Guide for Planning, Executing, and Presenting ACT-SO STEM Projects

Are You Thinking About Entering the ACT-SO STEM Competition?

ACT-SO national STEM judges are very impressed with the students who compete in the science categories and with the projects they present. As a result, the STEM judges would like to see even more students compete in the science categories. The information provided here is meant to assist students in planning, executing, and presenting projects in the science category at future ACT-SO competitions.

You will find **tips** throughout this text. Students should take these tips to heart. They are not suggestions. They are, in fact, instructions for making your project stand out as a near-perfect project.

Tip # 1: Start Early!

Start early and give yourself time to examine your topic and know your information backward and forward. By starting early, you will have time to decide whether or not your topic is too broad or too narrow and adjust your topic accordingly. By starting early, you will have time to recover from mistakes, change your procedure, or get additional equipment if needed. So start early. Do a little each day. Remember, "It's hard by the yard. It's a cinch by the inch." If you start early, time is on your side.

Tip #2: STEM Judges Want to See Experiments—Not Demonstrations.

A demonstration is not an experiment. What's the difference between a demonstration and a science experiment? A ***demonstration*** shows how something works or how it is used. An ***experiment is*** discovering something unknown or designed to determine if something is practical.

A project entitled "How an Electromagnet Works" is a demonstration. How an electromagnet works is common knowledge. A project like this would repeat work that has already been done and appears in many middle and high school science books.

On the other hand, a project entitled "The Effect of Different Metals on the Amount of Magnetic Force Produced by an Electromagnet" is an experiment. In this experiment, you are testing different metals to see their effect on an electromagnet's strength.

Here's another example. A project entitled "How Does Insulation Work?" is a demonstration. Many books have been written that will tell you exactly how insulation works. A project like this would not bring out any new knowledge. However, a project entitled "Which Type of Clothing Material Is the Best Insulator?" is an experiment. In this experiment, you are testing the insulating quality of different materials. You are testing or investigating the insulating properties of different materials.

If you want to perform an experiment dealing with insulation, then knowing how insulation works is very important. However, it is essential because it will serve as background information about insulation. From that background information, you can generate ideas about the aspects of insulation you would like to test.
Demonstrations do not meet the criteria of a science experiment and will receive low marks at the ACT-SO competition. Before you start your science project, talk to your science and math teacher to ensure that you are doing an experiment, not a demonstration.

Tip #3: Choose a topic that interests and challenges you.
Do not be afraid to try something new. You can learn about it along the way. Remember that complicated-looking projects do not guarantee a win. Simple topics can actually turn into great projects. At most science fairs, students with simple projects who "know their stuff" will win over students with complicated projects who do not really know their topic and/or who are not good presenters.
Easy topics such as "Which soda tastes best?" will not impress the judges unless you know the ingredients and chemical makeup of each soda tested and can point to which of those ingredients is responsible for people preferring one soda taste over another.

Tip #4: Use the scientific names associated with your materials.
Let's pretend our topic will be "The Effect of Water on the Growth of *Tagetes Erecta*." What the heck is *tagetes erecta*? They are African marigolds.

Science judges like to see that you know the scientific names associated with the materials you will use in your experiment. So, although it may sound a little pretentious, use the scientific name and only the scientific name in your research report and on your presentation backboard. Now I realize that *tagetes erecta* may be a little complicated to say repeatedly during your presentation. So, to get around this, at the beginning of your presentation, you can say, "The title of my experiment is 'The Effect of Water on the Growth of *Tagetes Erecta*' otherwise known as African marigolds." Then, you can drop the scientific name after that and talk about marigolds.

Tip #5: Know your material!

You should know more information than you put on the presentation board and your research report. Here's an example. If your topic is "The Effect of Water on the Growth of *Tagetes Erecta,*" you should be absolutely clear about how photosynthesis works. You won't necessarily explain how photosynthesis works on your presentation board. Still, I can guarantee that at least one judge will ask you about photosynthesis. Suppose you mention carbohydrates and chlorophyll in the research report (and you should) or on your presentation board. In that case, you should know what a carbohydrate is and how it is formed. You should also become very knowledgeable about chlorophyll. You should know if *tagetes erecta* are annuals or perennials. You should know how tall the *tagetes erecta* will grow (12 to 14 inches) and how long it takes to get to that height (approximately 70 days from when the seed is planted in the soil).

