Advanced Manufacturing & Prototyping Integrated to Unlock Potential

STATISTICS AND PROBABILITY

Data-Driven Decision Making

PERFECTING YOUR CRAFT

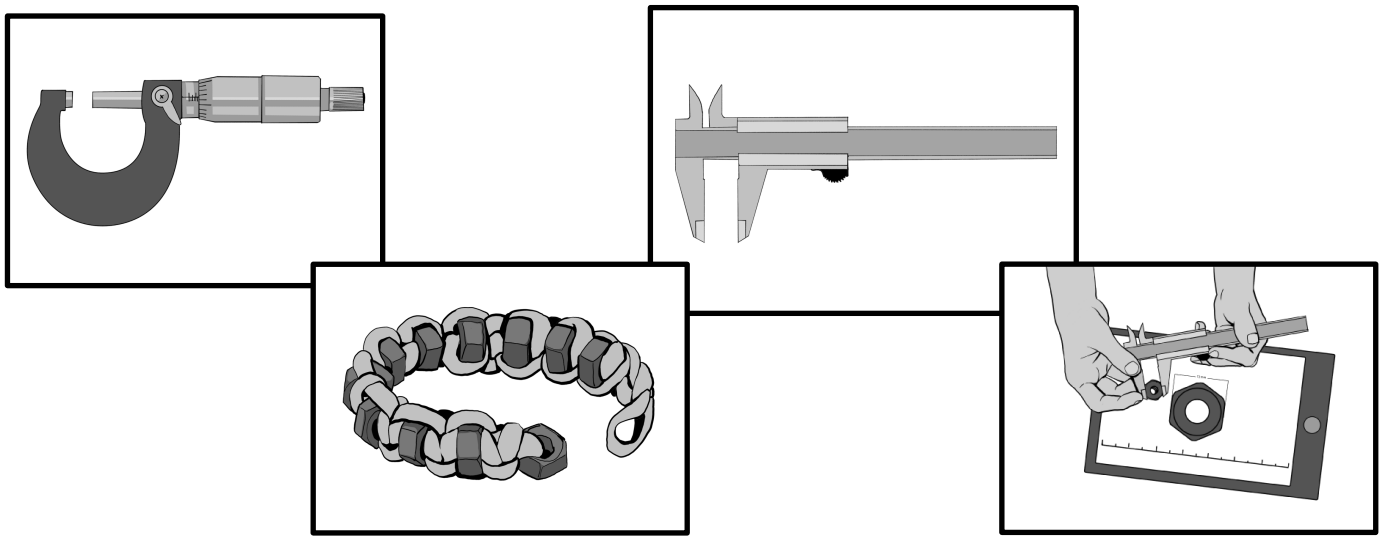
Manufacturing Quality Control Challenge

Annotated Teacher's Edition

Fall 2018

7DMM

SECTION 1 – THE MANUFACTURING QUALITY CONTROL CHALLENGE



1.1 INTRODUCTION

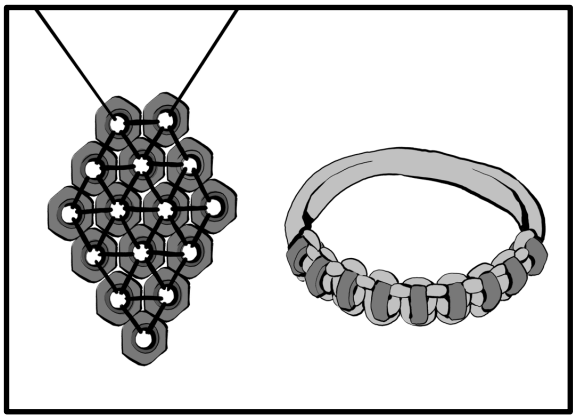
Teacher note: Read as a class or students on their own

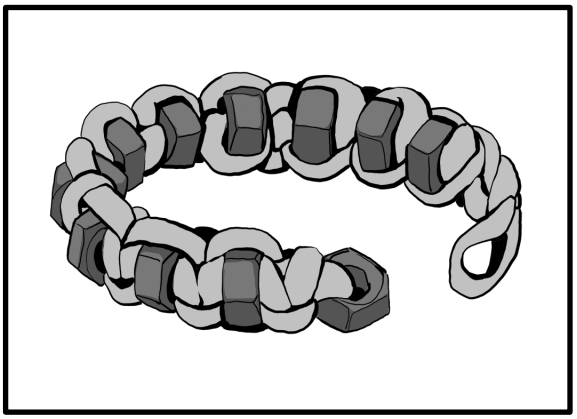
When you think of a hardware store, what comes to mind? Construction projects? Leaky toilets? Paint? Nails, nuts, bolts, and washers? Jewelry? What…. jewelry?

