Engineering Design vs Scientific Method

While scientists formulate testable theories that answer the question “why”, engineers formulate steps to address the question “what” or “how”. Often the overarching goals of scientists and engineers are the same; however, the approaches are different. Scientists perform experiments using the scientific method; whereas, engineers follow a creativity-based engineering design process. Both processes can be broken down into a series of steps, as seen in the table below.

The Scientific Method	The Engineering Design Process
State the question	Define the problem
Research the problem as well as any existing solutions or attempts at solutions	Research the problem as well as any existing solutions or attempts at solutions
Formulate a hypothesis, identify variables	Specify requirements a. Define the problem by gathering needed information b. To be a requirement by definition it must be verifiable! For example, “Go to the Moon” is a requirement, “Go Fast” is not.
Design experiment, establish procedure	Create alternative solutions, choose the best one and develop it
Test your hypothesis by doing an experiment	Build a prototype
Analyze your results and draw conclusions (if hypothesis is not true or partially true, re-formulate hypothesis)	Test and redesign as necessary; determine if the design specifications have been met, if not loop back to one of the previous two steps
Communicate results	Communicate results reports, plans, and specifications

Keep in mind that although the steps above are listed in sequential order, you likely return to previous steps multiple times throughout a project. It is often necessary to revisit stages or steps in order to improve that aspect of a project.

Why are there two processes?

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. A scientist asks a question and develops 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.

Which process should I follow?

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 – programmers creating new products. A project may fall in the gray area between science and engineering, and that's OK. Many projects, even if related to engineering, can and should use the scientific method. However, if the objective is to invent a new product, computer program, experience or environment, then it makes sense to follow the engineering design process.

Notes on Statistical Considerations:

Statistical analyis is an important part of experimental design and experiments are made up of several trials. These trials may have different results, but you should evaluate the validity of your hypothesis based on average performance (mean) of variables within your experiment. It is unlikely that your hypothesis will be true 100% of the time, but are you able to prove that your hypothesis is true *on average* a certain percentage of the time? This percentage is referred to as your *level of significance (α).* An example for level of significance is the following: "One application of Disinfectant A prevents 99 % of bacterial growth ($\alpha = 0.05$)." In this example the level of significance is 0.05, which means that in order for this statement to be true, it must be valid 95% of the time. Don't be confused by the 99% in the hypothesis. This percentage is only a measurable value that allows us to evaluate our variables. The key to thinking about level of signicance is to consider how confident we are that the hypothesis is true when our experiments say that it is true. Therefore, 95% can be thought of as our confidence level (i.e. "We are 95% sure we are correct in saying this hypothesis is true").

You can also imagine that since we are evaluating the average performance of our variables, it is important to conduct enough experiments to ensure that the average value we report is truly an average (and not just one or two observations that may or may not be representative of the situation). Think about it like this. Let's say that you are taking a class that only has two exams, a midterm and a final. You really enjoy the material and you have a good understanding, however, on the day of the midterm you have the flu and you score poorly on the exam (50%). But because you really do enjoy the material and understand it, you later score a 100% on the final exam. Your average score for the class would be 75%, even though you may feel that your final examination score and your overall understanding of the course material does not reflect a C-level grade. You may feel in this case that you would have benefited from more assignments that would contribute to your average and give a better picture of your true level of understanding of course material. This scenario illustrates the importance of having a proper *sample size*, or number of trials/experiments, to ensure that your average value is truly indicative of the results, and that one bad trial does not heavily skew the outcome. Determining the proper *sample size* can be calculated through conducting a *power analysis* of your experiment. The way that a *power analysis* is conducted is outside the scope of this introductory research experience, but it is an important concept as you begin to design and conduct your own research experiences.