By taking these steps, you will not only know something about your topic, you may find what techniques and equipment are best for investigating your topic. You will also better understand why your experiment's results turned out the way they did. You will be able to answer the judges' questions. Finally, you will have enough knowledge to predict what will occur in your experiment.

Tip #6: Follow the scientific method.

The scientific method is a procedure scientists use to answer questions and explore observations. Scientists use experiments to search for cause-and-effect relationships in nature. That means scientists design experiments so that changes to one item cause something else to change in a predictable, observable, and quantifiable way. These changing quantities are called variables. Variables are a crucial element of the scientific method.

Components of the Scientific Method

The components of the scientific method include:

1. Purpose,
2. Hypothesis,
3. Materials,
4. Procedure,
5. Data,
6. Results and analysis, and
7. Conclusions.

1. Purpose

The Purpose section should appear in your research report and science presentation backboard. The Purpose section should take up at least 2 pages in your research report. You should condense the information from your Purpose section into two paragraphs for your science project presentation.

Use the library and the Internet to get background information on your chosen subject. Science judges like to see that you understand the theory behind your experiment. So go to the library and look up information to understand what is already known about the subject of your science project. Look for important concepts and equations that explain how and why your experimental results turn out the way they do. Find equations that help you predict the outcome of your experiment. Learn as much as you can about math, physics, or chemistry facts and concepts that are important to fully understanding your project. Also, periodically discuss any questions or problems you have encountered with your science project with your teachers to get their feedback.
The Purpose section should include why your topic is necessary (e.g., Is it essential to the environment? How so? Why does the topic pique your curiosity? Why are you curious?).

The Purpose section should also discuss what you are going to do and how what you are going to do relates to the importance of your topic and/or helps satisfy your curiosity.

Within the Purpose section, you must identify your independent, dependent, and control variables. There is no need to go into a lot of detailed explanations. Identify and list your independent, dependent, and control variables.

Unless you have a unique experiment, virtually all experiments have three types of variables. They are:

1. An independent variable
2. A dependent variable

3. A control variable

The independent variable is the thing you are changing or manipulating. In this case, it would be the amount of water. When conducting your experiment, you must ensure the only thing you change is the independent variable. In so doing, you are only measuring the impact of that single change. The dependent variable is the thing you are trying to measure. In this case, it's the height of the *tagetes erecta*. The control variable is what you do not change. In this example, you keep the amount of sunlight the same for all the *tagetes erecta*. So, the control variable is, that's right—the control variable is sunlight. You can have more than one control variable. For instance, if you were going to ensure that all the plants were exposed to the same amount of sunlight, fresh air, and plant food, then your control variables would be sunlight, fresh air, and plant food.

2. Hypothesis

A hypothesis ***MUST*** be included in your research report and on your science project presentation board. A hypothesis is a fancy term for making a prediction. It's an educated guess concerning the outcome of your experiment. You must state your hypothesis in a way that you can readily measure. But you're not done yet. You have to say why you think your hypothesis is correct.

1. Use the If, then format
2. Say why you believe your prediction will be correct.

Here's an example:

"If I give *tagetes erecta* half the recommended amount of water, then they will grow to half the height of the *tagetes erecta*, which received the fully recommended amount of water. I believe the *tagetes erecta*, which receive half the recommended amount of water, will grow to half the heights of the tagetes erecta, which receive the fully recommended amount of water because all plants that have chlorophyll use the energy in sunlight to convert carbon dioxide from the air and water from the soil to produce carbohydrates. Carbohydrates (along with fats and proteins) are the substances necessary for plant growth. So, by giving some plants half the water they need, they will only be able to produce half the food they need and grow to half the height of the plants that received the fully recommended amount of water."

Notice what the text in quotes did. First, it tells everyone what you think will happen. Second, you told everyone how much you think the plants will grow. By saying how much, you have expressed your hypothesis in a measurable (quantifiable) way. Third, the text tells everyone why you think the experiment will give the results you predict. Finally, the text tells everyone that you had based your prediction on the knowledge you gained while researching this subject. This research information is what you used to develop your Purpose section.