Hardware items like hex nuts, named for their hexagonal shape, are being incorporated into bracelets like the one in the picture above, as well as necklaces and even earrings. This Do It Yourself hobby has become so popular that some craft stores are selling kits for making hex nut bracelets and necklaces for both girls and boys.

Teacher note: Play Video 1- DIY Jewelry, first 2:06

Watch ***DIY: Hardware Inspired Jewelry*** video #1.





Spalding Nuts and Bolts (SNB) is a local manufacturer of metal hardware that has an excellent reputation for proucing and selling high quality hardware. The quality control manager is one of the most valued employees at SNB, and the quality control team is very important for the success of the company.

Quality control is a set of procedures used by the company to verify that all products made by the company meet certain **quality requirements**. These requirements might have to do with the size, weight, and strength of the item, and also whether it is the right color and works correctly. If a product is of poor quality, does not look right, or does not work, customers will not buy the product and the company will go out of business.

Play video 2

Watch ***Quality Control manager interview*** video #2.

Because of their reputation for high quality, SNB now has a contract to supply all the threaded hexagonal nuts, as known as hex nuts, for SuperCraftware, a national craft and hardware store. They will need to start up new production lines in order to increase their production of hex nuts. They have asked you to join their quality control team. Your job will be to help them figure out whether their new production lines are working well and whether the hex nuts meet the quality requirements set by SuperCraftware.

PLEASE DO NOT WRITE IN THIS BOOK.

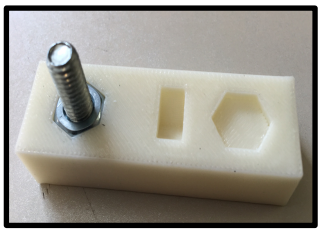
1.2 TESTING FOR QUALITY

The Quality Control Manager for SNB has given your quality control team a list of quality requirements for the hex nuts that SuperCraftware has ordered.

The following are the quality requirements for threaded hex nuts produced at SuperCraftware:

1. **Size:** The outer diameter of the hex nut should be 11mm.
2. **Height:** The height, or thickness, of the nut should be 5.5mm.
3. **Thread match:** The hex nut will thread onto a particular threaded bolt.

Teacher note: distribute the testing device and cardboard tray. You should have enough for each student to have their own.



You have been given a device, pictured on the right, for testing each of the three requirements listed above. Before you test your hex nuts, it is important to understand how to properly use the testing device.

Teacher note: Grab a hex nut from the bin and demonstrate during this discussion

Discuss this question as a class:

1. How can you test each hex nut requirement using this device?

Each team member will be given a scoop of hex nuts, taken from Production Line #1 of the manufacturing plant. Using the provided scoop, give each student a scoop of hex nuts. You should vary the scooping so there is a variety of different amounts in the class. Some can be heaped, others may be even with the top. It's ok if there are extra hex nuts left over to test. You will have the totals to make the numbers complete.

Procedure:

1. Count the number of hex nuts in your scoop and record the number on your *Testing for Quality Sheet*.
2. Using your testing device, test each of your hex nuts for all three requirements, one at a time. Record the results on your *Testing for Quality Sheet*. You have room to record the results for up to 20 hex nuts, although you might not have that many in your scoop. Students will record their results for each hex nut on the student sheet. Collect the materials once they have recorded their test results. The materials will not be utilized again during the challenge.
3. Circle the hex nut # for any hex nut that you found did not meet all of the requirements (i.e. the nut had at least one "x".)

1.3 DRAWING INFERENCES ABOUT SCOOPS OF HEX NUTS

Discuss this question as a class:

1. If the Quality Control Manager uses the same scoop for each sample of hex nuts, do you expect each sample to have exactly the same number of nuts in it? Why, or why not?

This part reviews Mean, Median and Mode. If desired it can be skipped as it does not influence the remainder of the challenge.

To properly analyze the variations in the scoops of hex nuts, you need to draw some **inferences** about them. As you have learned, in mathematics you can draw inferences by using statistical measures such as **mean**, **median,** and **mode**, which are called **measures of center**. To do this, you need to know how many hex nuts were in each scoop in the class. Your teacher will lead the class in a discussion to gather that information and to review these statistical measures.

