. Be sure to include an introductory paragraph about the type of company (no names necessary) as well as the specific process you are critiquing.

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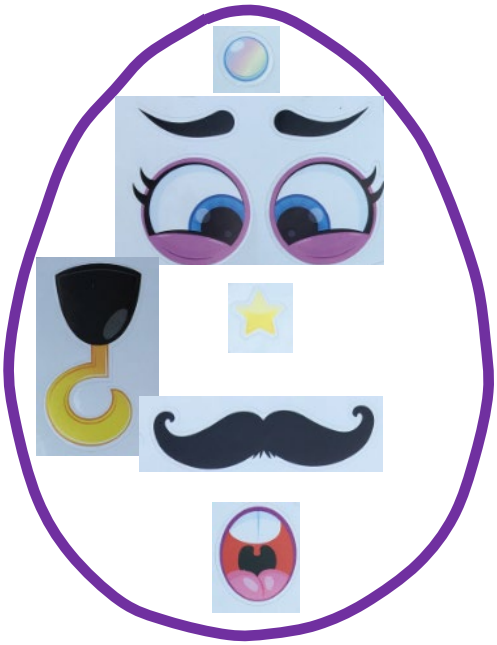
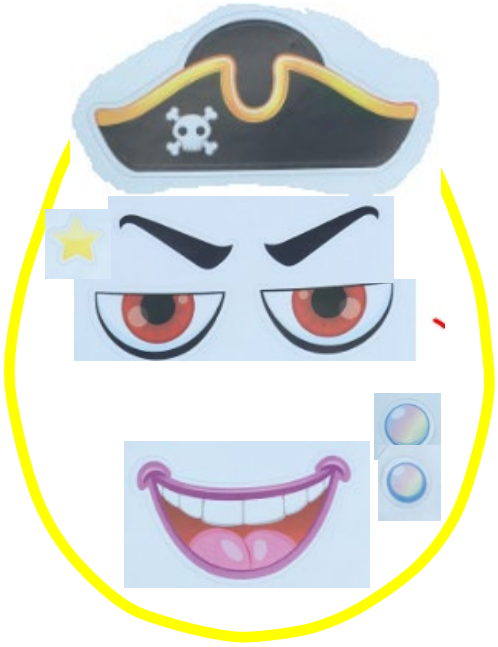
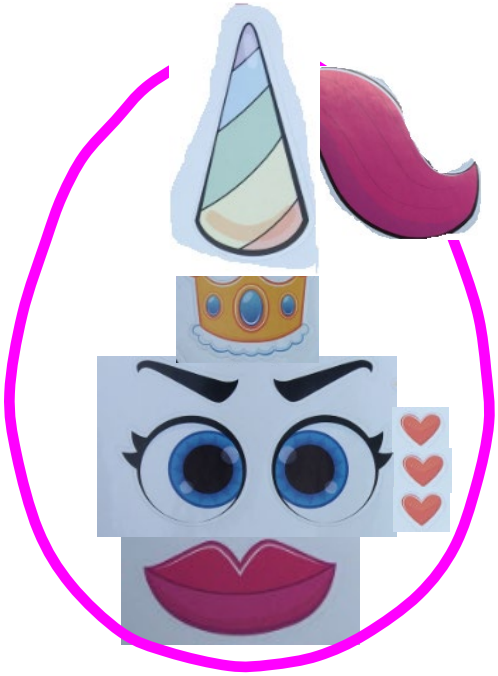
Group 1







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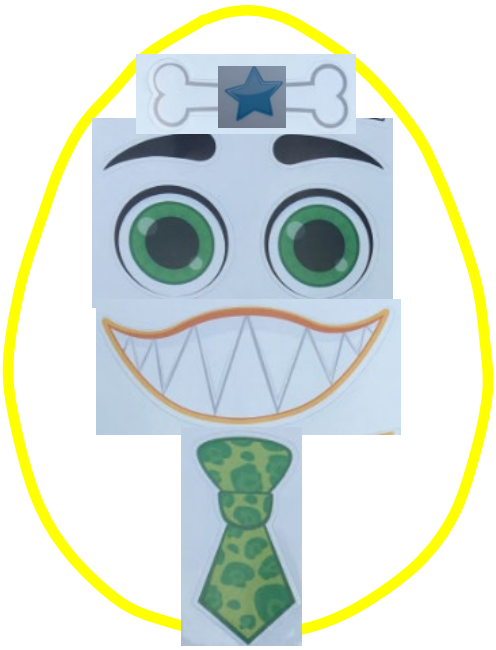
Group 2



