**How (Human Factors) Science Works for Sixth Graders**

**What is Human Factors?**

Human Factors is called Ergonomics in most of the world, but that really does not matter unless you want to waste a lot of energy and mental moochings looking up a lot of definitions and descriptions. Some people say Human Factors is more about applied psychology and that ergonomics is more about physiology and engineering, but most people have both a body and a brain and these are usually inseparable! Really HFE is about how people interact with technology and their environment, how to design technology so people can use it effectively, efficiently and safely, and how to protect people from those things in our environment that we cannot change, like the sun or gravity.

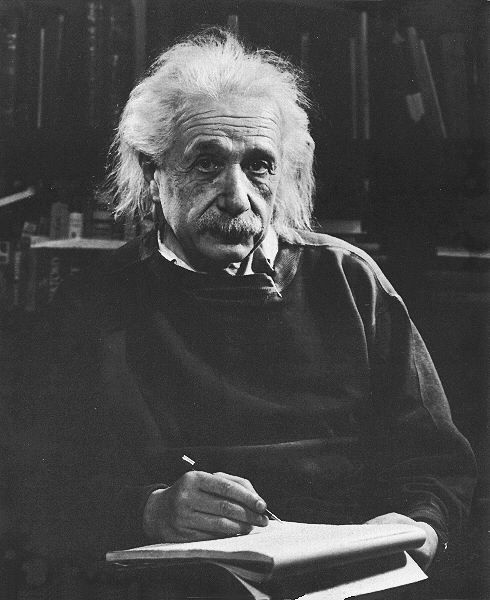
One thing about applied sciences, including Human Factors, that you must remember is that somebody has probably said or done it before, so the first thing you must do is search the library and the Internet to see what other people have already found out. Nowadays you can find lots of human factors and ergonomics ideas and tools in the form of applications (apps) for an iPad or Android tablet. Another thing about human factors science is that it is fun to do it in teams, that way you will get to a lot of answers and generate a lot of more interesting questions.

**People are Different**

In fact, people are quite similar, they mostly have arms and legs and eyes and hearts, and brains and they are quite easily distinguished from a horse or a tree. But when we look more closely every person is different in a lot of ways from every other person, just look at these astronauts. You might like to know that the short lady, Dr Nancy Currie, has a PhD in Human Factors and has flown into space four times.



People vary in their brains as well as in their bodies; if everyone were the same there would be no need for human factors, “one size would fit all.”



* ***Project: Make a list of the number of ways that people are different and similar***

**Charts, Graphs and Statistics**

Because people are different, we need to use charts, graphs, and statistics to describe how and by how much they differ and how similar they are in many ways. First, we need to know why, how and when to use charts and graphs, and other statistical tools.

* ***Project: Make a list of the months in which each member of the class was born, and then make a chart of the number of children who were born in each month. The chart should look something like this:***
* *Project. Make a list of the heights of each student: The chart will look something like this:*
* ***Project: make a list of the weights and heights of each student and draw a graph of weight against height.***

**Applied Physiology and Job Design**

Perhaps HFE is about energy and mental moochings. People are good at dealing with energy. They eat food and work; most of their physical work is countering the force of gravity – every time we walk, we lift our body mass against the force of gravity. If we lived on the moon or on Mars, we would need to eat less because the forces of gravity are less. Another problem we have with energy is that most of the energy we eat in the way of food is converted into heat to keep our bodies at about 360 Celsius. Mars is cold so we would have to use a lot of energy to keep ourselves warm.

* Question: when we go to Mars what are we going to eat and how are we going to keep warm?

How do we know all this? We study Physiology. How do we study Physiology? We measure food and oxygen (which we need to convert the stored food energy); we can also measure heart rate because when we work harder, perhaps by running or lifting loads, we need more food and oxygen to get to our muscles. But when we work harder, we produce more heat, so we measure our temperature and how much we sweat to get rid of excess heat. When we work hard in hot climates it’s harder to get rid of excess body heat so we get tired more quickly or we use shades to protect us from the sun, fans to help with convection or air conditioning to make our environment cooler and more comfortable.