KEY TERMS

Inference: the act or process of reaching a conclusion about something from known facts or evidence

Mean: the average as calculated by taking the sum of a collection of numbers and dividing by the number of items in the collection

Mode: the value that appears most frequently in a data set

Median: the number that is in the middle of a data set that is arranged in order from smallest to largest

Procedure:

1. Report your number of hex nuts to the class.
2. As other people report their number of hex nuts, record them on your *Testing for Quality Sheet.*
3. Calculate the mean, median, and mode for the class collection of scoops.

Discuss these questions as a class:

1. What are some explanations why the scoops of hex nuts vary in size?
2. How could the scooping procedure be changed to make the size of the sample of nuts more consistent ?

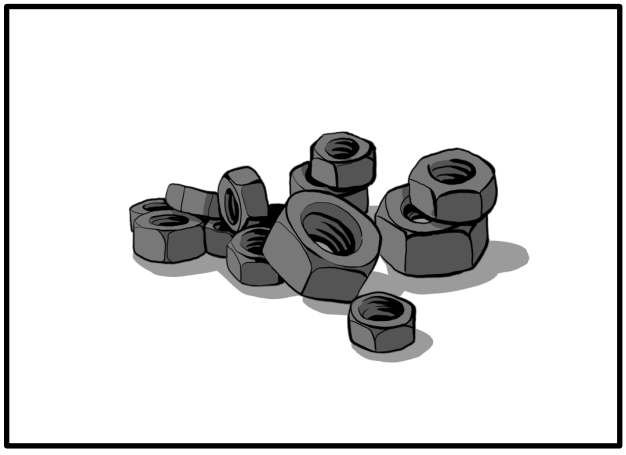
PLEASE DO NOT WRITE IN THIS BOOK.

SECTION 2 – ANALYZING YOUR SAMPLE READ ALOUD

2.1 ADD TO YOUR UNDERSTANDING: RANDOM SAMPLING

SNB has four production lines. Each line produces more than 500,000 hex nuts per day. As you have seen, not all nuts meet the specified quality requirements. The percentage of hex nuts that do not meet the requirements is called the **error rate**.

Your quality control team is responsible for making sure that all of the production lines have a very small error rate. If the error rate of a line gets too high, that production line will need to be shut down and repaired, or workers will need to be re-trained. Both things are expensive.



One way to check whether something meets the quality requirements is to examine each item individually and test it, like you did with your scoop of hex nuts. Expensive items, like cars, computers, and fancy jewelry are judged that way before they are sent to a store. But SNB makes over two million hex nuts every day, and testing each one individually is just not practical. Instead, to determine how high the error rate is, you need to use a technique called **random sampling**.

The scoop of hex nuts that you received from the production line was a **random sample** of hex nuts. That means that the hex nuts in your sample are all there just by chance. There was no picking and choosing which hex nuts you received. Using a random sample will allow you to draw conclusions about all of the hex nuts made on that production line. But the size of your sample is very important. If your sample is too small, your conclusions may not be accurate. If it is too large, it will take you a long time to test each one. How do you decide the right sample size?

2.2 PERCENT ERROR RATE

Students will now calculate their samples' error rate

You have been tasked with determining how well a SNB production line is working. In section 1.2, you tested your random sample of hex nuts for mistakes. You will now use the data you collected to compute the error rate.

Procedure:

1. On your *Error Rate Information Sheet*, record the total number of hex nuts in your sample, and the number that didn't meet the quality requirements.
2. Calculate the percent error rate of your sample of nuts by dividing the number of hex nuts in your sample that had errors by the total number of hex nuts you tested. Record the error rate.
3. Share your sample's error rate with the class. Your teacher will record the percent error rate on the class histogram.

Discuss these questions as a class:

1. Each person received a sample from the same production line. Did everyone have the same error rate?
2. Can you make a decision about the error rate of the whole production line just from your sample? Why or why not?

Using the grid chart paper place a mark for each error rate to create the histogram to help students see what will happen as the sample grows. The error rates will have a wide range at this point. That is intended to help them visualize sample size and its impact. Keep this chart so when you do the next part you will be able to add to it with the next level of sample size data.

PLEASE DO NOT WRITE IN THIS BOOK.

2.3 EXPAND THE SAMPLE SIZE #1

Students should be in groups of 4-6.

Attempt to make them the same size groups if possible.

