**Making Sense of the Data**Print:[print_icon.gif](https://mccwdta.edc.org/print/125)[pdf_icon.gif](https://mccwdta.edc.org/printpdf/125)[sm-icon-word.gif](mccwdta-word-export/125) How statistical progress charts are used to monitor a manufacturing process Industry Sector: [Advanced Manufacturing](industry-sector/advanced-manufacturing)Content Area: [Mathematics](content-area/mathematics)Core Topic: [Data analysis](core-topic/data-analysis)Expand All | Collapse All

**Common Core State Standards**

**Standards for Mathematical Practice:**

* **1.** Make sense of problems and persevere in solving them.
* **2.** Reason abstractly and quantitatively.
* **3.** Construct viable arguments and critique the reasoning of others.
* **4.** Model with mathematics.
* **5.** Use appropriate tools strategically.
* **6.** Attend to precision.

**Statistics and Probability:**

S-ID: Interpreting Categorical and Quantitative Data

**S-ID.1**: Represent data with plots on the real number line (dot plots, histograms, and box plots).

**S-ID.2**: Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

**S-ID.3**: Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

**S-ID.9**: Distinguish between correlation and causation.

S-IC: Making Inferences and Justifying Conclusions

**S-IC.4**: Use data from a sample survey to estimate a population mean or [proportion](lexicon/6#Proportion); develop a margin of error through the use of simulation models for random sampling.

**S-IC.6**: Evaluate reports based on data.

**Adult Basic Education Standards**

**Standard 4S1.** Collect, organize and represent data.

**Standard 4S2.** Read and interpret data representations.

**Standard 4S3.** Describe data using numerical descriptions, statistics and trend terminology.

**Standard 4S4.** Make and evaluate arguments or statements by applying knowledge of data analysis.

**Industry Overview**

**Today?s Manufacturing Workplace**

A manufacturing renaissance is occurring in the United States. The United States is the largest manufacturing economy in the world, producing 21 percent of the goods manufactured across the globe. In addition to the 12 million Americans working directly in the manufacturing industry, manufacturing supports more than 6.5 million other jobs, thus accounting for nearly 17 percent of all private sector jobs in the United States. In 2010, the average U.S. manufacturing worker earned $77,186, including pay and [benefits](lexicon/6#Benefits) (the average in all industries was $56,436).1

While manufacturing jobs in Massachusetts have declined, as they have nationally, manufacturing is still a critical industry in this state and provides opportunities for good, high-paying jobs. In the Greater Boston area, most of the manufacturing jobs are in computer and electronics companies, and much of the state relies on manufacturing positions in these and other very high-tech areas, such as aerospace and biotechnology.2

Advanced manufacturing involves the use of computers and technology in the [manufacture](lexicon/6#Manufacture) of products. While not all manufacturing companies use technological innovations in developing their products or processes, the competitive advantage of the United States in the [manufacture](lexicon/6#Manufacture) of goods relies on technological innovations. This means that today?s manufacturing workplace is usually highly technical, which accounts for the high-paying positions many workers in this field receive in compensation for their work. It also means that today?s advanced manufacturing workplace is very different from many people?s conceptions of factories and mills as dark, dirty, and unsafe. Today?s advanced manufacturing facilities are usually bright, clean, and very safe, and the emphasis is on working efficiently?with as little waste as possible.

In the advanced manufacturing industry, there has been a marked [shift](lexicon/6#Shift) from the traditional role of [line workers](lexicon/6#Line_Workers) to workers who demonstrate creativity and innovation. Innovation is a hallmark of the U.S. manufacturing industry, and key to maintaining its position in the global market since products can often be produced at a lower cost in developing countries. Critical-thinking, problem solving and reasoning are important components of the innovation process. Today?s manufacturing workers are expected to formulate solutions to problems using critical thinking and reasoning skills while working independently and/or in teams.