3. Materials

This is where you list the supplies and equipment needed to conduct your experiment.

A "Materials" section must appear on your project presentation board and research report. Just listing the supplies and equipment is all that is really necessary. What do you list? Everything!!!

If we use the example of measuring the growth of *tagetes erecta*, your materials list might look like this:

Materials List	
QUANTITY	DESCRIPTION
40	1-Liter plastic potting plants *(Later we will discuss why the number "40" is important.)*
40	*tagetis erectum* seeds

2	8-liter bags of potting mix *(This is the soil in which you will plant your seeds.)*
	tap water
1	graduated beaker which holds at least 300 ml of water
1	cm ruler
1	No. 2 pencil
20	sheets of notebook paper *(to record the results)*
	10' x 12' room with windows so that the *tagetes erecta* will be exposed to sunlight
	table or other hard surface
	software (Microsoft Excel) which will (1) calculate statistics such as the median height and average deviation and (2) draw graphs, tables, and charts

Notice how we were very specific about the materials. We didn't just say, "pots for plants." We told what type of pots. We also said how big the pots were (e.g., the volume of the pots). In this case, the pot's capacity was 1-liter. You want to use the same material each time you conduct the experiment. In this example, you do not want to put one *tagetis erectum* seed in a 2-liter clay pot and another *tagetis erectum* seed in a 1-liter plastic pot. You don't want to measure the height of some *tagetes erecta* in centimeters (cm) and other *tagetes erecta*in inches. You want to conduct your experiment the same way every time. Also, you want to use the same material because using different materials could cause the results to be different (Scientists call this "introducing other variables"). In other words, you want to see how water affects plant growth. If you use the same material, you won't have to worry about whether the results are different because you used clay pots for some *erecta* and plastic pots for other *erecta*. Using the same materials, you can say that your results are only due to changing the amount of water you gave the plants. Recall, in this case, water is your independent variable.

Tip #7: Take all measurements in the metric system.

All measurements must be taken in the metric system: grams (or kilograms), centimeters (or meters), milliliters (liters), and seconds. STEM judges dislike seeing inches, ounces, or gallons used in any experiment. Suppose you have a science project in the earth and space sciences where measurements are typically larger than grams, centimeters, and milliliters. In that case, your measurement units will most likely be kilograms, meters, liters, and seconds.

4. Procedure

Now that you have developed a hypothesis, you need to develop a procedure for testing whether it is true or false. The procedure *must* appear in your research report and on your presentation board. The procedure involves changing your independent variable and measuring the impact this change has on the dependent variable. All the controlled variables must remain constant.

Scientists run experiments more than once to verify that results are consistent. In other words, you must verify that you obtain the same results every time you repeat the experiment with the same value for your independent variable. This ensures that the answer to your question is not just an accident. Each time you perform your experiment, it is called a *run*or *trial.*

Every good experiment also compares different groups of trials with each other. Such a comparison helps ensure that the changes you see when you change the independent variable are, in fact, caused by the independent variable. *There are two types of trial groups: experimental groups and control groups.*

<u>Experimental Groups</u>

The experimental group consists of the trials where you change the independent variable. For example, if your question asks if giving *tagetes erecta* half the recommended amount of water will affect their growth, then the experimental group consists of all trials in which the plants receive half the recommended amount.

<u>Control Groups</u>

In many experiments, performing a trial with the independent variable in a unique setting is essential for comparison with the other trials. This trial is referred to as a control group. The control group consists of all those trials where you leave the independent variable in its natural state. In our example, running trials in which the plants get the recommended amount of water

would be essential. These trials with the plants receiving the thoroughly recommended amount of water provide a basis for comparison and would ensure that any changes you observed when you gave the experimental group half the recommended amount of water are, in fact, caused by the different amounts of water and not due to something else.
However, only some experiments are similar to our plant example. In another kind of experiment, many groups of trials are performed at different independent variable values. For instance, if your question asks whether an electric motor turns faster if you increase the voltage, you might do an experimental group of 15 trials at 1.5 volts, another group of 15 trials at 2.0 volts, 15 at 2.5 volts, and so on. In such an experiment, you compare the experimental groups to each other rather than comparing them to a single control group. You must evaluate whether your experiment is more like the plant example, which requires a particular control group, or more like the motor example, which does not.