All this measurement stuff needs science which we can do in a laboratory with food calorimeters, treadmills, gas analyzers, thermometers, and heart rate meters. Outside the laboratory we do applied science – converting basic science to practical use. In the world outside the laboratory we use much less sophisticated measures; we have tables of food calories and work calories and we use diaries and checklists and cameras to record what people are doing, and sometimes measure things like heart rate and body temperature or simply ask the person how hard they are working. With all this information we can design real jobs so that people do not get too tired.

Now here is the big challenge for this applied physiology science. When we look at most people, we see that they eat too much and spend most of the time sitting in front of a computer. So, all the spare food energy they eat doesn’t get used and is stored as fat. When we eat too much and store too much fat and do not do enough physical work our hearts and blood vessels get clogged up and we may get diabetes. So, the biggest challenge for applied HFE science today is how to solve the problem of sedentary work.

* Question: Should we make a law that everyone has to run five miles a day.
* Applied Science Projects:

1. Keep a diary (every hour) of what you eat and what you do (physically) for a week. You may also record your temperature and your heart rate. Use a scale of one to ten to rate your physical effort. Look on the Internet for tables of food calories and work calories. Do you eat too much or too little?
2. How much food do marathon runners need?
3. How much rest do building site workers need?

Another physiological problem for Human Factors is shift work. We get used to working during the day and sleeping at night. But there are a lot of jobs that need doing 24 hours a day, such as police, electricity generation, hospitals, transportation, and manufacturing. So, we arrange shift work cycles. The problem is that our bodies need time to adapt to these changes so the cycles must either be very long (like a month) or noticeably short (like two days).

* Project: Ask your friends and parents if they know anyone who does shift work. If they are agreeable you should interview them about their shift schedule and the problems that they face with shift work.

**Anthropometry and Workplace Design**

A problem with sitting around all day is that we must design chairs and desks and other things in our workplaces to suit the shape and size of the people who may use the workplace. If everybody was the same size and shape, then we would not have to do this. One size fits all? Not really. But what about the furniture in the restaurant, the football stadium, the theater, or the bus? There are big people and little people, adults, and children. Anthropometry is about the measurement of the variability of body size and shape. The description of variability needs us to understand the science of mathematics and statistics. As you grow up, every birthday your parents stand you against a door frame in your home, place a book flat on your head and measure how tall you are. Sixth graders often get growth spurts; you can almost see them grow. Now people are fairly similar in their proportions; tall people usually have long legs and small people usually have small hands and feet. So, it is possible to use a chart to predict the length of body segments from their total height. If you want to be more precise you need to use body weight to predict widths and girths. If you want to be really accurate then you use tape measures and calipers to measure segment lengths and width and girths or you can even use body scanners. The suits worn by astronauts are designed by using body scanned information.

If we take a lot of these measurements from a lot of people we usually find that the measurements can be described by a bell shaped curve – there are a lot of people around average shape and size and fewer smaller and larger ones. It is fun to ask all your class members their heights and make a graph on the white board. Or if you want to be scientific you can use a spreadsheet on your computer to record the measures and draw the graphs. Then you can learn about statistics and averages and percentiles and all those wonderful mathematical ideas.

Once you have these data from what we call a sample or a population, we can then use it to design chairs and desks and workplaces for reach and fit. How high should a chair be so that most of the intended users can reach the floor without getting a pain in the back of their leg? How high should the underside of the desk be so that the bigger people can fit their knees under it comfortably? You should use the data you got from your class to check whether your workplace is suitable or not. Because we cannot afford to make a personal workplace for everybody, we perhaps should use adjustable furniture, but that again costs more money.

* Applied Science Projects:

1. Record the shoe sizes of everyone in your class. Draw a graph of the numbers of each size. Find the average and the range (biggest and smallest). Do boys have bigger feet than girls?
2. How much adjustability should there be in a car seat so small parents can reach the pedals and see over the steering wheel, and tall parents can sit comfortably?
3. How wide should the seats be on the school bus?
4. Can you design a workplace that allows you to sit, stand or lean?