1. <http://www.nam.org/~/media/AF4039988F9241C09218152A709CD06D.ashx>
2. <http://www.bostonglobe.com/business/2012/05/08/high-end-factory-jobs-boston-paying-high-wages/3gZuNc6GywDGKoYNP2hnaO/story.html?camp=pm>

**Careers in Advanced Manufacturing**

The manufacturing sector includes jobs related to planning, managing, and performing the processing of materials into intermediate or final products and related activities such as production planning and control, maintenance, and engineering. Thus, this industry includes not only those people who actually produce the manufactured goods, but also managers, maintenance staff, scientists and researchers, analysts, administrative personnel, and IT personnel.

**Career Pathways**

The manufacturing industry includes six career pathways:

Production is the construction and assembly of parts and final products. People in these positions work in factories and mills, with machines, to make or assemble parts, construct components of parts (such as plastics), and print materials. Occupations in this pathway range from production helpers who move parts and materials around the factory, to numerical control machine operators who run the computer-controlled machines that modify metal and plastic to create products, to manufacturing production technicians who oversee production.

Manufacturing production process development occupations are involved in designing products and manufacturing processes. People in these occupations work with production workers to set up the machines and processes to develop new products. These occupations include engineers and production managers.

Maintenance, installation and repair workers take care of products after they?ve been sold and delivered to customers?they install the products, perform maintenance on machines, tools, and equipment so that they work properly, and repair systems that are not performing adequately. Workers in this pathway include automotive technicians, automotive electronics installers, building maintenance workers, industrial electronics repairers, industrial machinery mechanics, millwrights, and small engine mechanics.

Quality assurance is provided by quality control inspectors and technicians, who ensure that products both meet design standards and are of high quality.

Logistics and [inventory](lexicon/6#Inventory) control workers ensure that those working in Production have the materials they need to complete their work. Workers in these occupations [inventory](lexicon/6#Inventory) materials and products, move materials to the line, and pack and ship finished products. Thus, they include production and planning clerks, and operators of moving machinery such as cranes and forklifts, and packers.

Health, safety and environmental assurance occupations are focused on keeping the workplace safe by ensuring that workers are using equipment safely and that manufacturing processes are as safe as they can be. The also conduct investigations and conduct inspections.

**Mathematics and Communication Skills Needed in Advanced Manufacturing**

Mathematics and communication are key skills needed for success in today?s high-performance advanced manufacturing workplaces. Mathematics is used in the advanced manufacturing industry to measure the amounts and sizes of materials and parts, create ?recipes? used to [manufacture](lexicon/6#Manufacture) man-made materials, and analyze data. Data analysis is critical at many levels of a manufacturing organization in order to ensure quality and to continuously improve both quality and processes. Today?s manufacturing industry must operate extremely efficiently and produce very high-quality products in order to maintain competitiveness. Many front-[line workers](lexicon/6#Line_Workers) are involved in collecting data and working to improve quality and efficiency. Thus, in addition to basic mathematical calculations (which rarely involve simple whole numbers), workers are engaged in mathematical reasoning and solving problems using a variety of mathematical tools.

To succeed and move up the ladder in today?s advanced manufacturing workplace, workers need reading skills to understand technical concepts, vocabulary, and to bring together information needed for a particular situation; to locate, organize, and document written information from various sources needed by co-workers and customers; and to locate written information needed by co-workers and customers. They need to use correct grammar, punctuation and terminology to write and edit documents and to develop and deliver formal and informal presentations using appropriate media to engage and inform audiences. In addition, they need to interpret verbal and nonverbal behaviors to enhance communication with co-workers and clients/participants; apply active listening skills to obtain and clarify information; and interpret and use information in tables, charts, and figures to support written and oral communications. They also must communicate with co-workers and customers using technology tools. As they move up the corporate ladder they will need to explain written organizational policies, rules and procedures to help employees perform their jobs.

