Hardware Store Science Curriculum

Experimentation Through Design

ICP Maker-STEM Content Document

Key Terms

Caliper - a device used to measure the distance between two opposite sides of an object
Dimension - an expressed numerical value used to define the size, location, orientation, form or other geometric characteristics of a part
Engineering Tolerance - allowable amount of variation in the dimensions of a machine or part
Measurement - the determination of the size or magnitude of something with applied units
Prototype - a first/preliminary model from which others are developed

Lesson 1 – Variation Within Measurements: We will begin this module by learning how to collect accurate measurements. This will be reinforced throughout the curricular program, so that we gain an intuitive feel for accuracy in measurements, both within the design process and during experimental data collection. *(ESPS.2, 5; IED-6.10)*

Lesson 2 – Accuracy and Tolerance: Next, we will look at tolerances associated with assembly of individual components to form complex systems. A focus on fit will prepare us for designing our investigation models throughout the course and specifically during the upcoming MSTEM Accel Car design project. *(ESPS.2, 5; IED-1.5, 6.10)*

Lesson 3 – The Engineering Design Process: Armed with and understanding of measurements, dimensions, and variance we will introduce the engineering design process and apply this process while designing a first iteration chassis for the MSTEM Accel Car project. *(ESPS.3; IED-1.5, 6.10)*

Lesson 4 – Prototyping and Modeling: Finally, design teams will model the Engineering Design Process from concept to working prototype. After completing the model build, teams will evaluate final prototypes based on design requirements and established standards detailed in project requirements/constraints. *(ESPS.3; PEO-5.3)*

Module 4 Guiding Question

How are functionality and ease of assembly ensured by accuracy of dimensions and tolerances?

Equilibrium and Conservation

Science has been defined as knowledge about “natural” laws by the testing of hypotheses through repeatable experiments. Curiosity and inquiry are the driving forces for the development of investigations and experiments within science and improvements and innovations within engineering. Scientists and engineers seek to understand and improve the world and the way it operates. In doing so, they apply inductive and deductive logical thinking to their curiosity and inquiry of these “natural” laws.

Inductive reasoning is a form of logical thinking that uses related observations to arrive at a general conclusion. This happens when we make observations in the form of notes, measurements, drawings, pictures, photos, or videos and come up with conclusions. In **deductive reasoning**, the pattern of thinking moves in the opposite direction. Deductive reasoning is a form of thinking that uses a general principle or law to predict specific results. These logical reasoning processes can be descriptive or hypothesis based. Descriptive (or discovery) science is usually inductive and aims to observe, explore, and discover, while hypothesis-based science is usually deductive; beginning with a question that can be tested. Most science and engineering activities combine some form of each approach.

Lesson 1: Objectives

- Define the importance of engineering tolerances and dimensions using specific examples

Content

- Accuracy in Measurements
- Measurement Tools

We share scientific thoughts and ideas with a wider world than our own communities, as such it is important to understand that personal and cultural beliefs influence both our observations and our conclusions of natural phenomena. Scientists have traditionally used a standardized set of procedures to minimize the influence of personal and cultural beliefs when developing scientific knowledge. Technology is developed to help us learn and experience the natural world to our greatest potential. Engineers apply the collective store of scientific knowledge to create and maintain technological advances. Mathematics is used to express the governing rules, laws and theories that cut across each discipline.

For example, The story goes that in 1948, a man named George de Mestral was walking his dog in the Alps of Switzerland when he noticed that burrs were stuck to his dog's fur as well as George's socks, pants and jacket. Being curious, he looked at the burrs under a microscope where he noticed they were covered in tiny hooks. He reasoned that one hook by itself was not strong, but that lots of them together allowed the burrs to hold on tightly to the fur, socks, pants, and jacket.

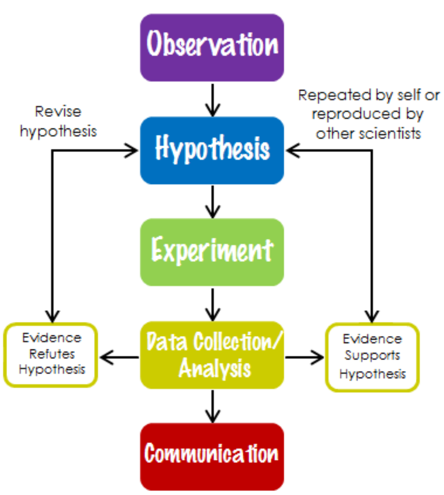
Inspired by the hooks on the burr, Mestral thought that he could invent a new type of fastener to be used instead of metal zippers. After several years of trial and error he finally discovered that nylon could be used to make the strong hooks. In 1955 he patented "Velcro" (a combination of the French words "velour" (velvet) and "crochet" (hook)). Velcro was an immediate success and today is used to fasten and attach all kinds of things from equipment to clothing.

