UNIT 28 SCIENTIFIC METHOD

The scientific method is a framework for conducting scientific investigations. It is a method of systematic enquiry about the natural world. It is an orderly system for learning how to determine the underlying scientific laws from the observed data of an experiment.

OBSERVATION/ FORMULATION OF A QUESTION

The question can be a specific observation, like “why is the sky blue”. It can also be open ended, like “does sound travel faster in air or water” or “how can I design a drug to cure this disease.” This stage of the scientific method looking up an evaluating previous evidence from other scientists.

HYPOTHESIS

A hypothesis is a tentative statement that proposes a possible explanation to some phenomenon or event. The term comes from Greek. A hypothesis is an educated guess or prediction of what you think will happen, based on the knowledge obtained while formulating the question. A good hypothesis takes the form of “if I do this, then that will happen”.

For example “I hypothesize that seeds given an organic fertilizer will germinate faster than those given a regular chemical fertilizer”.

EXPERIMENT

An experiment is an investigation or test that is needed, to prove or disprove a hypothesis. An experiment is a test that is carried out to find a solution to a problem.

Controlled Experiment: It is an experiment testing only ONE factor at a time. It tests the effect of a single variable by changing it, but keeping all the other variables the same. The advantage of this experiment is that you can be more certain about the results of the experiment. For example, if you want to know what type of soil affects seed germination, you take 5 identical pots, with similar bean seeds, amount of watering, and amount of sunlight, all you do is change the soil in each pot. This is a controlled experiment because you keep every variable constant except the soil.

Are all experiments controlled? No. It is still possible to get useful data from uncontrolled experiments, but it is harder to draw conclusions. Let's say, you are trying to find out if a new diet pill helps with weight loss. You try to control as many variables as possible, like what the subjects eat, how much exercise they get. But you will have several uncontrolled variables like age, sex, their individual metabolism, how overweight they were before. Scientists try to record as much data as possible when conducting an uncontrolled experiment, so that they can see any additional factors that may affect their results. Sometimes new patterns can show up, that might not have been observed in a controlled experiment. The new diet pill may work better on females than males. This can lead to a breakthrough, which might not have been noted if the diet pill had only been used on males.

INDEPENDENT, DEPENDENT & CONTROL VARIABLE - When you do an experiment, you test the effect of something. So you can divide test subjects into two groups. One is normal and the other does what jkyou are testing for. So if you want to test whether eating candy makes people fat, then one group (the control group) eats their normal diet. This is the control variable. The other group eats lots of candy. An independent variable is what you are changing (the amount of candy a person eats). The dependent variable is the effect that you are measuring (how fat they get).

1. **INDEPENDENT VARIABLE** - It is a variable that you can control. It is the variable that the experimenter changes or does, in order to do the experiment. For example, in an experiment to check the effect of 8 hrs or 4 hours of sunlight on plant growth, the amount of hours of sunlight is the independent variable.
2. **DEPENDENT VARIABLE**- It is the variable that you observe and measure. You have no control over the dependent variable, you only observe what happens to it when the independent variable is changed. For example, in the experiment studying the effect of light on plant growth, the amount that the plant grows, is the dependent variable.
3. **CONTROL VARIABLE** - Every good experiment needs to control certain variables so that they do not influence the outcome of the experiment. A controlled variable is one that you keep the same for all conditions of the experiment. For example in the previous variables, the type of plant, the amount of water it gets, should be kept constant and not changed. These are the control variables.

OBSERVATION - Observation in science consists of receiving knowledge of the outside world through the 5 senses, or by recording of data using scientific instruments like weighing scales, clocks, telescopes, microscopes, cameras. Observation is one of the steps taken in a scientific investigation.

When we describe an experiment based on our 5 senses or by instruments, it is called an observation. For example "upon viewing under magnification by microscope, the eggs appear bluish and round". Observations are direct enough that most people would make the same observation given the same situation.