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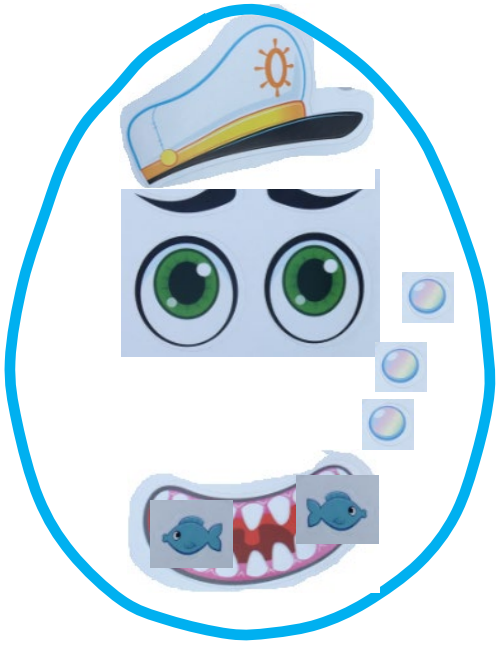
Group 3



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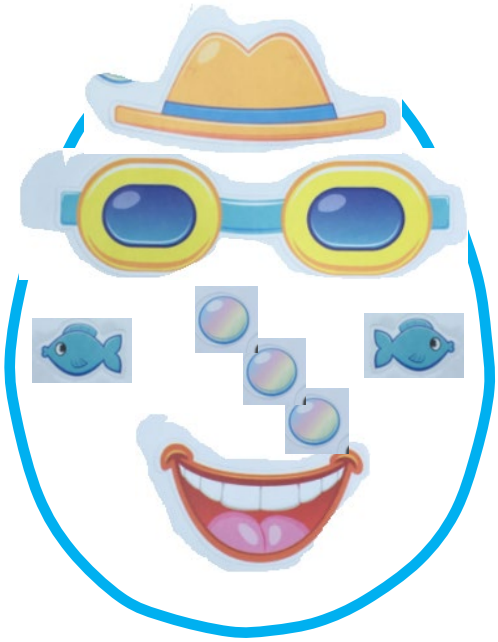
Group 4



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Group 1 / Product 1
Octopus

Purple egg
Round eyes
Oval mouth
Star nose
One bubble top of egg
Left hook arm
Mustache

Group 1 / Product 2
Octopus

Yellow egg
Red eyes
Smile mouth
One star above left eye
Two bubbles right side of mouth
Pirate hat

Group 1 / Product 3
Unicorn

Pink egg
Blue eyes
Lipstick mouth
Rainbow unicorn
Crown
Three hearts on right cheek
Pink hair

Group 1 / Product 4
Unicorn

Blue egg
Pink eyes
Plain unicorn
White tooth smile
Rainbow on forehead
Rainbow hair
Wand

Name: **Date:** **Class:**

Group 2 / Product 1
Tiger

Yellow egg
Green eyes
White mouth
Green tie
Long bone across forehead
Large blue star in middle of bone

Group 2 / Product 2
Tiger

Blue egg
Pink eyes
Pink oval mouth
Black hat
Scars on left cheek
RAWR sign right side of mouth

Group 2 / Product 3
Elephant

Pink egg
Green eyes
Closed mouth sticking out tongue
Hair bow
Peanut on tongue
Short trunk

Group 2 / Product 4
Elephant

Purple egg
Blue eyes
Trunk with branch
Black hat
Gritted teeth mouth
Yellow star centered in each ear

Name: **Date:** **Class:**

Group 3 / Product 1
Shark

Blue egg
Green eyes
Captain's hat
Red smiling mouth
Two small fish in mouth
Three bubbles to the right of mouth

Group 3 / Product 2
Shark

Pink egg
Blue eyes
White mouth
Seaweed under mouth
Purple star on right cheek
Three bubble to left of mouth

Group 3 / Product 3
Monkey

Yellow egg
Green eyes
Banana hat
Nose with round nostrils
Mouth with tongue sticking out
Banana bubble
Mustache

Group 3 / Product 4
Monkey

Purple egg
Blue eyes
Red bow in hair
Nose with narrow nostrils
Open mouth
Yellow star in the middle of each ear

Name: **Date:** **Class:**

Group 4 / Product 1
Clownfish

Yellow egg
Blue eyes
Circular black mouth
Snorkle with bubbles
Purple shell on left side
Pink shell on right side
Pink star for nose

Group 4 / Product 2
Clownfish

Blue egg
Goggles
Smiling mouth
Orange hat
Blue fish facing left on left side
Blue fish facing right on right side
Three bubbles coming out of the right side of mouth

Group 4 / Product 3
Lion

Purple egg
Golden eyes
Mouth without tongue
Green bandana
Whiskers on both sides
One flower on each ear