Control Variables

Remember, whether or not your experiment has a control group, every experiment has several control variables. Control variables are those we don't want to change. At the same time, we conduct our experiment, and they must be the same in every trial and every group of trials. In our plant example, we would want to ensure the room temperature, light, and plant food available to all plants were the same for every trial. Even though an experiment measuring the effect of voltage on the motor's speed of rotation may not have a control group, it still has control variables: the same brand and type of motor are used for every trial, and the load on the engine is kept the same.

A little advance preparation can ensure that your experiment will run smoothly and that you will minimize (or eliminate) unexpected surprises at the last minute. You must prepare a detailed procedure for your experiment to ensure consistency from beginning to end. Think about it as writing a recipe for your experiment. A straightforward procedure also makes it much easier for someone else to test your experiment if they are interested in verifying how you got your results.

Critical Elements of Procedure for an Experiment

The essential elements of the procedure for an experiment are as follows:

- The procedure must tell how you will change your one and only independent variable and how you will measure that change.
- The procedure must explain how to measure the resulting change in the dependent variable or variables.
- If applicable, the procedure should explain how the control variables will be maintained as a constant value.
- The procedure should specify how often you intend to repeat your experiment so you can verify that your results are reproducible.

Tip #8: Conduct at least 15 trials for the experimental and at least 15 trials for control groups.

Science fair judges like to see between 15 and 20 trials for each group. Why? In most cases, 15 to 20 trials will give you significant information. What do we mean by substantial? Well, let's say that the more trials you run, the more likely it is that your data and the statistics you compute based on the data represent fundamental differences between the experimental and control groups and didn't just happen by chance or didn't just happen because you conducted the experiment only two or three times. That's why, in the *Materials* section, we said we needed 40 planting pots and 40 *tagetis erectum* seeds. We wanted 20 trials for the experimental group and 20 for the control group.

Sample Procedure

1. Place a cm ruler in each pot.
2. Fill each pot with potting mix until the potting mix reaches the 11 cm mark on the ruler.
3. Remove the ruler and tap the bottom of the pot on a table or other hard surface three times to compact the potting mix.
4. Plant one *tagetis erectum* seed in each pot so that the seed is two cm below the top of the soil.
5. Number each pot in the control group from 1 to 20.
6. Number each pot in the experimental group from 21 to 40.
7. Place the numbered pots in a room with windows.
8. Water the plants every other day. Use the graduated beaker to place 240 ml of water in each one of the pots numbered 1 to 20 (the control group). Use the graduated cylinder to place 120 ml of water in each one of the pots numbered 20 to 40 (the experimental group).
9. Every third day, record the growth of the *tagetis erectum* in each pot. Record the height in cm.
10. Stop the experiment after 70 days. (Remember, from your research you found that it takes about 70 days for the *tagetes erecta* to grow to their full height.)

Remember: All measurements must be taken in the metric system (grams (or kilograms), centimeters (or meters), milliliters (liters), and seconds). Science judges do not like to see inches, ounces, or gallons used in any experiment. Suppose you have a science project in the earth and space sciences where measurements are typically larger than grams, centimeters, and milliliters. In that case, your measurement units will most likely be kilograms, meters, liters, and seconds.

5. Data

Now that you have obtained the materials and planted your seeds, you can conduct your experiment and record your data. When you record your data, be sure to put it in a form that is easy to read. Also, make sure the observations you record are legible. Nothing is more frustrating than looking back at your records and being unable to read your handwriting. The data must appear in your research report and on your presentation board.

For this experiment, there are many ways to record data. Look at *Figure 1* and *Figure 2* to see what I did. You'll find these and any other figures at the very end of this document. Notice what we did. The title of the first chart is "Height of Plants in Experimental Group (cm) vs. Observation Day." There are two essential things in this title. First, we will record the plants' height for each observation day. Second, we state what units we will use to record the plant heights. In this case, we are using cm. Also, within the table, each column is labeled, and each row is labeled. Since we already stated that we are measuring the heights in cm, it is not necessary to put units following the numbers in the table's cells. The title already states that the heights recorded in each cell are in cm.

Tip #9: Label your charts, tables, and graphs to clearly show what you are recording.