INFERENCE

It is important for students to understand the difference between observation and inference. Students should learn to make good observation and inferences and understand the role they play in the development of scientific knowledge.

When we bring past experience into making a judgment, based on an observation, it is an inference. For example "the caterpillar appears as if it is about to form a chrysalis" This is an inference because you are interpreting observations, according to knowledge from past experience. One must be careful not to confuse observations with inferences, when conducting a study

EVIDENCE

In a broad sense, evidence is everything that is used to demonstrate or determine the truth of an assertion. In scientific research, evidence is accumulated by observations or by experiments. This can lead to supporting or rejecting a hypothesis and finding a conclusion.

ANALYSIS

This involves determining what the results of the experiment show and deciding on the next course of action to take. If the experiment has proved the hypothesis false, then a new hypothesis is needed. If the experiment supports the hypothesis, but the evidence is not strong enough for high confidence, then other predictions from the hypothesis must be tested.

CONCLUSION

A conclusion in science states the final findings from the experiment that was performed or the hypothesis. For example you asked a question (hypothesis), then did an experiment and then recorded your results. The conclusion is the “answer to your question, plain and simple”.

COMMUNICATION

It is the key to sharing the scientific method with others. As a scientist, being able to communicate your thoughts and ideas is critical. It is also important to cross check information. If you find a result, it is important that it be confirmed by somebody else. Without communication, your result cannot be reproduced and confirmed by another scientist. Also, science is cumulative. One discovery is often made on the work of others. The purpose of communication

1. Encourage repeated testing
2. Agreement of the scientific community
3. Public understanding

SCIENTIFIC THEORY AND SCIENTIFIC LAW

Words have precise meanings in science. For example, the words “hypothesis”, “law”, and “theory” do not mean the same thing in science.

A **hypothesis** is an educated guess, based on an observation. It can be supported or disproved based on an experiment or more observation.

A **scientific theory** summarizes a hypothesis or a group of hypotheses, which have been supported by repeated testing. If enough evidence accumulates to support a hypothesis, then the hypothesis can become accepted as a good explanation. One definition of a theory is to say that it’s an accepted hypothesis. A theory is valid as long as there is no evidence to dispute it. Theories can be disproven.

A **scientific law** generalizes a body of observations. At the time it is made, no exceptions have been found to a law. It is an absolute rule. An example is the law of gravity. Scientific laws explain things but do not describe them. One way to tell a law and a theory apart is to ask if the description gives you a means to describe “why”.

BRANCHES OF SCIENCE

EARTH SCIENCE: It is the branch of science that deals with the constitution of Earth and its atmosphere**.** It has four sub branches.

1. **Meteorology:** the study of the atmosphere, climate, and weather.
2. **Oceanography**: the study of the oceans.
3. **Geology:** the study of the Earth.
4. **Astronomy**: the study of the universe**.**

PHYSICAL SCIENCE: It is the branch of science that studies non-living systems, in contrast to the life sciences. This is a little arbitrary because there is often overlap between the different branches of science.

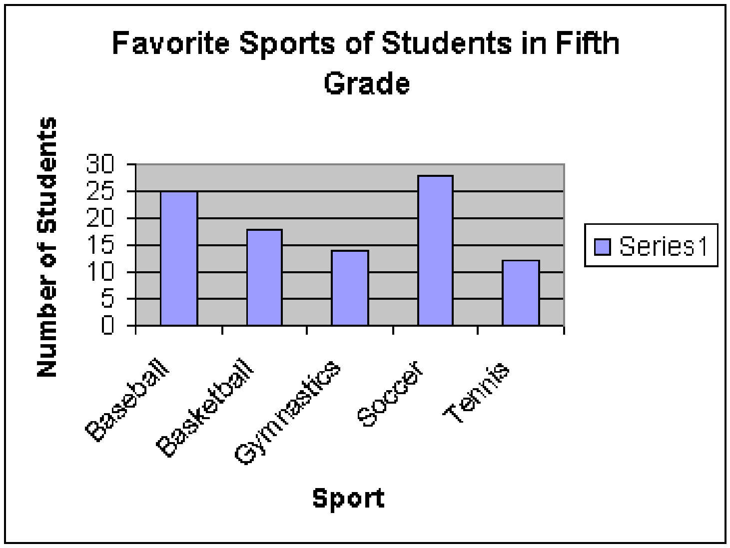
1. **Physics**: it involves the study of matter, along with energy and motion. More broadly, It is an analysis of nature, to understand how the universe behaves.
2. **Chemistry**: it is the science of matter and the changes that it undergoes. The study of matter is also done in physics but chemistry is more specialized. It studies composition, behaviour, structure, and properties of matter, as well as changes it undergoes during chemical reactions.