Inductive reasoning created a testable idea from detailed observations, principles of engineering applied this knowledge of biological form and function to create a product that would mimic the observed phenomenon. The effectiveness of its use is then communicated numerically/mathematically.

Trump - *(verb)* to outrank or defeat something

Lesson 1: Variation Within Measurements

Although scientists do not always follow a rigid set of steps, investigations do follow a general pattern. In fact, every experimental test lead to either the confirmation of a hypothesis or its ruling out as a viable prediction. The scientific processes involved require that a hypothesis be ruled out or modified if its predictions are clearly and repeatedly incompatible with experimental results. In every science experiment the collected results trump everything, and verification of hypothetical predictions is absolutely necessary.



Before beginning an investigation, we need to gather and examine observations and interpretations from reliable sources. This background helps us fine-tune our question(s) and form a hypothesis. This plausible explanation is based on the observable facts and testable through experimentation. In a controlled experiment the manipulation of an independent variable is compared to its effect on the dependent variables, under strict controls. An important part of every investigation includes recording observations and organizing the test data into easily read tables and graphs. These collected data are then pondered over to determine the generalized statements that can be made and communicated to others. Finally, after analyzing the data it must be decided whether the hypothesis tested by the experiment is supported.

One consideration for a hypothesis to be described as supported and accepted is that experimental results are reproducible.

Bias occurs when our expectations change how the results are analyzed or the conclusions are made. Personal bias may lead us to select the results from one trial over those from other trials. Running as many trials as possible and by keeping accurate notes of each observation made helps reduce the possibility of bias in our conclusions. Valid experiments must also have data that is measurable. This allows others to compare our results to data they obtain form similar experiments. First and foremost, the experiment must be repeatable. The underlying concept throughout all of this is the importance of accurate experimentation, data collection, and interpretation.

Accuracy - *(noun)* the condition or quality of being true, or free from error.

Precision - *(noun)* how close measurements of the same item are to each other

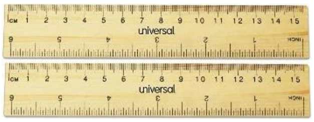
Validity - *(noun)* the quality of being logically or factually sound

Conclusions based on accurate and precise measurements are the most error free. We can define a measurement is a numerical value that describes some property of an object or event. All measurements are made by comparing a quantity with an established standard unit, i.e. a football field is 100 yards from endzone to endzone; horses are measures in hand widths and automobile speeds are recorded in miles per hour (MPH). Since this comparison cannot be perfect, measurements inherently include error, which is how much a measured value deviates from the true value. The accuracy with which an observation is measured and recorded is another way of reducing errors within collected data.

There are many measurement systems that have been used throughout history and around the world. Today, most of the world utilizes the standardized International System of Units (SI) to collect, record, and communicate physical measurements in seven base units: length, mass, time, current, temperature, amount, and luminous.

Measuring tools have been used for centuries and are important for understanding the world around us. There are many different types of measuring tools used, which can measure anything from angles to temperature to time. The type of tool you will need depends on exactly what it is you want to measure, and how you want to collect the information. In some instances, there could be several tools all appropriate for one job.

Tape measures and rulers are the most familiar measuring tool. They have an incredibly simple premise and are easily used by everyone. These measuring devices are used for obtaining linear distances with an expected accuracy. Tape measures and rulers are commonly used when doing geometry, and in construction and engineering. The profession they are intended to be used in will largely determine the type and scale associated with the tape measure or ruler.



Tape measure

Calipers are a less common measuring tool that accurately measures the distance between two opposing sides of an object. A caliper has two adjustable tips that can be pushed up against opposite sides of an object, and when removed from the object, the user is able to read the measurement given between the two tips of the caliper. These are commonly used in various career fields, including wood or metalworking, medicine, science, and engineering. A micrometer works in a similar way to a caliper but can measure the length, depth, and thickness of an object. Measurements are not made with

Caliper

Micrometer

a ruler, but by a calibrated screw. Micrometers, assuming they are used correctly, offer incredible accuracy.