If the chart, table, or graph contains measurements, be sure to include the units of the measurement somewhere on the chart, table, or graph. The best place to put the units is in the chart, table, or graph title.

Calculating Statistics

Calculating statistics will help us make sense of the data and help us determine if our hypothesis is correct. For these numbers, it is best to calculate the median height and average deviation for the control group on each observation day and the median height and average deviation for the experimental group on each observation day. The ***median***is the midpoint in a distribution. For example, suppose you have 5 numbers (1.0, 2.0, 2.5, 2.7, 1.5, and 1.7). If we take these numbers and put them in order from high value to low value, the median would be the 3rd value (the value right in the middle of the 5 numbers when ordered from high value to low value). The median gives you a ballpark value of the observations you took. The median is a helpful statistic to use if you have a lot of data and want to find out the typical value of the data. In our science experiment, the units associated with the median height will be cm.

Now, let's talk about ***average deviation***. The average deviation will tell you how different the observations are on any given observation day. For example, suppose you have 5 numbers (1.0, 2.0, 2.5, 2.7, 1.5, and 1.7). These numbers don't differ that much from each other. The average deviation for this set of numbers is 0.40. Now, look at another set of 5 numbers (1.5, 1.0, 3.0, 7.0, and 9.0). The average deviation for these numbers is 2.7. The average deviation of the second set of numbers (2.7) is larger than the average deviation of the first set of numbers (0.40) because the numbers in the second set are not close. They are more spread out. We'll discuss these statistics in the Results Analysis and Conclusion sections. Who cares if the numbers are spread out? You do. The average deviation is a mathematical tool to help us assess how far the values are spread above and below the median. A high average deviation shows that the data are widely spread (less reliable), and a low standard deviation shows that the data are clustered closely around the mean (more reliable).

Tip #10: When it is helpful to calculate statistics, and you don't know if your data are typically distributed, calculate the median and the average deviation.

A common assumption of statistics users is that data are "normally" distributed. Others have written many pages on this topic. I will leave you in the dark (like many statistics users) about what this assumption means and how you test it. Several good courses and books would include these topics. Also, you can go to your math teacher to learn more about what normal distribution means. The good news is that there are statistics you can use even if you aren't sure if the data you collect are typically distributed. Statistics that provide helpful information, even if applied to not-"normally" distributed data, are called robust statistics. Median and average deviation are considered robust statistics.

Selecting Which Data Points to Plot

Figure 3 plots the median height values for the experimental and control groups. Why did we choose to plot the median values? Why didn't we plot all the data points? That's a good question. Let's think about it for a minute. Let's look at the data points for the experimental group. We have measurements for 20 plants, and we will take measurements every three days up to and including day 70. So that means we take 20 measurements on 24 different occasions. That's 480 observations for just the experimental group. You have another 480 observations for the control group. *If we tried to put that many data points on a graph, the only thing we would do is make a graph that looks like spaghetti!* So, we must simplify our data presentation. Suppose we plot the median height value for each day. In that case, we have reduced the number of points from 480 to 70 for the control group and 480 to 70 for the experimental group.

Labeling Graphs

Also notice that the axes of the graph are labeled. The abscissa (the x-axis) is labeled "Observation Day." The ordinate (the y-axis) is labeled "Median Height (cm)." Notice I put "cm" in parenthesis in the graph's title and on the ordinate. This informs the reader that the data will be presented in cm. *Always, always, always specify your units on any chart, table, or graph you present.*

There may be other types of calculations you can make. For example, you could calculate the growth rate of the *tagetes erecta*. Discuss the possibilities with your science and math teachers.

Also, you will see in *Figure 3* that we did not plot the median height for each observation day. We did that in this example to save time. It would be best if you did not take this shortcut. If you were doing this experiment, you would have a figure that shows the median height on each observation day.

6. Results and Analysis

The Results and Analysis section must appear in your research report and your presentation board. You have statistics in the graphs and charts that appear in the Data section. In the Results and Analysis section, you should state the formulas (or equations) for the statistics you used. This is where you go to a statistics book and look up the formula for any statistics you use. In our case, we need to place the median and average deviation formulas into the Results and Analysis section of my research report. There is no need to put the statistical formulas on your presentation board. However, it would help if you were sure that any statistics you calculate are placed on your presentation board.