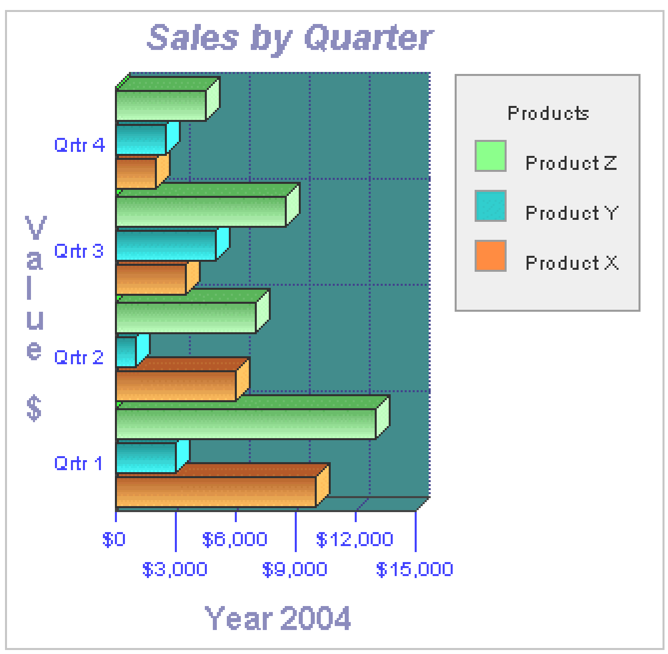
LIFE SCIENCE: It is the branch of science that involves the study of living organisms like plants, animals, and human beings. **Biology** is the branch of natural science that studies life and living organisms; their structure, function, growth, origin, and taxonomy.

1. **Zoology**: it is the study of animals, both living and extinct.
2. **Botany**: it is the study of all plants and plant life.
3. **Human biology**: it is the study of humans and can include sub branches like anatomy, physiology, pathology, neurology, genetics, immunology, opthamology, and much more.

BAR GRAPH

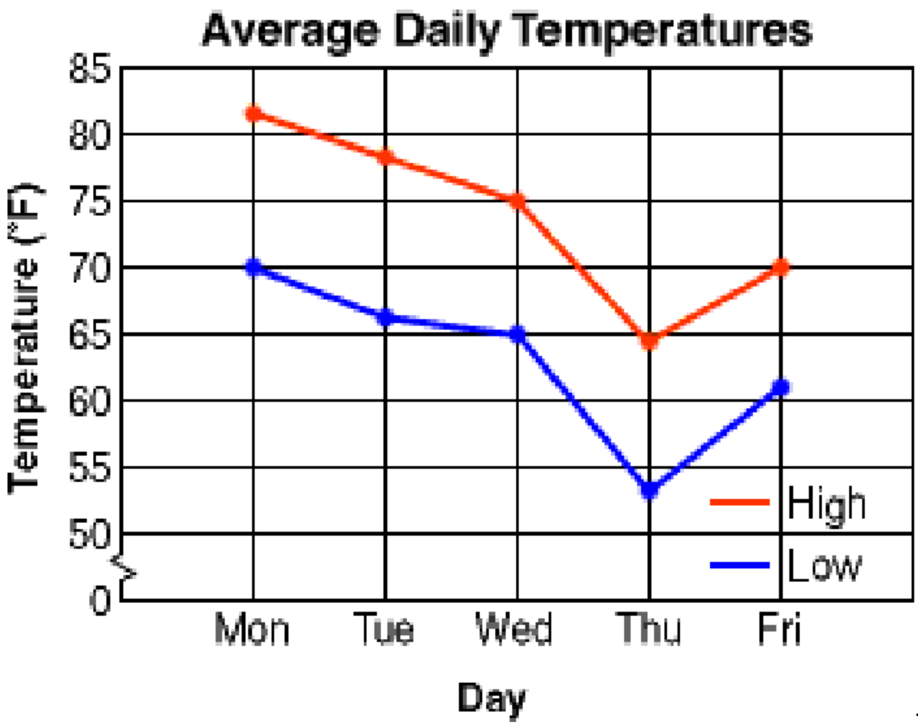
It is a chart with rectangular bars on it. The length of these bars is proportional to the values they represent. In a bar graph the bars can be horizontal or vertical. The greater the height (length) of the bar, the greater is their value. A bar graph compares amounts.