**Career Opportunities in Advanced Manufacturing with Education from Community Colleges**

Massachusetts Community Colleges play an important role in preparing the state?s citizens to take advantage of the career opportunities available in advanced manufacturing. Degree and certificate programs prepare students to enter advanced manufacturing occupations, including:

production occupations, including people who work as assemblers (such as airplane assemblers), machine operators, machinists, systems operators, [CNC](lexicon/6#CNC) machine tool operators, machine setters, laminators/fabricators, metal and plastic workers, packers, molders, semiconductor processing operators, welders and solderers, tool and die makers, and other production workers;

manufacturing production process development occupations, including numerical control tool programmers who write the programs that control machine tools and industrial production managers who plan and oversee production;

maintenance, installation and repair occupations include automotive, electronics, and biotechnology technicians, industrial machinery mechanics, and millwrights (who install and maintain heavy equipment);

quality assurance occupations including quality control technicians and inspectors.

**Recent Career Opportunities in Massachusetts**

The following is a sample of advanced manufacturing job listings in Massachusetts that require associate?s degree or certificate:

* Manufacturing Engineering Technician, Randstad Corporation, Framingham, MA,
* Quality Control Technician, QD Vision, Lexington, MA
* Manufacturing Technican, Hologic, Marlborough, MA

**Employment Outlook for Advanced Manufacturing**

Advanced manufacturing continues to be a high-growth industry, given the knowledge capital in the United States. However, the work in this industry is increasingly technical and requires far fewer workers as more tasks are automated. Entry-level positions in this industry require the same skills that only a select group of highly-experienced and well-paid workers once had. Unfortunately manufacturers find it difficult to fill these high-skill positions. A 2011 survey found that there is a persistent skills gap between the skills that are needed in the today?s manufacturing workplace and the skills that candidates bring to the workforce.

Most of the advanced manufacturing companies in Massachusetts are small to mid-sized operations that employ smaller numbers of workers and rely on computer-operated machinery for production. While the numbers of workers are smaller than in the past, the more highly-skilled nature of the work means that these are high-paying jobs and provide workers with opportunities to grow through training and education and to be part of the effort to innovate.

**Resources:**

Advanced Manufacturing Industry

* [National Council for Advanced Manufacturing](http://www.nacfam.org/)
* [Advanced Manufacturing](http://en.wikipedia.org/wiki/Advanced_manufacturing)
* Brookings: ?[Why Does Manufacturing Matter? Which Manufacturing Matters?](http://www.brookings.edu/~/media/research/files/papers/2012/2/22%20manufacturing%20helper%20krueger%20wial/0222_manufacturing_helper_krueger_wial.pdf)? (2012)
* National Association of Manufacturers: ?[A Manufacturing Renaissance: Four Goals for Economic Growth](http://www.nam.org/~/media/AF4039988F9241C09218152A709CD06D.ashx)? (2012)

Advanced Manufacturing Industry Outlook Information

* [Bureau of Labor Statistics: Manufacturing Industry at a Glance](http://stats.bls.gov/iag/tgs/iag31-33.htm)
* [Massachusetts Labor Market Data](http://www.mass.gov/lwd/economic-data/)
* [Massachusetts Career Information System](http://masscis.intocareers.com/info2.aspx?FileID=Occ&FileNum=111300&TopicNum=0)

Careers in Advanced Manufacturing

* [Massachusetts Career Information System](http://masscis.intocareers.com/info2.aspx?FileID=Occ&FileNum=111300&TopicNum=0)
* [Manufacturing Career Opportunities](http://www.amcsquared.com/careers.asp)
* [Manufacturing Career Pathways](http://www.iseek.org/iseek/images/content/pathways/large/production-pathway.html)
* [Industry Competency Model for Advanced Manufacturing](http://www.careeronestop.org/competencymodel/pyramid.aspx?hg=Y) shows the skills and knowledge needed to work in this industry
* [National Association of State Directors of Career Technical Education Consortium?s Common Career Technical Core](http://www.careertech.org/career-technical-education/cctc/)
* [National Association of State Directors of Career Technical Education Consortium?s Knowledge and Skills: Manufacturing](http://www.careertech.org/career-clusters/resources/clusters/manufacturing.html)
* [O\*NET](http://www.onetonline.org/find/career?c=13)
* [WorkKeys Occupational Profiles](http://www.act.org/workkeys/analysis/occup.html)
* [Manufacturing?s Missing Generation](http://www.massmac.org/toolbox/workforce_training.htm)
* [A Career in Toolmaking or Machining Technologies: The Right Choice for Students, Community, & Country](http://www.massmac.org/toolbox/careers_in_mfg.pdf)