The mass of a n object represents the amount of matter within that object. Measuring mass does not necessarily measure weight, as weight changes depending on the effect of gravity. Mass, however, does not change regardless of where an object is located. The amount of matter in an object remains the same. To measure mass, scientists use various tools depending on the size and location of the object. For most everyday objects, scientists use a balance to obtain an object's mass. A balance compares an object of known mass to the object in question. One example of a balance is the triple beam balance. With the standard unit of measure based on the metric system and is typically denoted as kilograms kilograms or grams. Within the home, modern digital and spring scales aid in determining mass. An o bject is placed on the scale, which obtains the objects weight. A digital scale calculates the object's mass by taking the weight and dividing it by gravity.

Stop watches are essential to accurate time measurements

Stopwatches and timers are instruments used to measure time interval, which is defined as the elapsed time between two events. Unlike a conventional clock that displays time-of-day as hours, minutes, and seconds from an absolute starting point (such as the beginning of the day or year), a stopwatch or timer simply measures and displays the time interval from an arbitrary starting point that began the instant the stopwatch was started. The standard unit of time interval is the second (s). Seconds can be accumulated to form longer time intervals, such as minutes, hours, and days; or they can be sliced into fractions of a second such as milliseconds or microseconds.

StopwatchCamera app available at app stores makes for a useful resource

Current is one of the basic electrical measurements, and therefore it is often necessary to measure the current flowing through a circuit to check its operation. Current measurements are easy to make, but electrical measurements are done in a slightly different than other types of measurements do to safety concerns. However, electrical measurements often need to be made to find out whether a circuit is operating correctly, or to discover other facts associated with power and energy consumption. Electrical measurements can be made with a variety of test instruments, but the most widely used pieces of test equipment for making electrical measurements is a digital multimeter. These items of test equipment are widely available and at very reasonable prices.

Multimeter

A thermometer is the traditional tool for measuring temperature in units of both celsius and Fahrenheit A classic thermometer will consist of a glass tube that has a small amount of colored alcohol in the bulb at the base, and as the temperature rises, the colored fluid level rises up the tube to indicate a higher temperature. The fluid level will decrease as the temperature cools. Temperature measurements can be obtained by reading the preset markings on the glass tube that match up to the level of colored fluid.

There are also digital and infrared thermometers. The type of temperature measurement needed determines the type of thermometer used

Pressure gauges are a common measuring tool that is used when measuring the amount of pressure produced by liquids and gases such as water, air, or oil. If you have a water heater in your home, you will likely find a pressure gauge attached to the front of it so you can keep a check on your water pressure and ensure it stays in the correct range. Pressure gauges are important tools in industrial and commercial environments, where they help maintain the plant and/or system safety. They are also useful tools to use when checking the pressure in hoses, containers, and fluid systems.

Photometers are used to regularly measure the light intensity. In photometry, luminous intensity is a measure of visible light that is emitted in a given direction. Photometry deals with the measurement of visible light as perceived by human eyes. The human eye can only see light in the visible spectrum and has different sensitivities to light of different wavelengths within the visible spectrum. When adapted for bright conditions, the eye is most sensitive to greenish-yellow light at 555 nm. Light with the same radiant intensity at other wavelengths has a lower luminous intensity.

Infrared Thermometer

Tire Pressure Gauge

Lesson 2: Accuracy and Tolerance

In engineering measurement terms such as error, precision, accuracy, tolerance and uncertainty are used frequently and occasionally interchangeably. Yet in metrology, the science of measurement, each of these terms means something different and must be used correctly. Science investigations and engineering projects depend on getting the details right, understanding metrology terms is critical for safe and cost-effective investigations and projects.

When dealing with measurements, "error" means the difference between the recorded measurement and the true measurement value. Error, whether intentional or unintentional, is unavoidable so scientists and engineers design investigations and projects to limit this effect. In the design stages investigations and projects must be carefully explained to help reduce error. All measurement tools have a limited level of accuracy so the chosen measurement tool and units must be properly defined to meet specifications and increase the likelihood of success. This may include the need to specifying the range of acceptable measurements allowed.