**Biomechanics and Force Exertion**

Many jobs require us to lift, hold, carry, push, or pull things. We have to lift and carry our school bags; we have to push the pedals on our bicycles, we have to open and close doors, we kick footballs and throw basketballs, we have to carry or pull our luggage. Did you every watch the men from the sanitary department lift your recycling bins? Some people on farms and in mines lift very heavy loads all day long. Think about the UPS or Fed Ex driver.

* Question: What is a moment? It is weight times the length of the lever arm.
* Demonstration: Pick up your backpack; now hold it out at arm’s length.
* Questions:

1. Why is there a handle on a hammer or a wrench?
2. Why is the door handle a long way from the hinge?
3. How does a screwdriver work?
4. How does a crane work?
5. How do the gears on your bicycle work?
6. Why do ballet dancers or ice skaters move their arms in and out when they spin around?

Analysis of manual materials handling jobs requires us to understand muscle strength and endurance, and fatigue. Like most science however there are already lots of answers. We can apply the NIOSH lifting guidelines and the Liberty Mutual Push and Pull Tables, so that we can analyze all sorts of manual materials handling and similar physical jobs and design them to be within the capabilities and limitations of the expected workers.

* Question. If we select a teacher because she or he passed some exams in college, should we select manual workers by having them take a lifting test or should we re design the jobs so most people can do them?

In the laboratory we can measure peoples’ strength with dynamometers and lifting, hand grip and push pull and pinch gauges. Just like in anthropometry we can make graphs of the strength of samples of people, such as your class, and calculate averages and ranges and percentiles. In the Olympic Games we measure strength in weightlifting and shot putting and discuss throwing. But these activities need skill as well as strength.

* Questions and Projects:

1. Who is the strongest person in the class? Have an arm-wrestling competition. No cheating!
2. How much force do you need to open a soft drink can or bottle, or a medicine bottle or packet of chips? How can these be designed so that only the right person can open them?
3. How heavy is your backpack? What is the length of the moment arm around your hips? Why do you need to carry so many books?
4. Why are bigger people usually stronger than smaller people?

**Motor Skills**

People vary a lot in their abilities to do tasks like typing and assembling products like cars and cell phones. Some children are good at games like football and baseball while others prefer other pastimes. Skill needs a mixture of strength, agility, and control, which comes from your brain. A neat think about skill is that it improves with practice. You become faster and more accurate if you repeat an activity over and over again. Sometimes it is possible to measure improvement over years. One thing about skills is that more difficult or precise tasks take longer to do than simpler ones.

* Project: It’s fun to measure skills with a pencil and paper. Draw two circles, an inch in diameter, three inches apart. Place 10 dots with a pencil alternately in the two circles and record the total time taken. Next make circles of smaller diameter at various distances apart and repeat the exercise. When you analyze the data you will find that smaller, further apart targets take longer than larger and closer targets This skill was measured by a famous Human Factors Expert, Paul Fitts, who described the Index of Difficulty at log2 (W/2A). Another scientist from Holland (J R de Jong) showed that performance improved with the logarithm of the number of repetitions.

These scientific observations are enormously important in industry, especially assembly lines for making cars, computers or cutting up chickens to send to the supermarket. The people who work on these assembly lines do the same task over and over again, sometimes as often as every 5 seconds. They become very skilled with practice, but their tasks can become much easier if the targets are made bigger.

* Applied Science Projects:

1. How long does it take to disassemble and then reassemble a ball point pen? How would you lay out a production line for ball point pen assembly so that movement distances are small and target sizes large? How would you design jigs and fixtures to make the assembly operation easier? If your company needed to produce 5000 ball point pens a day, how many employees would they need?
2. Look at your family car and discuss with your friends how it is assembled.
3. How long does it take to mend a puncture on your bicycle tire?

**Vision**

Most of the things we do need vision to take in information, brains to sort out the information and hands to do things. So, if we don’t get the right information in through our eyes then we are stuck. Try walking to the door of the classroom with your eyes closed! Do not try eating your dinner with your eyes closed! Just like all human anatomical features eyes are very complicated and there are many differences between different people’s eyesight. Eyesight is very important for reading, driving, flying airplanes and looking at all those dials and gauges and computer displays in a nuclear power plant.