Group 4 / Product 4
Lion

Pink egg
Blue eyes
Mouth with tongue sticking out (no epiglottis)
Safari hat
One heart as each ear
Scar on left cheek

Name: Date: Class:

Group 1 / Product 1
Octopus
Quality Control Checklist

- ❑ Purple egg
- ❑ Round eyes
- ❑ Oval mouth
- ❑ Star nose
- ❑ One bubble top of egg
- ❑ Left hook arm
- ❑ Mustache

Group 1 / Product 2
Octopus
Quality Control Checklist

- ❑ Yellow egg
- ❑ Red eyes
- ❑ Smile mouth
- ❑ One star above left eye
- ❑ Two bubbles right side of mouth
- ❑ Pirate hat

Group 1 / Product 3
Unicorn
Quality Control Checklist

- ❑ Pink egg
- ❑ Blue eyes
- ❑ Lipstick mouth
- ❑ Rainbow unicorn
- ❑ Crown
- ❑ Three hearts on right cheek
- ❑ Pink hair

Group 1 / Product 4
Unicorn
Quality Control Checklist

- ❑ Blue egg
- ❑ Pink eyes
- ❑ Plain unicorn
- ❑ White tooth smile
- ❑ Rainbow on forehead
- ❑ Rainbow hair
- ❑ Wand

Name: Date: Class:

Group 2 / Product 1
Tiger
Quality Control Checklist

- ❑ Yellow egg
- ❑ Green eyes
- ❑ White mouth
- ❑ Green tie
- ❑ Long bone across forehead
- ❑ Large blue star in middle of bone

Group 2 / Product 2
Tiger
Quality Control Checklist

- ❑ Blue egg
- ❑ Pink eyes
- ❑ Pink oval mouth
- ❑ Black hat
- ❑ Scars on left cheek
- ❑ RAWR sign right side of mouth

Group 2 / Product 3
Elephant
Quality Control Checklist

- ❑ Pink egg
- ❑ Green eyes
- ❑ Closed mouth sticking out tongue
- ❑ Hair bow
- ❑ Peanut on tongue
- ❑ Short trunk

Group 2 / Product 4
Elephant
Quality Control Checklist

- ❑ Purple egg
- ❑ Blue eyes
- ❑ Trunk with branch
- ❑ Black hat
- ❑ Gritted teeth mouth
- ❑ Yellow star centered in each ear

Name: **Date:** **Class:**

Group 3 / Product 1
Shark
Quality Control Checklist

- ❑ Blue egg
- ❑ Green eyes
- ❑ Captain's hat
- ❑ Red smiling mouth
- ❑ Two small fish in mouth
- ❑ Three bubbles to the right of mouth

Group 3 / Product 2
Shark
Quality Control Checklist

- ❑ Pink egg
- ❑ Blue eyes
- ❑ White mouth
- ❑ Seaweed under mouth
- ❑ Purple star on right cheek
- ❑ Three bubble to left of mouth

Group 3 / Product 3
Monkey
Quality Control Checklist

- ❑ Yellow egg
- ❑ Green eyes
- ❑ Banana hat
- ❑ Nose with round nostrils
- ❑ Mouth with tongue sticking out
- ❑ Banana bubble
- ❑ Mustache

Group 3 / Product 4
Monkey
Quality Control Checklist

- ❑ Purple egg
- ❑ Blue eyes
- ❑ Red bow in hair
- ❑ Nose with narrow nostrils
- ❑ Open mouth
- ❑ Yellow star in the middle of each ear

Name: Date: Class:

Group 4 / Product 1
Clownfish
Quality Control Checklist

- ❑ Yellow egg
- ❑ Blue eyes
- ❑ Circular black mouth
- ❑ Snorkle with bubbles
- ❑ Purple shell on left side
- ❑ Pink shell on right side
- ❑ Pink star for nose

Group 4 / Product 2
Clownfish
Quality Control Checklist

- ❑ Blue egg
- ❑ Goggles
- ❑ Smiling mouth
- ❑ Orange hat
- ❑ Blue fish facing left on left side
- ❑ Blue fish facing right on right side
- ❑ Three bubbles coming out of the right side of mouth

Group 4 / Product 3
Lion
Quality Control Checklist

- ❑ Purple egg
- ❑ Golden eyes
- ❑ Mouth without tongue
- ❑ Green bandana
- ❑ Whiskers on both sides
- ❑ One flower on each ear

Group 4 / Product 4
Lion
Quality Control Checklist

- ❑ Pink egg
- ❑ Blue eyes
- ❑ Mouth with tongue sticking out (no epiglottis)
- ❑ Safari hat
- ❑ One heart as each ear
- ❑ Scar on left cheek