**Workplace Scenario (8th Grade Level)**

This scenario is based on the work of a machinist. For more information, view [this video](http://www.careerinfonet.org/occ_rep.asp?next=occ_rep&Level=&optstatus=111111111&jobfam=51&id=1&nodeid=2&soccode=514041&stfips=25&x=59&y=20).

You are a machinist. You work at a company in northeastern Massachusetts. Your company manufactures and assembles jet engines. These engines are used in both commercial and military planes. Both are precise machines with no margin for error. There are steps to take before you begin machining the parts. You first need to read the blueprint. The blueprint tells you the precise [dimensions](lexicon/6#Dimensions) for the completed piece. You also need to know its [specification limits](lexicon/6#Specification_limits). These limits say how much the piece can differ from the precise [dimensions](lexicon/6#Dimensions). If a piece differs too much, it will not work properly in the engine. Each year you fly to visit your family for the holidays. You know that any variation from the blueprint could cause problems. It could keep the engine from working. An engine malfunction in flight can lead to disastrous results.

Throughout the manufacturing process you develop ?statistical control charts.? You use information from those charts to adjust your machine. This helps ensure that the parts are made within the [specification limits](lexicon/6#Specification_limits). Too small or too large and the parts will not work well in the engine. You use a [micrometer](lexicon/6#Micrometer) to measure the size of every 10th part produced. This lets you see if your machine is ?holding [dimensions](lexicon/6#Dimensions).? This means it is producing high quality, usable parts. You add the measurements to your [statistical control chart](lexicon/6#Statistical_control_chart). Sometimes you find a piece with the wrong measurements. When this happens, you recheck the set-up of your process. You make adjustments as needed. You are continually monitoring the manufacturing process. You also maintain statistical control charts. These charts document the manufacturing process. Sometimes a process does not work well. When this happens you use critical reasoning skills to take action.

These statistical control charts are reviewed by co-workers. The review happens when they take over the work at the end of your [shift](lexicon/6#Shift). The control charts are also integrated with other charts. Then they are converted to graphs. Production teams review them during monthly team meetings. The production team discusses production goals. The team also talks about improvements that could be made. These improvements could increase profits for the company. You are very careful to document your process. You hope your team will win this month?s award for machining efficiency.

**Workplace Scenario (High School Level)**

This scenario is based on the work of a machinist. For more information, view [this video](http://www.careerinfonet.org/occ_rep.asp?next=occ_rep&Level=&optstatus=111111111&jobfam=51&id=1&nodeid=2&soccode=514041&stfips=25&x=59&y=20).

You are a machinist who works at a company in northeastern Massachusetts. Your company manufactures and assembles jet engines. These engines are used to power both commercial and military aircraft. Both are precise machines with no margin for error. Before you begin machining the parts, you need to read the blueprint to find the precise [dimensions](lexicon/6#Dimensions) for the completed piece. You also need to know its [specification limits](lexicon/6#Specification_limits). These indicate how much larger or smaller the piece can deviate from the precise [dimensions](lexicon/6#Dimensions) to work properly in the engine. Each year you fly to visit your family during the holidays. You understand that the smallest variation from the specifications listed on the print (blueprint) could keep the engine from working. An engine malfunction in flight can lead to disastrous results.

Throughout the manufacturing process you develop ?statistical control charts.? You use information from those charts to adjust your machine. This helps ensure that the parts being produced remain within the limits specified on the print. Too small or too large and the parts will not work well in the engine. You use a [micrometer](lexicon/6#Micrometer) to measure the size of every 10th part produced. This lets you see if your machine is ?holding dimensions? and producing high quality, usable parts. You add the measurements of every 10th piece to your [statistical control chart](lexicon/6#Statistical_control_chart). Sometimes you identify a manufactured piece where the measurements fall outside the tolerance limit. In these cases you need to recheck the set-up of your process and make adjustments. As a machinist, you are continually monitoring the manufacturing process. You also maintain the statistical control charts needed to document the manufacturing process. You use critical reasoning skills to take action when a process is out of tolerance.