Eye Anatomy: go to the internet and search for Eye Images – there are lots of them, mostly they are shown as cross sections. You can find the lens and the iris and the retina and the optic nerve which takes light images to the optical cortex of the brain for interpretation. You should also look for information about rods and cones and about night and day vision. You should especially look for stuff about color vision.

* Applied Science Projects:

1. Sit at your desk and have a friend hold up a newspaper 10 meters away. Write down which words you can read. Have him move towards you one step at a time pausing while you write down the smallest words you can read. When you have finished, measure the height of the letters, and draw a graph of the letter size and the distance from which it can be read.
2. Calculate the (subtended) visual angle of each letter size at each distance
3. Repeat the exercise with different amounts of light in the room (anyone with an iPad can download a light meter app)
4. If you wear glasses, try the experiment with your glasses off. How do glasses work?
5. Compare your graphs with your friends and talk about individual variation and the effects of ambient light on visual acuity

**Knobs and Dials (Controls and Displays)**

When we make machines like cars, computers, televisions, ovens, cooktops, room lights and all sorts of industrial equipment, the operator is usually interested in what he or she can understand about what is happening and about how changes in the activity of the system can be made. These “human – machine control tasks” need displays and controls. It is important that the displays provide useful and clearly readable and understandable information and that the design of controls (the buttons, knobs and levers) make it easy for the user to control the equipment quickly and accurately. If the displays and controls are not designed properly then users may make serious mistakes that may have catastrophic consequences.

* Projects:

1. Design the controls for a crane.
2. Look for Images on the Internet for Three Mile Island and The Airbus A 380. Just look at all those displays and controls. It takes a lot of training and practice to understand all this information and control the process or vehicle accurately. In the case of the Three Mile Island nuclear plant, the operator was overwhelmed with information in a short period of time resulting in a serious nuclear incident.
3. Look at all the displays and controls in your family car. Ask your parents what each of them do and the driving situation when each control or display in important
4. Look at the switches in your classroom and on your teacher’s desk. Which light switch turns on which light? Do you flip the switch up or down for on? Why?
5. Now look at the oven and cook top at home. Which control turns on which burner? Do you turn the knob clockwise or counterclockwise for on and to increase power? Which way do you turn your faucet for on and to increase the flow of water? Why are these conventions different?
6. Now look at all the air conditioning, TV, video, computer, tablet PCs and smart phones in the house. Describe the displays and controls.
7. Which is better for sending text messages – a keyboard with “hard” buttons, like a Blackberry or one with “soft” touch buttons like an iPhone? Have a competition in class to find out the answer. Type: “THE QUICK BROWN FOX JUMPED OVER THE LAZY DOG.”

**Human Information Processing**

If you look in one ear of your classmate and wave your hand on the other side of his head, can you see through? If not, then he probably has a brain. Now brains are useful for human information processing. There are many stages of this especially important function.

First there is attention; if you do not pay attention to a visual or auditory message then you will not be able to start your information processing activities. The problem with attention is that it is easily distracted, and everybody becomes less attentive to a particular source of information as time passes. This is called vigilance decrement. Does your teacher often have to tell you to pay attention when you are distracted and looking forward to recess or lunch? What if a car or train driver or a pilot or a power plant operator gets distracted? Crash!!! The thing about attention is that it is usually attracted to important, interesting, and intense sources of information. A big bang may suggest that something important happened, so you had better pay attention.

Question: Is talking to your friend more important than listening to your teacher? Are some classes more interesting than others? How can teachers maintain the attention of the class?

* Applied Research Projects:

1. Have three people talk to you at once then ask you questions about what they said. This is the problem of Divided Attention. Describe some common divided attention tasks.
2. Watch the second hand of a clock intensely and make a mark on a piece of paper every second. See how long you can last, say about two minutes. When you have finished count how many marks you have made and compare with the number of seconds that have actually passed. This is called Focused Attention. Describe a task where focused attention is important.