No two manufactured objects or parts are identical in every way. Some degree of variation will always exist between measured objects. Tolerance is a word engineers and technicians use to express an acceptable amount of "wiggle-room" for an object's dimensions and allows for certain variations in size. The acceptable "wiggle-room" resulting from the tolerance maintains an object's ability to function correctly due to the variation in object dimensions. There are several different kinds of tolerances that we should be aware of when conducting investigations.

Using an example from our industry, when an oil or gas pipeline is being built pipes must be within a certain tolerance to ensure the pipeline is welded and laid correctly and safely. Achieving

Lesson 2: Objectives

- **Use measuring tools to add 1:1 scale engineering tolerances and dimensions to describe MSTEM Accel Car add-on components**

Content

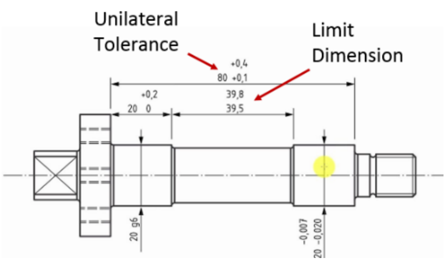
- **Variation and Tolerances**
- **Understanding Fit**

Tolerance - *(noun)* the allowable deviation from a standard

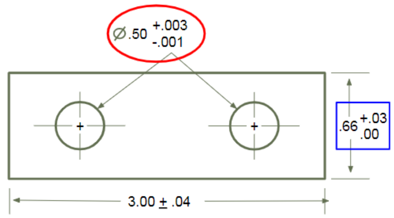
Uncertainty - *(noun)* the range of possible values within which the true value of a measurement lies the acceptable tolerance helps ensure welding will meet the required fatigue design, particularly in stress-sensitive areas and straightness requirements. Getting the tolerance right means pipelines are welded and laid safely and costs are managed.

Variation - *(noun)* a change or difference in condition, amount, size or level

A **Limit Dimension** is a dimensional value that shows the largest and smallest measurements allowed. They describe the acceptable range of variation, i.e. a 1-inch rubber band may be as long as 1.0625-inches or as short as 0.9375-inches. Typically, limit dimensions are placed on top of one another in a part design plan. Any dimension within the two values is acceptable for manufacturing. **Unilateral Tolerance** is a target dimension is given along with a tolerance that allows for variation in only one direction (be that bigger or smaller). The +0.4 indicates that the dimension can allow for variations in size up to +0.4. This suggests that the object may be slightly larger and still function correctly. However, if the dimension is smaller than the stated measurement it will not function correctly.



A **Bilateral Tolerance** is a target dimension is given along with a tolerance that allows for variation in both a positive and negative direction (meaning bigger or smaller). The image to the left illustrates two common ways of writing bilateral tolerances. A unilateral tolerance (blue square) shown as a comparison. If no limit dimensions, unilateral, or bilateral tolerances are written on design plans, then a general tolerance may be applied simply by determining how many values beyond the decimal point any dimension can go before the manufactured part will not function correctly. A general tolerance may also be applied to an investigation to state the acceptable range of data to support a hypothesis or expected outcome.

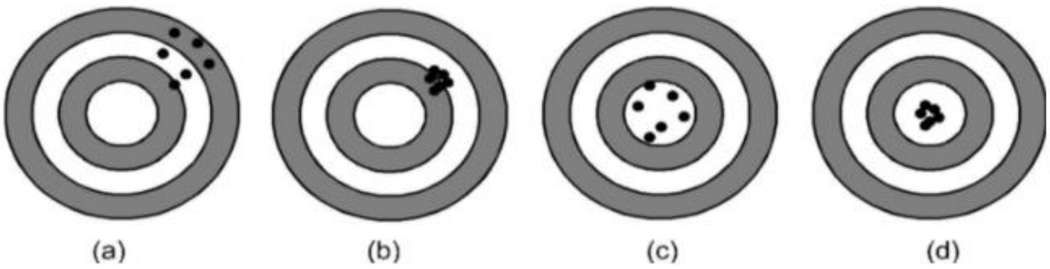


From an engineering point of view, you may have noticed, applying tolerances can determine what kind of "fit" parts have when assembled together.

