The “Scientific Method” and your required paper.

So you have to write a paper based on research and/or your own experiment that has an introduction, material and methods section, statistics, conclusion, etc.? What’s that all about? Well, parts of it can be understood better with the following discussion of the scientific method. Some requirements would be better understood by reading an existing “professional” research paper- if you can accept that you need to imitate some of its characteristics. Some of the requirements you have may be better understood if you realize that sometimes it’s just hoop time. Some of it is just science fair biz.

First, check out but don’t memorize (unless you can’t help it) a couple of standard definitions of the “scientific method”:

From a dictionary:
“-principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses”
Find another one on the Internet.

It is recommended (by someone, surely) that you go to the Internet and read two or three definitions/discussions of the scientific method to amplify and clarify these points and find other implications. Some of these ideas are:

1. The <u>four steps</u> of the scientific method- observation and description of phenomena or a phenomenon, form a hypothesis of cause and effect perhaps with a math model, make predictions of results of new observations, and perform experiment(s) to test the hypothesis and its predictions. Several independent experimenters should do this last step (real world). Note: It would be cool if your work were interesting and/or important enough to cause someone else to want to repeat it. At that point you’d be on your way to a theory. Usually graduate students working under a PhD who has claim on the hypothesis hold this sort of interest as part of their implicit job description!

2. A hypothesis must have power to make predictions that are testable. A hypothesis can never be proved, only disproved. This sounds questionable and seems based on statistical terminology- more about the hypothesis and its “null” will occur on down the page.

3. Measurements must have quoted error, whether random or systematic (unidirectional bias) error.

4. A hypothesis or theory may have a limited range of validity such as is the case with quantum, Newtonian, and relativistic physics.

5. Most experimental scenarios require a "**control**", usually a group or sample which is in every way like the group or sample being treated with the proposed causal factor except for that factor only (ceteris paribus). For example, if one is "proving" that "Bush bean plants fertilized with Tide with Bleach will grow taller...", there must be one batch of the same variety as the tested batch(es) that receive the same soil, temperature, light, water, etc. as the test group minus the Tide. Otherwise, how could a comparison be made? Sort of common sense, isn't it? But you'd be surprised.

6. The scientific method guides research and experimentation to explain the "how" and cause and effect of phenomena. The "why" is not addressed.

7. Observations are made objectively, devoid of any effects of preconceptions.

8. Acceptability of results (like of your scientific study and paper) is based on the **degree to which observations and experimentation can be reproduced**.

9. Bacon's approach was to make observations and collect a lot of data to derive a hypothesis or explanation of cause/effect - <u>inductive</u> reasoning. Descartes said to start with the clear idea or hypothesis first and then support it with sufficient data- <u>deductive</u> reasoning. Of course, it's <u>usually not purely like either</u> one of those alone. The way it usually goes is-start with a hypothesis based on past experience or casual observation, do some data (experiment), see that your theory doesn't work or doesn't exactly work, revise your theory to fit the observations, attempt verification by experimentation/data gathering (the old data would of course fit the revised hypothesis), repeating the cycle until you get a warm feeling that others could repeat your experience or until you tire of it all and go on to a higher calling.

But don't worry. You won't have to go beyond the first cycle here. Were you on a long-term government grant, you could work on the repeat cycles to build your credibility and eventually hope to have your hypothesis turn into a <u>theory</u> with your name on it.

10. Every effect is assumed to be linked to a cause. Ha! Try that on some individual human behavior and you will see why psychology is often termed a pseudo-science. Some would argue that there is always cause but that it is simply not discoverable.

11. Unfortunately and perhaps not fairly, the perceived validity of your hypothesis may depend on its consistency with other aspects of the scientific framework, like

other established theories, which themselves may ultimately prove to be faulty. Let's not get in any deeper on that.

12. Many of the greatest and most useful scientific discoveries have been made by accident, often during legitimate scientific research. This is called serendipity.

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Now let's talk hypotheses.

For most scientific experimental work, a proper hypothesis will be a succinctly and carefully worded statement of cause and effect of a phenomenon. This (your) hypothesis will be called the alternate hypothesis or simply your hypothesis and will be matched with a "null" hypothesis, the antithesis of your hypothesis.

The wording of your hypothesis will be led from and/or will lead to your research design and is often difficult to make logically robust, much less bullet proof. For example, let's revisit the bush beans to be fertilized with Tide with Bleach. After the above discussion of the control group, valid questions would be like "grow taller than what?" and "how much Tide per plant" and even many other details of the experimental procedure. These details should be covered in the "Materials and Methods" section of your paper. You can now see how important this section would be for someone else to verify your experimental results. The hypothesis won't cover the details but should be, for example, "Bush bean plants will reach greater mature height with the addition of a household detergent to the soil in which they are grown". The null hypothesis would be "Bush bean plants will not...". Notice that the hypothesis and null hypothesis together cover all possible outcomes of the experimental research. Otherwise, you would need one or more additional alternate hypotheses to close the set of all possible outcomes. You most likely will not use additional alternate hypotheses in your ISEF project.

For some engineering projects (The E in ISEF is for engineering), the hypothesis if required will be simpler and trivial, like "A device for astral travel can be constructed with kite string and rubber bands". For this project the null hypothesis is "A device for astral travel cannot be constructed with kite string and rubber bands".

In the parlance of statistics for scientific research projects, the conclusion will be either "Reject the null hypothesis and accept the alternate (your proposed) hypothesis" or "Cannot reject (or Retain) the null hypothesis and reject the alternate hypothesis". It would be reaching to assume that the failure of your endeavor would prove the impossibility of astral travel contrived from string and rubber bands. The null is not proven.

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Research design in brief-

The research you propose for yourself should be feasible, like doable within the most conservative range of expectation (pretty easy).

There are many fancy terms for research design flaws, but all of them involve violations of common sense. If research involves polling, for example, it is difficult to find and poll an unbiased portion of the intended population and to word the survey so as to avoid misinterpretation or bias. Most of the problems with other types of research with controls are those of missing or not accounted for causative factors introduced into the experiment. Effective research often requires keen thought, awareness, and vigilance. Keep it simple and you may have a chance at not embarrassing yourself at presentation time.

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Why third person passive for your paper? - to remove any intimation of personal bias and to save changing your final paper which is written after the research is completed. You're not actually lying when you say in your rough draft that something "was" done when it hasn't been, after all! Somehow a politician might consider a variation of this argument. Your writing teacher may have other reasons.

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What about this MLA citation (vs. APA, Chicago style, and maybe others)? MLA citation is probably what you will be asked to use in your paper. It is best learned and even better mimicked by example for each kind of source. There are books, articles on the Internet, and even software like Endnote, Citation, and Procite should you decide to do this for a living or would just like to play with them. Some like Biblioscape will help you with citing electronic research. Find sources on the Internet under "electronic research". Citation of Internet sources is still being standardized. Consult your writing instructor for their wishes. Copy and paste something from Encarta and see what you get citation wise.