These statistical control charts are reviewed by co-workers who take over the machining of parts at the end of your [shift](lexicon/6#Shift). They are also integrated with other charts, converted to graphs and reviewed by production teams during monthly team meetings. The production team discusses production goals, quality control issues and the improvements that could be made to increase profits for the company. You are very careful to document your process. You hope your production team will win this month?s award for machining efficiency.

**Core instructional context**

Data analysis can help us to make better decisions in both our daily lives and in our work. Students may be used to reading information in charts and graphs, making sense of the data, and then making decisions based on that data?decisions about their finances, what type of automobile to purchase, whether and where to buy a house, or about where to send their children to school.

In the workplace, data analysis can be crucial to the success of a business. In many industries, there is a strong emphasis on ensuring that the quality of a product or service remains stable (and high) by constantly analyzing data about the process and making improvements. A machinist is an important occupation in the advanced manufacturing industry?a highly-skilled technician who operates the machines in a factory and creates or replaces machine parts and tools. The machinist is also critical to ensuring quality in the company?by helping to monitor the quality of the products produced, identifying sources of poor quality, and helping to develop solutions that will lead to an overall better quality.

When analyzing data, often the data is reorganized and represented graphically. Using graphs and charts help people to ?see? the data and make sense of it?whether they are used to show a comparison, trend, or relationship between the data. For example, you might create:

* a pie chart line to compare how much of your salary goes to different expenses
* a line graph to show the temperature over the past month
* a bar graph to show the amount of rainfall in different states

Histograms are a type of bar graph?they show the frequency of any particular value or range of data in a data set. Histograms are relatively easy to create and update in order to analyze data and are one of the tools used in quality control. Histograms, along with such tools as cause-and-effect diagrams and control charts, are used to troubleshoot issues with quality in a range of industries, including manufacturing, IT, and healthcare.

Histograms make it easy to see where most of the items occur in a given set of data, and very useful for the machinist. For example, in the following histogram, which shows the radius of a metal tubing generated in a manufacturing process, you can see that most of the tube samples had a 15.5-15.6 mm radius, but that some pipes had slightly larger / smaller radii. This distribution is a normal distribution, often referred to as a ?bell curve?:

Similar data can also be represented using a control chart. A control chart shows the statistical variation of a process over time. For example, the control chart below shows the variation in average width of a metal panel for an airplane?s fuselage.

In this control chart, the thickness of several samples of the metal were measured over time and plotted. The control chart shows how the thickness varied with each sample, and also shows control limits (dotted green lines) which show the acceptable tolerance for the product

**Worked Example**

The histogram below represents the following list of employee ages at a small company:

21, 25, 30, 31, 32, 33, 33, 33, 41, 42, 43, 44, 45, 48, 49, 50, 51, 53, 62, 69

Calculate the mean, median, and mode of this employee age data. Find and interpret the data set?s standard deviation.

The **mode** of a dataset is the value that occurs the most. Though it might at first seem that this value should be between 40 and 50, looking at the list of ages shows that 33 is the mode, the value that occurs more than any other in the dataset.

The **mean** can be found by adding each value in the data set and dividing by the number of data points. This is sometimes called an average. The sum of all of the values is 835 and there are 20 data points, so the mean is 835 / 20 = 41.75 years.The **median** is the middle data point. The median should have half of the data points below it and half of the data points above it. For example, for the data set below, the median is 16 because there are two data points below it and two above it.

1, 2, **16**, 17, 18

When the data set has an even number of points, the median is the mean (or average) of the middle two points. For example, the employee data above has 20 points, so the average of the 10th and 11th points would be the median. In this case, the 10th data point is 42 and the 11th data point is 43, giving us a median of 42.5.