In section 2.2, you learned that the error rates in the different hex nut samples were not all the same. That is because each person had a fairly small, randomly scooped sample, and some of these samples just happened to have more mistakes in them than others. It was strictly by chance. What would happen if the sample size was bigger?

Each member of your quality control team analyzed one sample of hex nuts. We will now combine the numbers for all of the team members to make a larger sample. Using the same chart paper from the previous part, use a different color marker to indicate the new error rates found by the larger groups.

Procedure:

1. In your team, share with each other all the information each person has from their individual samples, and record this on the *Error Rate Information Sheet*.
2. Calculate the total number of nuts your whole team tested, and record this on the *Error Rate Information Sheet*.
3. Calculate the total number of errors in this larger sample and record.
4. Calculate the error rate for the larger team sample, and record it on the *Error Rate Information Sheet.*
5. Answer the question #1 below the chart on the *Error Rate Information Sheet*.

If you did not give out all the hex nuts on day one you will want to add that data to the chart. There was a total of 500 hex nuts and 75 total errors. Using the numbers the student groups reported make your numbers complete the set.

Discuss these questions as a class:

1. What was your team's sample error rate? Your teacher will record the error rate on the class histogram.
2. Did each team have the same error rate?
3. Can you make a decision about the error rate of the whole production line just from your sample? Why or why not?

2.4 EXPAND THE SAMPLE SIZE #2

This part will be done as a whole class and should arrive at the error rate of the entire sample, which is 15%

In section 2.3, each quality control team combined individual samples to create one larger sample, and calculated the error rate. We will now combine the numbers for all of the team samples to make an even larger sample.

Procedure:

1. In your class, share with each other all the information each team has from their team samples, and record this on the *Error Rate Information Sheet*.
2. Calculate the total number of nuts your whole class tested, and record this on the *Error Rate Information Sheet*.
3. Calculate the total number of errors in this larger class sample, and record this on the *Error Rate Information Sheet.*
4. Calculate the error rate for the class sample, and record this on the *Error Rate Information Sheet*.
5. Answer the question #2 below the chart on the *Error Rate Information Sheet*.

Discuss these questions as a class:

1. What was the class error rate? Your teacher will record the error rate on the class histogram.
2. How did the class error rate compare to the team error rates?
3. Can you make a decision about the error rate of the whole production line just from your sample? Why or why not?

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SECTION 3 – INTERPRETING DATA FOR DECISION MAKING

3.1 MULTIPLE SAMPLINGS

The class sample of hex nuts that you analyzed was taken at one time during a 16-hour production day at the SNB manufacturing plant. In a production line, you have to consider that the machines have been running for many hours and different people are working on the production line. How can you be sure that the results of measurements taken at 9:00 a.m. are the same as they would be if you sampled late in the day? We are developing the need to sample a few times during the day in this discussion and the importance of sampling.

Discuss these question as a class:

1. What procedure could you use to make sure that the hex nuts produced on the SNB production line are of high quality all day?
2. Why is this important?

The SNB Quality Control Manager has asked that random samples from Production Line #1 be taken every 4-5 hours during the 16-hours production day and that the data be given to your quality control team for you to analyze. Each sample consists of 500 hex nuts. The data you receive is in the table below, and on your *Production Line #1 Error Rate Sheet*.

Production Line #1	Sample 1	Sample 2	Sample 3	Sample 4
Time sample taken	9:00 am	1:00 pm	6:00 pm	10:00 pm
Number of errors found	75	4	3	3

For this line the rates will be 15%, .8%, .6%, .6%. The second part is asking about a box of 100 based on the % found

Procedure:

1. Calculate the error rate of each sample, and record on your *Production Line #1 Error Rate Sheet.*
2. Calculate the number of errors you would find in a box of 100 hex nuts, and record on your *Production Line #1 Error Rate Sheet*. We are going with <1% as being acceptable for our challenge

Discuss these question as a class:

1. What error rate do you think would be acceptable?
2. What might be causing the different error rates over the course of the day?

3.2 A NUTS AND BOLTS PRODUCTION LINE

As a Quality Control Officer, you need to know the details of the production line so you can figure out where errors might be coming from.

Show video 3

Watch ***Nuts and Bolts Production Line*** video #3.

Discuss these questions as a class:

1. In a real nuts and bolts manufacturing plant, where might errors be introduced?
2. What types of errors might you expect to see?