**Long Term Memory and Perception**

People have enormous long-term memory capacities. They can remember all sorts of facts, procedures, meaning of words and symbols, where things are, what things do and so on. They can even remember things about their families, teachers, and friends. They read books and watch TV and remember what they were about.

* Applied Science Projects:

1. Write down as many things that you can remember in five minutes
2. Look at your list and group and link the items
3. Make a mind map of all your memories, groups and links

When we attend to things, we must have a framework in long term memory so that we can perceive and understand what we see. For example, we recognize an apple as something to eat or a name as a person we know. So, the process of perception involves some external (or internal) item, attention and a framework from long term memory. As we learn these frameworks become much better defined. One problem with perception occurs when the image that we are attending to does not fit in neatly to the framework. Sometimes we see what we expect to see rather than what we actually see. This is called an illusion.

* Applied Science Projects

1. Look on the Internet for “illusions”. Explain what you see and why your framework and expectancies cause misperceptions
2. Why can’t you understand the meaning of speaking or writing in a foreign language?

**Short Term Memory**

Short term memory is sometimes called working or operational memory. It is the link between long term memory, attention and perception. Short term memory has a limited capacity – we can only remember a few things at a time, although we can keep things in short term memory by rehearsing them.

* Applied Research Projects:

1. Write down lists of between 3 and 10 digits. Show a list to a classmate for a few seconds and have him or her write down the numbers. You will notice that as the list gets longer more digits are forgotten. You may also notice that digits in the middle of the list are more likely to be forgotten that those at the beginning or end.
2. Write down a list of three letter words, such as the names of animals. Jumble up the letters in each word and show them to your classmate for a few seconds and have him or her write them down. Next show your classmate the unjumbled original words and repeat the exercise. You will notice that his or her memory for the “meaningful” words is better than that for the jumbled letters. The explanation is that the words become chunks of information and short-term memory handles these chunks as a single item.
3. Now tell your classmate a set of instructions of how to get to your house and have him or her repeat the instructions back. Observe the errors.
4. Repeat this exercise with other sets of instructions, such as how to bake a cake or how to mend a puncture. Note the mistakes they make. It is always a good idea to write down instructions then you don’t run the risk of forgetting.
5. Read a piece of poetry to your friend and have him or her repeat it back to you. Then repeat the activity, back and forth, until he or she gets it right. The poem is now remembered as a chunk.
6. Repeat all these short-term memory exercises but distract the receiver with other (similar) information during the retention period. Discuss the effect of “interference” on Short Term Memory

**Decision Making**

Often we have to make choices between alternatives such as what to eat for lunch, which game to play on the computer, which is the correct answer in a test, or whether to do our homework or play with our friend. Other simple decisions are whether to call heads or tails when our friend tosses a coin or which investment to buy (ask your parents about investments). A complicated driving decision is whether to stop or go when the traffic light turns amber and you are very close to the intersection. All these decisions have two things in common – what is the chance or probability of being right and what is the benefit of being right or the cost of being wrong? Often, we must make decisions quickly without time to consider all our options fully.

When we make decisions, we pay attention to the available information, link this to other information in our memory, add in the desirability of being right or the fear of being wrong and then we make our choice. The big problem with decision making is that there may be a lot of uncertainty and our operational memory may not be very good at weighing all the options, so we make our best guess.

* Applied Research Projects:

1. Describe your decision of what to choose for lunch. Why did you make that choice?
2. Toss a coin or play scissors, paper, stone with your classmate, record who wins the most out of ten or twenty rounds. Explain the chance of being right or wrong on each round. Explain why you made certain choices.
3. Decide where you would like to go for a holiday if you had $1000 to spend. Explain your choice.

**Judgment**

Often, we need to use subjective judgments to make decisions, when all the facts are not available. Judgment is easy when the choices are very distinct, but difficult when the choices are very similar. The science behind subjective judgment is called psychophysics (Psychology and Physics). Some famous researchers a couple of hundred years ago, called Weber and Fechner, studied how people made subjective judgments about physical objects or quantities. They showed that the accuracy (and speed) of judgment was related to the logarithm of the physical difference between the object or quantities.