The **standard deviation** of a data set is not usually calculated by hand. With the help of some statistical software (for example, Microsoft Excel), you can easily find that the standard deviation of the employees? ages data set is 12.2. The standard deviation can show how spread out the data is from its mean. If most of the employees were around 42 years old, the standard deviation would be much smaller. If there were more employees between 10-20 years old and/or between 70-80 years old, the standard deviation would be much bigger.

**Contextualized learning activities**

**Pre-Reading**

Share with students the following scenario:

*Peter arrives at work in a terrible mood. He tells his co-workers that he needs to find a new way to get to work?it took him almost 45 minutes to drive to the office today. His co-worker Leanne asks how long it usually takes him to get to work, and Peter responds ?15 minutes.?*

Ask students what other information they might ask Peter if they were his co-workers, and how they might respond to him about his decision to change his commute. Students might say that they would ask whether his commute always takes 15 minutes and this was a unique instance, or whether the commute time has been getting longer and longer. You might offer the information that after sitting in traffic for 30 minutes, Peter passed an accident that was being cleared from the road, and his commute continued normally after that (so he would have gotten to work in his usual 15 minutes had there not been an accident); see how students respond?hopefully they will understand that Peter shouldn?t change his commute because of a single, special cause that led to his much longer commute. You might then tell the class that Peter responds to his colleagues that while he used to make the drive in 12-18 minutes, he?s been noticing?even before today?s extremely long commute, the drive was taking more like 18-23 minutes most days (traffic on this route is becoming a common cause of a longer commute). Given this information, students might say that perhaps peter should find an alternative route. These two cases?special causes and common causes of variation?need to be treated differently, and industries hoping to improve the quality of their products and services focus on the latter. These common causes are something predictable that can be addressed?by changing your commute if you are Peter or by adding more workers on the manufacturing floor, increasing the frequency with which machines are serviced, or purchasing higher-quality materials for a company. Special causes of variation?such as the car accident or the catastrophic failure of a system because of a machine malfunction?cannot be predicted and therefore companies wouldn?t change their way of doing business as a result?nor should Peter change his commute because of this one day.

**Reading the Scenario**

Have students read the scenario?either as a whole group, in pairs, or to themselves. Ask students to circle or highlight mathematical concepts and terminology.

Many of the key responsibilities of a machinist involve designing and building, maintaining, and running manufacturing machines, which in the advanced manufacturing industry means working with computers. In addition, in many medium and small manufacturing companies, all front-line employees have a critical role in quality control. Ask students to [brainstorm](lexicon/6#Brainstorm) ways that mathematics is used to help with these daily work activities in this industry. In particular, ask students if they can identify ways that data analysis are used. Discuss the possible consequences of not having good, continuous data about quality and performance in this profession.

Optional extension: Ask students to think about how they picture a manufacturing facility-?what things come to mind? Have them share their thoughts about what this work and workplace would look and feel like. Show two short video clips, one of an older production facility and one of a modern facility, or a video of a modern-day plant, such as the re-designed, environmentally-sustainable [Ford Rouge plant](http://www.youtube.com/watch?v=fax-JSIv8O4).

**Central Tendency & Histogram Exercise: Graphing Height and** [**Weight**](lexicon/6#Weight)

For an activity that introduces the skills needed for this scenario, break the class into groups and have each group collect data on each other?s physical traits such as height, [weight](lexicon/6#Weight) and eye color. Aggregate the data and have students graph it using histograms. After creating the data, they find mean, median, mode, and range. They then add fictional data from a really tall person to see the effect of outliers on the mean, median, mode, and range.

**Analyzing Variation**

Each group has a bag of objects (such as Legos, bolts or nails, safety pins, paper clips) that are similar in shape but of variable length. They have to measure the length and create a histogram that shows the statistics on length. There is a maximum and minimum limit of acceptable lengths, and they have to find the percentage of objects outside of these tolerance limits.