Clearance fit is when the dimensions have applied a tolerance in such a way that there is always a type of clearance when assembling two parts together. Interference fit describes a fastening between two parts which is achieved by friction (or interference) after or while the parts are pushed together. Transition fit is a compromise between a clearance and interference fit. This type of fit is used for applications where accurate location is important but either a small amount of clearance or interference is permissible.

Accuracy and precision

The terms "accuracy" and "precision" are often used when discussing random and systematic errors. When dealing with measurements "Accuracy" indicates the closeness of a measurement to the true value. However, this cannot be actually measured because of limitations within the measuring tools and the object itself. "Precision" is a description of repeatability and is sometimes used, incorrectly, to mean accuracy. The figure below of target shooting practice illustrates the difference between accuracy and precision.



Target (a) shows inaccurate and low precision shooting.
Target (b) shows better precision but a similarly low level of accuracy. Both target (a) and target (b) show a consistent offset, or bias.
Target (c) is more accurate.
Target (d) is the most accurate and most precise.

Uncertainty is the expression of the level of doubt we have about any measurement. Unlike tolerance, which is specified by engineers and expressed as a value, uncertainty is described in statistical terms. All measurements are subject to uncertainty, since none can be exact, and understanding the level of uncertainty tells us how reliable a measurement is. Measuring tools likewise can never be 100% correct. During an investigation or project's design stages, scientists and/or engineers must define the uncertainty of their chosen measurement system so that it is compatible with requirements the hypothesis or project constraints. Understanding both tolerance and uncertainty means dimensions, data and observations are more likely to be correct.

Lesson 3: Objectives

- **Repeat the 5 phases of the engineering design process as they are applied to the development of the MSTEM Accel Car Chassis**

Content

- **The Design Process**
- **The Scientific Method**

Lesson 3: The Engineering Design Process

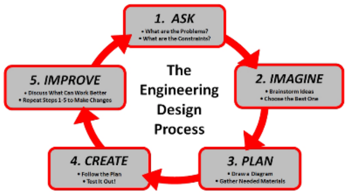
NASA's Engineering Design Model serves as a foundation for applying the principles of engineering into STEM activities, where the goal is to understand that the **engineering design process** as an iterative process used to guide and solve problems. Engineers and scientists working at NASA ask questions, imagine solutions, plan designs, create and test models, and then make improvements. These steps all contribute to NASA's mission success and may be described as follows:

Engineering design is an iterative process used to identify problems and develop and

The engineering design process will be discussed further during the Applied Engineering Design module

- **ASK:** this is the process of identifying the problem, requirements that must be met, and constraints that must be considered.
- **IMAGINE:** brainstorming solutions and researching ideas, while identifying what others have done.
- **PLAN:** choose two to three of the best ideas from the brainstorming process and sketch possible designs, ultimately choosing a single design to prototype.
- **CREATE:** build a working model, or prototype, that aligns with design requirements and meets all design constraints.
- **TEST:** evaluate the solution through testing; collect and analyze data; summarize strengths and weaknesses of the design that were revealed during testing.
- **IMPROVE:** based on the results of testing, make improvements on the design and identify changes needed and justify revisions.

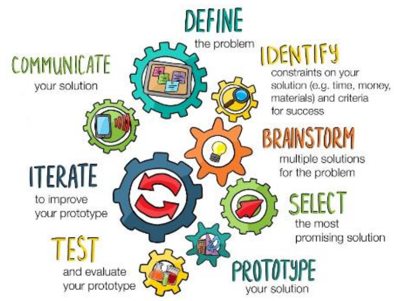
Iterative - *(adjective)* denoting a rule or process that can be applied repeatedly



The engineering design process involves tools and ways of thinking that people can use in almost any situation. Each part of the process reveals information about the problem and possible solutions. The iterative nature of this process includes steps like defining, planning, modeling, and testing, can be completed in different sequences to find the best possible solution. When better understanding requires problem-solving with a purpose that is specific and known, the goal of engineering design is to solve the problem through testing and experimentation.