* Projects:

1. Get a pile of books of different sizes. Have your partner close his or her eyes and place a book on each of their hands. Have them tell you which book is heavier. You will notice that as the pairs of books become more similar the subject makes more errors in judgment.
2. This demonstration can be repeated with all sorts of physical quantities like the lengths of pieces of wood, the colors of denim, the brightness of lights
3. Now think about salaries. If someone earns $100,000 dollars a year, they are much richer than people who earn $50,000 dollars a year. But what about the difference between two Basketball players who earn $2,000,000 and $1,000,000? They are both very rich!
4. Now think about the distances between Atlanta, Phoenix, Chicago, St Louis, New York and Los Angeles, or London, Lisbon, Paris, Berlin, Madrid, Athens. Which pairs of cities are the closest and which are the furthest apart?
5. Sometimes judgment of differences is made on more complex features of objects, or people or events. How do you judge which is the best gymnast or painting? Pretend to be a judge on American Idol. You can listen to the song, watch the singer without listening or both watch and listen. Do you think that your judgments would change? You can actually do this experiment.

**Decisions Take Time**

Simple reaction time requires you to hear a signal then make a response. For example, your parent sees the traffic light turn to amber and they react by putting their foot on the brake. People vary in their reaction times.

* Demonstrations:

1. When your teacher drops her hand, everybody should clap their hands. You will notice that some students react more quickly than others. With practice, like a well-trained orchestra, you will all clap together. Simple reaction time takes about a fifth of a second, but you have to remember that movement time plus reaction time equals response time. Now you should add choices into your reaction time game – When your teacher drops her right arm you clap and when she drops her left arm you stamp your foot. Again, you will notice variability in reaction times, and some will make the wrong choice. Now when the teacher drops both arms the class should shout “Hurray”. Finally, when your teacher jumps up and down you should clap your hands, stamp your feet and shout “hurray” at the same time. Chaos!!
2. In the Olympic Games sprinters win or lose by split seconds so it is especially important for them to react to the starting gun quickly. The problem is that some runners use anticipation and react too quickly, so a false start is called. A mechanism to detect a false start is a force gauge in the starting blocks which automatically signals a false start if the runner’s reaction is less than 100 milliseconds.
3. Get a pack of playing cards and record the time it takes for you to sort them (face down) into two piles. Now turn the pack over and sort them into reds and blacks. You will note that the added decision time of deciding whether a card is black or red makes the whole task take longer. Next (shuffle the pack) and sort them into Hearts, Clubs, Diamonds and Spades. This more complicated decision task will take even longer.

We make decisions all day long and difficult decisions take a lot of time. Sometimes these decisions are not simply yes and no, they involve adjustments to all sorts of controls. Think about flying an airplane. You must control your altitude, direction and airspeed by adjusting your yoke, pedals and throttle. You must also coordinate all these control responses so that you make neat turns and soft landings.

**Mental Workload and Situation Awareness**

In complicated tasks like driving or flying or performing a surgical operation it is necessary to take in information from many sources and make extraordinarily complex decisions, often with time stress. When your mental workload gets too much you make mistakes. Also, you lose “situation awareness” – the ability to detect, understand and predict the future state of the system you are controlling. The challenge for human factors specialists is to analyze these tasks and design the controls and displays to aid the controller in his or her decision making. Sometimes it is useful to have different members of a team share the tasks, mental workload, and decisions.

* Project: Download Google Earth on to your computer, Select Flight Simulator from the Tools menu and learn to fly. It is easy; all you need is a lot of practice. As you learn and make lots of mistakes think about your mental workload and the causes of your errors.

These are just a few examples of Human Factors / Ergonomics Applied Science. There are many more examples on the Internet and lots of books in the library. It is an interesting and challenging profession; you should learn more about it.

Now go to: <https://sites.google.com/site/educationbyentertainment/human-capabilities-and-limitations> you will find many more Human Factors games there