**Building a Tower**

Each group has parts A, B, and C. Across the class, there is variation in how long a part A is. For example, between 3.25 and 3.75 cm. Each group measures part A and submits their measurement, perhaps by writing it on a transparency or telling the teacher, who inputs it into the computer. Those measurements are recorded and run through an [online histogram tool](http://easycalculation.com/graphs/create-histogram.php), generating a histogram for part A. Repeat for parts B and C, and now you have three histograms, one for each part. (The more groups in the class, the better the data.)

Then, it's up to each group to put parts A, B and C together to create their tower. Again, they submit data on their length, and are able to view the histogram of lengths. Some groups may have had all UL parts, others all LL parts, and others a mixture. They can then try to fit their tower into the overall machine. The ones built from all UL parts are too big, the ones built from all LL parts are too small, and the ones built from a mixture are usually just right.

**Contextualized Problems**

Before having students work on the following contextualized problems, you might first have them work through the worked example problem in this module individually or in pairs, and share their answers with the class.

*You are the quality machinist at a factory that produces a common component for fabrication machines. The ideal length for this component is 5.3 cm, but there is considerable variation in the lengths of the component that are actually produced. In fact, their lengths range from 5.05 to 5.53 cm. On a routine basis, you collect data on the lengths of the components and reject the ones that do not fall within the acceptable range of 5.2 to 5.5 cm. Your goal is to determine the amount of components that fall within the acceptable range.*

1. **DATA SET 1.** Below is the data collected on the lengths of components that were produced on the first [shift](lexicon/6#Shift) at the plant today.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Length (cm)** | **5.05** | **5.15** | **5.25** | **5.35** | **5.45** | **5.55** |
| # of Components | 5 | 10 | 15 | 20 | 15 | 10 |

Make a histogram out of this data. Start by drawing out the histogram on graph paper. Rulers/straight edges and colored pencils are recommended. Title your histogram and label your axes clearly.

Once your hand-drawn graph is complete, plot this data using an [online histogram graphing calculator](http://easycalculation.com/graphs/create-histogram.php).

The width of each bar on the histogram represents the bin size?a range of values for length. Each data point should fit into one of the bins. For both your hand-drawn graph and your online histogram, bin sizes should be the following:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Bin Sizes for Length (cm)** | 5.01-5.10 | 5.11-5.20 | 5.21-5.30 | 5.31-5.40 | 5.41-5.50 | 5.51-5.60 |

Find the mean, median, mode, range, and standard deviation for this data set.

**ANSWERS**: MEAN: 5.33, MEDIAN: 5.35, MODE: 5.35, STDEV: 0.143

1. **DATA SET 2.** Below is the data collected on the lengths of components that were produced during the second [shift](lexicon/6#Shift) at the plant today.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Length (cm)** | **5.05** | **5.07** | **5.14** | **5.18** | **5.22** | **5.23** | **5.33** | **5.37** | **5.45** | **5.49** | **5.51** | **5.53** |
| # of Components | 3 | 5 | 10 | 15 | 20 | 25 | 30 | 25 | 20 | 15 | 10 | 3 |

Make a histogram out of this data. Your histogram bin sizes should be the following:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Bin Sizes for Length (cm)** | 5.01-5.10 | 5.11-5.20 | 5.21-5.30 | 5.31-5.40 | 5.41-5.50 | 5.51-5.60 |

Plot your data using the [online histogram graphing calculator](http://easycalculation.com/graphs/create-histogram.php). Find the mean, median, mode, range, and standard deviation for this data set.

**ANSWERS**: MEAN: 5.31, MEDIAN: 5.33, MODE: 5.33, STDEV: 0.126

1. If the tolerance range is 5.2 to 5.5, what percentage of components produced today are outside the tolerance range?

**ANSWERS**:

1: 33.8%

2: 25.4%

1. Add in 2 components to each data set that are 5.59 cm long. Re-plot your data and calculate the new mean, median, and mode. How do these two outliers affect the ?center? of the data?