A comparison between the scientific method and the engineering design process will be done during the Applied Engineering Design module

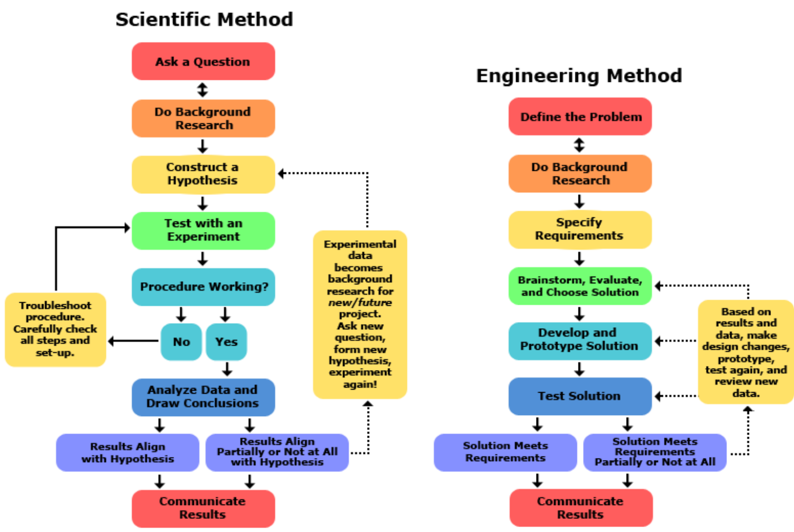
Evaluation is an important part of the process. Solutions have different strengths and weaknesses and have to stay within the physical limits of available time, cost, tools, and resources. Engineers have to choose the solution that provides the most desired features with the fewest negatives. That's why engineering is often called "design under constraint". The engineering design process is usually done in teams, where each member brings different knowledge and experience to the process, which usually improves the results.



Different models of the engineering design process include different "steps", but there are a few skills that anyone doing engineering design is likely to use - and most of these you are already familiar with.

Professional engineers may work on problems that are bigger in scale and complexity, but the basic process for solving them is the same as the ones we will work with during our study of motion, forces, gas laws, electrical circuits and other physical science topics. The difference between planning an investigation of levers and designing a city's water system is simply the amount of specialized knowledge and experience required to solve the problem.

While scientists study how nature works, engineers create new things, such as products, websites, environments, and experiences. Because engineers and scientists have different objectives, they follow different processes in their work. Scientists perform experiments using the **scientific method**; whereas, engineers follow the creativity-based engineering design process.



It is important to keep in mind that although the steps are often listed in sequential order, we will return to previous steps multiple times throughout each project and investigation. Revisiting stages or steps in order to improve some aspect of a project or investigation is often necessary.

Both scientists and engineers contribute to the world of human knowledge, but in different ways. Scientists use the scientific method to make testable explanations and predictions about the world. They begin by asking a question that leads to the development of an experiment, or set of experiments, to answer that question. Engineers use the engineering design process to create solutions to problems. An engineer identifies a specific need: **Who** need(s) **what** because **why**? And then, he or she creates a solution that meets the need.

In real life, the distinction between science and engineering is not always clear. Scientists often do some engineering work, and engineers frequently apply scientific principles, including the scientific method. Much of what we often call "computer science" is actually engineering as programmers creating new products. Your project or investigation may fall in the gray area between science and engineering, and that's OK. Many activities you will do, even if related to engineering, can and should use the scientific method.

However, if the objective of your activity is to invent a new product, computer program, experience, or environment, then it makes sense to follow the engineering design process.

Lesson 4: Prototyping and Modeling

Prototyping is an experimental process where design teams implement ideas into tangible forms from paper to digital. Teams build prototypes that closely model or simulate the real world and capture design concepts for experimental and testing purposes. With prototypes, we can refine and validate our designs so our investigations can provide accurate and valid data.

> *"They slow us down to speed us up. By taking the time to prototype our ideas, we avoid costly mistakes such as becoming too complex too early and sticking with a weak idea for too long."*
>
> *Tim Brown, CEO & President of IDEO*

Many engineers propose that prototyping is the most important step in the design process. It is an essential part of the STEM experience that comes after brainstorming ways to solve an investigation problem. In prototyping, we create a simple experimental model of our proposed solution so we can check how well it meets the experimental requirements and constraints. By considering prototyping from early on we can collect and analyze data that will help refine our working hypothesis and lead to better understanding of the phenomena under investigation.

The advantages of early prototyping are that we:

1. Have a solid foundation from which to ideate towards improvements, giving a clearer picture of the cause and effect aspects of the experiment.
2. Can make changes early, avoiding misconceptions or getting stuck later on.
3. Show the prototype to peers for feedback to help identify pros and cons and determine whether modifications are needed.