LINE GRAPH

It is a diagram or a graph with lines. These lines connect points. The points represent changes in the value of a variable quantity. The line graph has 2 axes: a horizontal axis and a vertical axis. The line graph displays information as a series of data points connected by straight line segments This graph represents the relationship between 2 continuous variables. It is most useful in showing data or information that changes continuously over time.



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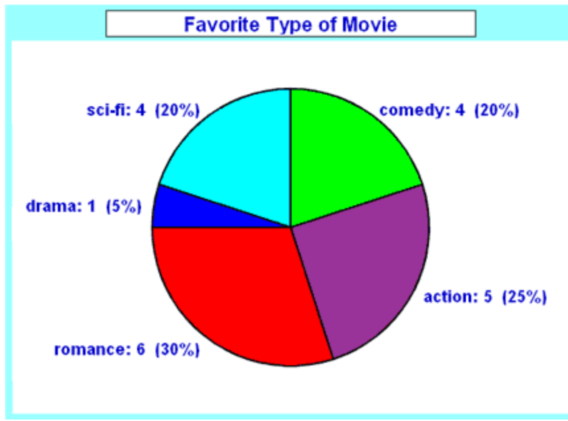
DATA TABLE

A data table is a method of visual communication and a means of arranging information collected. It makes it easier to sort and access information A data table has labeled columns and rows, used to arrange information. It can be used to organize disparate, unrelated data as well as to permit data to be analyzed and manipulated.

Priority EO Data Type	5-year continuity risk	Current key providers (and missions)	Future key providers (and missions)	Predominant Latency Requirement
Optical: Low Resolution	Low	NASA (MODIS) NOAA/EUMETSAT (AVHRR) JMA (MTSAT series)	ESA/EC (Sentinel-3 series) NOAA (NPP/JPSS series) JAXA (GCOM-C series) JMA (MTSAT series)	Hours/Weeks
Optical: Medium Resolution	High	USGS (Landsat-5/7)	USGS (LDCM) ESA/EC (Sentinel-2 series)	Days/Weeks
Optical: High Resolution	Low	USA commercial providers (Worldview, GeoEye)	USA & European commercial providers (Worldview, GeoEye, Pleiades) Airborne operators	Days/Weeks
SAR: C-band	Low	ESA (Envisat) CSA (Radarsat)	ESA/EC (Sentinel-1 series) CSA (Radarsat & RCM)	Weeks
SAR: L-band	No current supply	-	CONAE-ASI (SAOCOM-1A) JAXA (ALOS-2)	Weeks
SAR: X-band	Low	ASI (COSMO-SkyMed) DLR (TerraSAR-X)	ASI (COSMO-SkyMed series) DLR (TerraSAR-X series)	Weeks
Passive Microwave Radiometry	Medium	NASA (Aqua – just concluded) NOAA/DoD (DMSP series) JAXA/NASA (TRMM) ESA (SMOS)	JAXA/NASA (GCOM-W series) NASA (GPM, Aquarius, SMAP) NOAA/DoD (DMSP series) ESA (SMOS) ISRO (Megha-Tropiques, RISAT-3)	Hours
Radar Altimetry	Medium	EUMETSAT-NOAA (Jason series) ESA (Envisat)	EUMETSAT-NOAA (Jason series) ESA/EC (Sentinel-3 series)	Hours
Hyperspectral Imagery	High	NASA (EO-1)	DLR (EnMAP) ASI (PRISMA) METI/JAXA (ALOS-3)	Weeks
Lidar	High	NASA (CALIPSO)	ESA/JAXA (EarthCARE)	Weeks
Ocean Colour	Low	ESA (MERIS) NASA (MODIS) ISRO (OCEANSAT)	ESA/EC (Sentinel-3 series) JAXA (GCOM-C series) ISRO (OCEANSAT) NOAA (NPP/JPSS series)	Hours