**ANSWERS**:

1: MEAN: 5.33, MEDIAN: 5.35, MODE: 5.35, STDEV: 0 .147

2: MEAN: 5.32, MEDIAN: 5.33, MODE: 5.33, STDEV: 0.129

1. In another factory, the probability that a component will be rejected is 20%. What percentage of components are typically produced within the tolerance range?

**ANSWER**: 80%

**Contextualized test items**

*You?re examining the control chart above for quality assurance on a plastic insulation production process. Use the following chart to answer the questions below:*

1. How is the mean represented on the graph? (**ANSWER**: Dotted blue line)
2. What is the mode? (**ANSWER**: 99 mm)
3. What is the median? (**ANSWER**: 99.5 mm)
4. How many samples fall outside of 1 standard deviation from the mean? (**ANSWER**: 1)
5. How many samples fall outside of the control limits? (**ANSWER**: 0)
6. Given your answers to 5 & 6, do you think there are problems in the process that need to be resolved for quality assurance? (**ANSWER**: Students should recognize that the data does not indicate a problem in the process since the variation is well within the upper and lower control limits.)

*You?re working as a machinist creating ball bearings at an automotive supply plant. After today?s production line closes, you compare histograms of yesterday?s ball bearing size variation with today?s.*

1. Which day had more variation in its ball bearing sizes? (**ANSWER**: Today)
2. Which day has a smaller standard deviation? (**ANSWER**: Yesterday)
3. Your [supervisor](lexicon/6#Supervisor) noted that the production crew working yesterday was sloppy, does the data in the histograms support or refute her claim? (**ANSWER**: Refute)

**Contextualized project**

To explore the existence and importance of manufacturing process variations, have groups of students or individuals gather 100 samples of a common household item (such as paper clips, index cards, and paper plates) and take some kind of measurement (such as thickness with a [micrometer](lexicon/6#Micrometer) and [weight](lexicon/6#Weight) with a high-resolution balance) of each. Students should then plot out the sample data as a histogram and perform a statistical analysis, answering factual questions like:

1. How much variation is there in the size of your items?
2. What?s the standard deviation?
3. What?s the mean?

but also interpretive questions such as:

1. What, if any, effects does your measurement have on the overall performance of the product?
2. What do you think would be reasonable control limits on this measurement?
3. Did you find any items that you would have rejected at the production line?

Then have groups or individuals generate a multimedia presentation which shows their histogram with annotations, and present their findings to the rest of the class.

**Additional or extension activities, multimedia, readings and/or resources**

**Resources**

***Virtual Tours of Industries***

* [National Association of Manufacturers: Cool Stuff Being Made](http://www.nam.org/Communications/Cool-Stuff-Being-Made/Cool-Stuff-Being-Made-Manufacturing-Videos.aspx)
* [National Institute of Metalworking Skills](https://www.nims-skills.org/web/nims/home)
* [National Tooling and Machining Assocation](http://www.ntma.org/)
* [Machining Resources](http://www.khake.com/page88.html)

***Interactive Activities***

Statistics Online Computational Resources:

* [Histogram construction](http://wiki.stat.ucla.edu/socr/index.php/SOCR_EduMaterials_ModelerActivities_MixtureModel_1)
* [Histogram manipulation](http://wiki.stat.ucla.edu/socr/index.php/SOCR_EduMaterials_Activities_PowerTransformFamily_Graphs)
* [Histogram activities](http://www.socr.ucla.edu/htmls/SOCR_Charts.html)

Measures of Central Tendency:

* [Exploring measures of central tendency with histograms](http://geosim.cs.vt.edu/Sable/converted/MMM/activity.html)

**Instructor Adapted Classroom Materials**

[Making Sense of the Data GED Introductory Lesson Plan,](http://www.mccwdta.etlo.org/sites/mccwdta.edc.org/files/section_files/Making_sense_of_the_data_1.docx) Quinsigamond Community College, ABE/GED

[Making Sense of the Data GED Lesson Plan,](http://www.mccwdta.etlo.org/sites/mccwdta.edc.org/files/section_files/Making_sense_of_the_data_1-3.pdf) Quinsigamond Community College, ABE/GED