Lesson 4: Objectives

- **Identify aspects of the 5 phases of the engineering design process that contribute to the rapid prototype design model**

Content

- **Rapid Prototyping**
- **Modeling Software**
- **Designing to Standards**

Ideate - *(verb)* form an idea of; imagine or conceive

4. Have a model on which to experiment and gain insights into less-obvious aspects of the investigation.
5. Provide a sense of ownership to collected data and results fostering emotional investment into experimental success.

Engineers and designers use the term fidelity to refer to the level of detail and functionality included in a prototype. We can construct prototypes that give a broad view of the entire process or system or one that gives a detailed view of just one feature. The level of fidelity we choose should be appropriate for the assigned task. Interactive prototypes provide a more useful means of collecting data and analyzing observations. Prototyping allows us to test our ideas quickly and improve

on them in an equally timely manner. Most STEM careers encourage building and testing over thinking and meeting.

Prototyping provides a set of tools and approaches for properly testing and exploring ideas before too much time is spent collecting invalid and/or error filled data. Many of us may recall the art of prototyping from our early childhood where we created mock-ups of real-world objects with the simplest of materials such as paper, card, and modelling clay or just about anything else we could get our hands on. There is not much difference between these types of prototypes and the early rough prototypes we may develop at the earlier phases of testing out ideas.

A prototype is a simple experimental model of a proposed solution used to test or validate ideas, design assumptions and other aspects of its conceptualization quickly and cheaply, so that appropriate refinements or possible changes can be made.

Prototypes can take many forms, and just about the only thing in common the various forms have is that they are all *tangible* forms of your ideas. They don't have to be primitive versions of an end product, either—far from it. Simple sketches or storyboards used to illustrate a proposed experiential solution or role-playing to act out an investigation can provide valuable feedback. In fact, prototypes do not need to be full products: you can prototype a *part* of a solution (like a proposed grip handle of a wheelchair) to test that specific part of your solution.

Prototypes are usually quick and rough — useful for early-stage testing and learning — or they can be a fully formed idea — usually for testing or trials near the end of the project or investigation. Prototyping is about bringing conceptual or theoretical ideas to life. All too often, we arrive at ideas without enough research or validation before there is any certainty about the viability or accuracy of our thinking.

We can use prototyping as a form of research even before collecting experimental data, allowing us to explore problem areas and spot areas for improvement or innovation.

Some of the purposes that prototypes fulfil are:

- Exploring and Experimentation - You can use prototypes to explore problems, ideas, and opportunities within a specific area of focus and test out the impact of incremental or radical changes.

- Learning and Understanding - Use prototypes in order to better understand the dynamics of a problem, product, or system by physically engaging with them and picking apart what makes them work or fail.
- Engaging, Testing, and Experiencing - Use prototyping to engage with content, in ways that reveal deeper insight and more valuable experiences, to improve understanding going forward.

One of the most important aspects of making connections between science, technology, engineering, and mathematics is exploring unknown possibilities and uncovering unknown insights. This is the reason the STEM disciplines place emphasis on learning and on activities that increase our learning potential. We can boost action-orientated learning by experimenting and exploring the proposed solutions in order to understand what problems may exist with our assumptions behind those solutions.

Module 2 Activities and Resources

Lesson 1: Gummi Bear Tolerances & Dimensions Activity Sheet

Lesson 2: MSTEM Accel Car Component Dimensions Activity Sheet
Engineering Tolerances PowerPoint Slide deck

Lesson 3: Engineering Design Process Practice Quiz
Engineering Design Process PowerPoint Slide deck
SCAMPER Reference Sheet

Lesson 4: MSTEM Accel Car Design Checklist Activity Sheet

The following is an incomplete list of referenced resources

https://www.homestratosphere.com/types-of-measuring-tools/
https://www.omsmeasure.com/blog/accuracy-tolerance-uncertainty-primer
https://www.nasa.gov/audience/foreducators/best/edp.html
https://www.interaction-design.org/literature/topics/prototyping

The Purpose behind all resources within the hardware store science curriculum is to research the effective integration of STEM subjects into a physical science classroom. All material is organized from outside sources and solely intended to provide the researchers a framework for the development of original content based on experimental findings.