CIRCLE GRAPH / PIE CHART

It is a circular chart that is divided and each part represents a proportion or quantity. It is named for its resemblance to a pie that has been sliced. It can be an effective way to display information that compares the size of a slice with the whole pie, rather than only comparing slices with each other.



PICTOGRAPH

A pictograph is a graph that shows information by using picture symbols to represent data /information. The advantage of using a pictograph is that it is easy to read.

MAP PROJECTIONS

Globes are the most accurate way to represent the surface of the Earth. However it is not practical to carry a globe so map makers must figure out how to represent a round surface on a flat piece of paper.

A map projection is a method used to represent the 3-dimensional surface of the Earth on a 2-dimensional surface (map). The creation of a map projection is a mathematical procedure. It involves 3 main steps in which information is lost at every step:

1. selection of a model for the shape of the Earth.
2. transforming the geographical coordinates (latitude and longitude) to plane coordinates.
3. reducing the scale.

Choosing a map projection is a major challenge. Features like size, shape, and distance can be measured accurately on Earth. But when they are projected on a falt surface, only some of these can be represented accurately. Every map has some distortion. The larger the area covered by a map, the greater the distortion.

Depending on the map's purpose, cartographers must decide what kind of map projection to use. There are 3 basic types of map projections: planar, conical, and cylindrical.

www.youtube.com/watch?v=AI36MWAH54s

1. **CYLINDRICAL PROJECTION**: This is the most common map projection. It is like putting a paper in a cylinder shape around the globe. In this projection, the areas near the equator have very little distortion but the areas near the poles are much more distorted. For example, Greenland looks much bigger than it actually is.

2. **CONIC or CONICAL PROJECTION**: This is created by placing a cone shaped paper on the globe. This is more accurate than the cylindrical projection map but the further we travel down, the more distorted and the less accurate it becomes.

3. **PLANE PROJECTION**: This is formed by placing a paper directly above or below a globe. The image that results is called a plane projection. This type of map projection is not commonly used.

4. **INTERRUPTED PROJECTION**: These type of maps try to depict the continents as accurately as possible by leaving blank spaces in the less important areas of the map, like the oceans.

SHAPE VERSUS SIZE: CONFORMAL MAP AND EQUIVALENT MAP

Each map projection must consider two important factors. Which is more important- depicting accurate sizes of things, or accurate shapes. The challenge is that you cannot have both.

Conformal Map: A map which portrays shape accurately is called a conformal map. They help us understand the true shape of things on the map. But it has the drawback that it tends to get distorted, especially towards the top and the bottom of the map. This creates problems with scale. The scale may be accurate near the equator, but distorted near the poles.

Equivalent Map: A map which portrays size accurately is called an equivalent map. Their scale is quite accurate but the shape of objects gets distorted.

Hybrid Maps: By blending conformality and equivalency, we can create a map that balances the distortion of both size and shape. This is called a hybrid map.