Tip #11: Have a good understanding of any formula or equation that you present in your research report.

Although you don't have to place the formulas for the statistics on your presentation board, you are responsible for knowing how these statistics work and what they mean. In general, you should check with your math and/or science teacher to ensure that you understand any formula or equation you present in your research report. A STEM judge will likely ask you to explain the statistic or formula. So, become comfortable with any and all equations you have used. That also means you should know if a particular statistic should be written with associated units. Median should always be expressed with units. In our experiment, the units are cm. Average deviation never has units. You will understand why when you look at the formulas for median and average deviation. Ask your math teacher for help understanding these and any other statistics you may use in your experiment.

Tip #12: In mathematics projects, include mathematical equations in your research report and on your presentation board.

In your research report, you want to include virtually all equations that help explain your purpose, procedure, and results. On your presentation board, place only those equations in your Purpose section, which are crucial to making whatever point you want to make in your Purpose section. Do the same thing for your Procedure, Data, and Results sections on your presentation board. Ask your math and science teachers for advice on what equations you should include in these sections.

<u>Evaluating Data</u>

Now that you have taken your observations and calculated statistics, you are ready to look at your statistics and consider what these numbers mean. As we mentioned in the Data section, you have a lot of data. It's tough to look at that much data and make sense of it. That's where statistics come in. Statistics help us make sense of the data. Statistics allow us to reason mathematically from data to make some statement about the data. Instead of looking at all the data (480 observations for the experimental group and 480 observations for the control group), let's look at what our statistics are telling us. If we look at the statistics, we find that:

- The plants in the control group started growing above the surface of the soil sooner than the experimental group. The control group broke through the soil surface on day 4. The experimental group did not appear above the soil surface until day 7.
- On any given observation day, the plants in the control group were usually taller than those in the experimental group. For example, on day 10, the median height for the control group was 5.0 cm. On day 10, the median height for the experimental group was 3.25 cm. By day 70, the control group had a median height of 24.6 cm which was more than double the median height of the control group (12.0 cm). One notable exception to this trend was on day 7. On day 7, both groups had a median height of 2.85 cm.
- The average deviation for the control group was usually higher than that for the experimental group.

Notice how this analysis works. We made general statements backed up by numbers. For example, we said that the plants in the experimental group were usually taller than those in the control group. Then, we gave a specific example with specific numbers. As often as you can, back up anything you say with numbers. You worked hard to get these numbers… it would be best if you used them.

Additionally, the numbers help you back up your statement with facts. The statement is an assertion. It's what you believe to be true. The numbers are the facts to support your argument (or what you believe to be confirmed).

Also, notice that we discussed exceptions. For instance, most of the time, the median height of the control group was more significant than the median height of the experimental group. This was not the case on day 7. Within your research report, you should explain the reason for this exception. For these data, you can see that plant numbers 26, 30, 32, 35, 36, and 38 grew slowly for the first 4 days. That's the easy answer. In addition to stating the easy answer, you should go beyond stating the easy (and obvious) answer. You can see in your data that these plants were noticeably smaller than the other plants in the control group, but why? Try to figure out what caused this noticeably smaller growth. Was it because perhaps someone didn't open the blinds on that side of the room, so these plants did not get the same amount of sun for some time? Were there some other reasons? If so, you should present them in your research report.

Your research report's Results and Analysis section should be at least one page.

Tip #13: Your research report's Results and Analysis section should discuss general trends, exceptions, and the reason for the exceptions.

The Results and Analysis section on your presentation board should be a condensed version of your research report's Results and Analysis section. You probably will not have enough space on your presentation board to explain the exceptions; note them on your presentation board. However, it would help if you were prepared to discuss the exceptions and the reason for the exceptions with the judges—they will ask you about them.

Tip #14 Results from experiments dealing with medicine and health may have exceptions.

For example, all microbes (which you believe are the same type of microbe) in a particular sample may not respond to the same amount of UV radiation in the same way. The fact that the microbes reacted differently to the same amount of UV radiation could be due to the fact that some microbes in the sample were contaminated. A different response could occur because one or more control variables were not controlled (like you thought) in every single experiment run. Exceptions will occur Unless you work in a highly controlled laboratory environment. So, don't think your experiment fails because you see a few exceptions. The STEM judges are looking for you to explain why the exceptions occurred. If you are unsure why the exceptions occurred, give reasons why you think the exceptions occurred. The science fair judges also want you to talk about ways to revise your experiment to minimize these exceptions.