3.3 ANALYZE PRODUCTION LINES #2, #3, #4

You have calculated the error rate for Production Line #1. Your quality control team is responsible for making sure that all four production lines are working correctly. The data from production lines #2-4 are shown on your *Production Line Comparison Sheet*. This sheet will be used a few times during the challenge so you may want to keep them in a folder until the end of the challenge

Procedure:

1. Transfer your calculation for Production Line #1 on the *Production Line Comparison Sheet*.
2. Calculate and record the error rate of each sample on the remaining production lines using the information provided on the *Production Line Comparison Sheet*.

You now have the error rates for four samples taken from each production line. In the next section, you will use this data to decide whether there is a problem on any of the production lines. In the end, you will also make a recommendation to the Quality Control Manager about what actions SNB should take as a result of your data.

PLEASE DO NOT WRITE IN THIS BOOK.

SECTION 4 – USING A DECISION MAKING MATRIX

4.1 THE DECISION MATRIX

You will need colored pencils (red & green) for each student

In order to make a decision based on data, it is helpful to have all the information in one place and to be able to easily visualize the data. For this challenge, you will use a **decision making matrix** to do this. A decision matrix usually includes three types of data. Two are things you know, and one is what you tested for. In this case we know: 1) the production line the sample was collected from, and 2) the time the sample was collected. The third type of data in our challenge is the error rate of each sample.

Use the procedure below to complete the decision matrix in Part 1 of the *SNB Decision Matrix Sheet*:

Procedure:

1. In the column labeled Production Line #1, write the error rate that you calculated for each sample time in the appropriate square.
2. Repeat for production lines #2-4.
3. Color each square where you recorded the error rate using the following rule:
    a. An error rate less than 1% is considered satisfactory. Color satisfactory error rates **green**.
    b. An error rate greater than 1% is considered unsatisfactory. Color unsatisfactory error rates **red**.

Discuss these questions as a class:

1. Does there appear to be problems on some of the production lines?
2. What could be causing these problems?

The causes could be in the machine, or the people. One possibility to bring up is that it could be that the Quality Control team member may not have followed the correct procedure.

4.2 INFORMED DECISIONS

The Quality Control Manager wants you to help her make an informed decision about what to do about the production lines at SNB. To do this, you will need to take several different things into account, and there might not be an obvious right answer. You make these types of decisions every day, such as when you make a decision about what to wear in the morning. There are requirements that you have to consider: what the weather will be, what activities you will be doing, what is in fashion, and what is allowed by your school. Different people will make different decisions. Some decisions are probably better than others.

As a member of the SNB quality control team, you know that the hex nuts being produced must meet the quality requirements. So you might need to shut down a production line, but that will cost the company money. Your team's challenge is to decide the best option for SNB.

4.3 ANALYZE OPTIONS

To make a recommendation, you need to know which actions SNB might take to fix things. There are four different actions that you can recommend. The option you choose must be based on the data you analyzed and should take into account the costs to the company.

Option 1: The production line should be shut down and the equipment thoroughly inspected and repaired as needed. The production line must be shut down for 3 days. During this time, SNB will not manufacture as many hex nuts, but all line workers must be paid. The repair itself will cost money.

Option 2: The line should be shut down and all line workers should take a refresher course in how to follow company procedures and operate the machinery correctly. This will only require one day of down time, and all line workers will be paid while they take the training course.

Option 3: There may be a problem at some point in the production line, but we should continue running it and retest the line before taking action.

Option 4: The line is operating within company acceptable tolerance levels and can continue to run as scheduled.

PLEASE DO NOT WRITE IN THIS BOOK.

4.4 QUALITY CONTROL TEAM DECISION

Students can work individually or in groups of 3-5

Your team will need to decide on a recommendation, based on the error rates of the lines and the different options the company can take. Use your *SNB Decision Matrix Sheet* to help you make the decision.

Discuss this question with your small group:

1. For each production line, what action would you recommend to SNB?

On Part 2 of the *SNB Decision Matrix Sheet*, write which of options 1-4 your team decided is best for each production line.

4.5 MAKE THE RECOMMENDATION

Each student should complete their own recommendation sheet

Now that your team has completed the decision making, you are each ready to write a recommendation to the Quality Control Manager. On the *Production Line Recommendation Sheet,* write your recommendation and justification for your decision. Use proper sentence structure and reference the data and process that supports your decision.

Every student may have a different recommendation for each line. The option they decide is not the important piece here. They may have different recommendations, but if they reference their data and use it to justify their decision then that is the intended outcome of the challenge.

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