FACT VERSUS OPINION

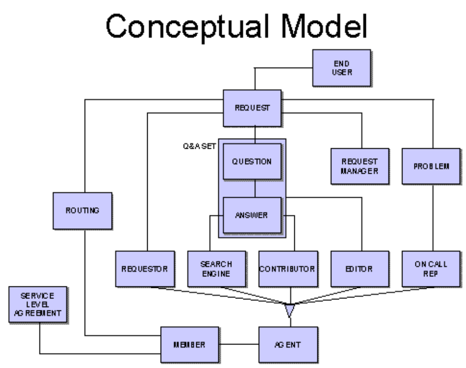
A fact is something that is true about a subject and can be tested or proven. An opinion is what some one thinks about a subject. For example: people must breathe to live is a fact. Blue is the best color is an opinion

MODELS

A model is anything that is used to represent anything else.

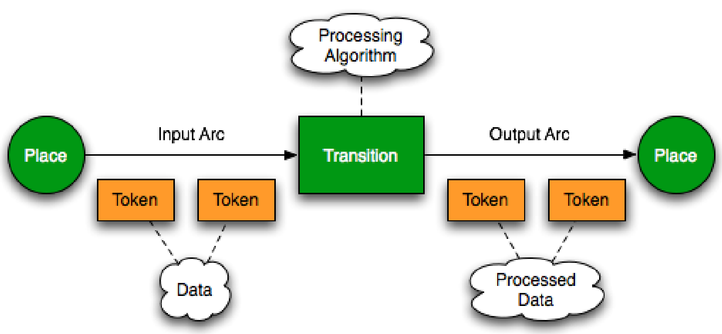
PHYSICAL MODEL: A physical model is a smaller or larger physical copy or replica of an object. The object that is modeled can be small (like an atom) or large (like the solar system). It can be a model of a building. It can be made to move, or have moving parts. A physical model allows visualization, from looking at and examining the model, to information about the thing that the model represents.

CONCEPTUAL MODEL: A conceptual model exists only in the mind. It is used to help us know and understand the subject, or the matter, that they represent. The main objective of a conceptual model is to convey the fundamental principles and basic functionality of the system that it represents.



COMPUTATIONAL MODEL: It is a model that studies the behavior of a complex system by computer simulation. It requires extensive computational resources. The system that is being studied by this model is a complex one for which simple analytical solutions are not readily available. Rather than trying to get a mathematical solution to the problem, experimentation with this model is done by adjusting the parameters of the system in the computer and then observing the differences in the outcome of the experiment.

Examples of computational models: weather forecasting models, earth simulator models to study the effects of global warming, flight simulator models to train pilots, neural network models to study the brain.



ESTIMATION

Estimation is a close guess of the actual value of something. It is an approximation, with usually some thought or calculation involved. For example: Alex estimated that there were 10,000 tulips in the field by counting the rows.

As you walk around and live your life, it would be good if you could easily estimate:

- how much a bill would be,
- which product was the best value for money
- and make other estimates such as lengths and angles
- It would be good if you could quickly guess how many people were in a room, how many cars in the street, how many boxes on the shelf, or even how many seagulls on the beach.

We are not talking exact answers here, but answers that are good enough for your life. In mathematics we often stress getting an exact answer. Estimation is finding a number that is close enough to the right answer. You are not trying to get the exact right answer

Advantages of estimation:

1. **Estimation can save you money**. Always do a quick estimation of how much you should pay. For example, you want to buy five magazines that cost $1.95 each. When you go to pay for them the cost is $12.25. Is that right? *"five at $1.95 each, is about 5 times 2, or about $10"* so $12.25 seems too much! Ask to have the total checked.

2. **Estimation can save you time**. For example you want to plant a row of flowers. The row is 58.3cm long. The plants should be 6cm apart. How many do you need? *"58.3 is nearly 60, and 60 divided by 6 is 10, so 10 plants should be enough."*

3. **Estimation can save you from making mistakes.** For example: you are calculating 107 times 56, and the calculator shows this: 952.00. Is that right? "107 times 56 is a bit more than 100 times 50, which is 5,000". This means that you accidentally hit a wrong key and the calculator answer is wrong.

<u>ACCURACY VERSUS PRECISION</u>

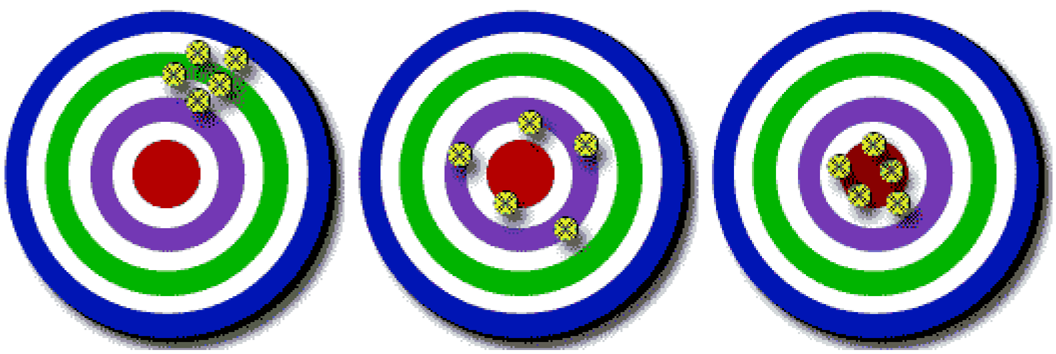
The terms accuracy and precision are often used interchangeably, but in the scientific method they are different.

Accuracy is how close a measured value is to the actual (true) value of that quantity.

Precision is how close the measured values are to each other. It is also called reproducibility or repeatability. It is the degree to which the repeated measurements show the same results.

Example: If you weigh something and get 3.2 kg, but its actual weight is 10 kg, then your measurement is not accurate. In the same example, if you weigh something five times, and get 3.2 kg each time, then your measurement is very precise. Precision is independent of accuracy. You can be very precise, but inaccurate. You can also have accuracy without precision.

Examples of Precision and Accuracy:



Low Accuracy **High Precision**	**High Accuracy** Low Precision	**High Accuracy** **High Precision**

ROUNDING

Rounding a number is when you take a number and “bump it up” or “bump it down” to a nearby and “cleaner” number. It can be rounded up to any place value you want. For example, 4.78 can be rounded up to 5 or 966 can be rounded up to 1000. A number can be round up or down. The result is less accurate, but easier to use.

Rounding is a way of simplifying numbers. For example if you bought a bag for $ 12.96 and a friend asked how much it cost, you might answer “it cost about 13 dollars”.

Why do we round numbers?

1. **It makes it easier to describe and understand**. For example, a newspaper headline says “700 people took part in the race”. There were actually 683, but 700 is easier to understand.

2. **It makes it easier to estimate answers**. For example you are asked “how much did you spend on your sister’s birthday?” You answer “20 dollars”. Though you spent 10.29 and 9.88, you rounded it up to calculate 20 dollars.

3. **To make a guess when the exact answer is not known**. For example you are asked “how long did it take you to get to class”. You answer “about 30 minutes”, even though it may have been a little less or more…you don’t have a stop watch to time yourself.

SIGNIFICANT DIGITS

Significant digits are the digits in a number starting with the 1st non-zero digit and ending with the last non-zero digit. These can be anywhere relative to the decimal.

Examples:

Number	***Significant Digits***
123	3 significant digits ("123")
987600	4 significant digits ("9876")
10001	5 significant digits ("10001")
5.0000	1 significant digit ("5")
5.00005000	6 significant digits ("5.00005")
100000.000000	1 significant digit ("1")
0.00000000001	1 significant digit ("1")
0.00001000001	8 significant digits ("1000001")
1.00000000001	12 significant digits ("1.00000000001")