7. Conclusion

A Conclusion section must be included in your research report and presentation board. Because space is limited on your presentation board, the conclusions on your presentation board should be a condensed version of the Conclusion section in your research report.

Your conclusions summarize how your results support or contradict your original hypothesis. Were the results what you expected? Why or why not? Include key background facts from your Purpose section and information you learned while researching your topic to help explain your results as needed.

Make sure you perform a hypothesis check. A hypothesis check is a statement that says whether you proved or disproved your hypothesis. (Engineering, mathematics, and computer science projects should state whether they met their design criteria.) State the relationship between the independent and dependent variables. For example, based on your data and the statistics you calculated, is the relationship between independent and dependent variables (which you stated in your hypothesis) authentic? Why are you not?

You should also summarize and evaluate your experimental procedure, commenting on its success and effectiveness. Suggest changes in the procedure (or design) and/or possibilities for further study.

If the results of your experiment did not support your hypothesis, don't change or manipulate your results to fit your original hypothesis; explain why things did not go as expected. If you need additional experimentation, describe what you think should happen next. Scientific research is an ongoing process, and by discovering that your hypothesis is invalid, you have already made considerable advances in your learning that will lead you to ask more questions that lead to new experiments. Science fair judges do not care about whether you prove or disprove your hypothesis; they care about how much you learned.

Tip #15: Remember to always include a hypothesis check in your Conclusion section and make sure it appears in your research report and on your presentation board.

Tip #16 Be prepared to talk about your ideas for improving your project and ideas for future research.

Science fair judges like to see that you have ideas about how the project could be improved or ideas for future research. Make sure you put these ideas in your research report and on your presentation board (if you have space) and be prepared to talk about these ideas when the judges interview you.

Bibliography

A bibliography lists the books, science journals, and Internet sources you use in designing, carrying out, and understanding your science fair project. You must include a bibliography in your research report. Still, you do not have to include a bibliography on your science project presentation board. ***Notice that we list not only Internet sources but also books and science journals.*** In your research report and on your science project presentation board, it is essential to include more than just Internet sources in your bibliography. It is OK to use Internet articles in your bibliography. Still, your bibliography must use other information (such as books and journal articles). Why? Before a book or journal article is printed, it must be reviewed by knowledgeable scientists. Internet articles do not always go through this type of rigorous scientific review. By including information from books and science journals, you are telling the science fair judges that you have gone through the trouble of finding reputable and scientifically sound information.

Tip #17: List no more than three Internet sources in your bibliography.

Science judges want to see something other than a bibliography of only Internet sources. You should have no more than three Internet articles listed in your bibliography. You should have at least two different types of citations for each Internet citation. For example, suppose you have three Internet articles listed in your bibliography. In that case, you should have at least six other types of citations (e.g., books and journal articles) for at least 9 citations in your bibliography.

You're Ready to Go!

Remember to rehearse your presentation. Ask your science and math teachers to listen to your presentation and ask them to critique how you present. They may stop you with questions. Be sure to write down any reasonable question, especially if you don't know the answer. Work with your science or math teacher to find the answer before you make your ACT-SO presentation. Get others to listen to your presentation. They may not know anything about science, but they can tell you if you are speaking loudly enough, if you look nervous, or if you are not looking them in the eye when you talk to them.

Tip #18: Be sure to rehearse your presentation before others.

If you have trouble getting someone to listen to your presentation, stand in front of a mirror and give it to yourself. Looking at yourself giving the presentation will provide you with practice looking someone in the eye when you are talking to them. It will let you see how others (especially the science fair judges) will see you.

The information you have just read summarizes the advice and knowledge of ACT-SO STEM judges representing NOAA (National Oceanic and Atmospheric Administration), Dow Chemical, NASA and Lockheed Martin. The websites www.sciencebuddies.org *and* www.physics.csbsju.edu/stats/descriptive2.html *are also useful references.*

Figure 1. Height of Plants in Experimental Group (cm) vs. Observation Day – Plants 1 to 20

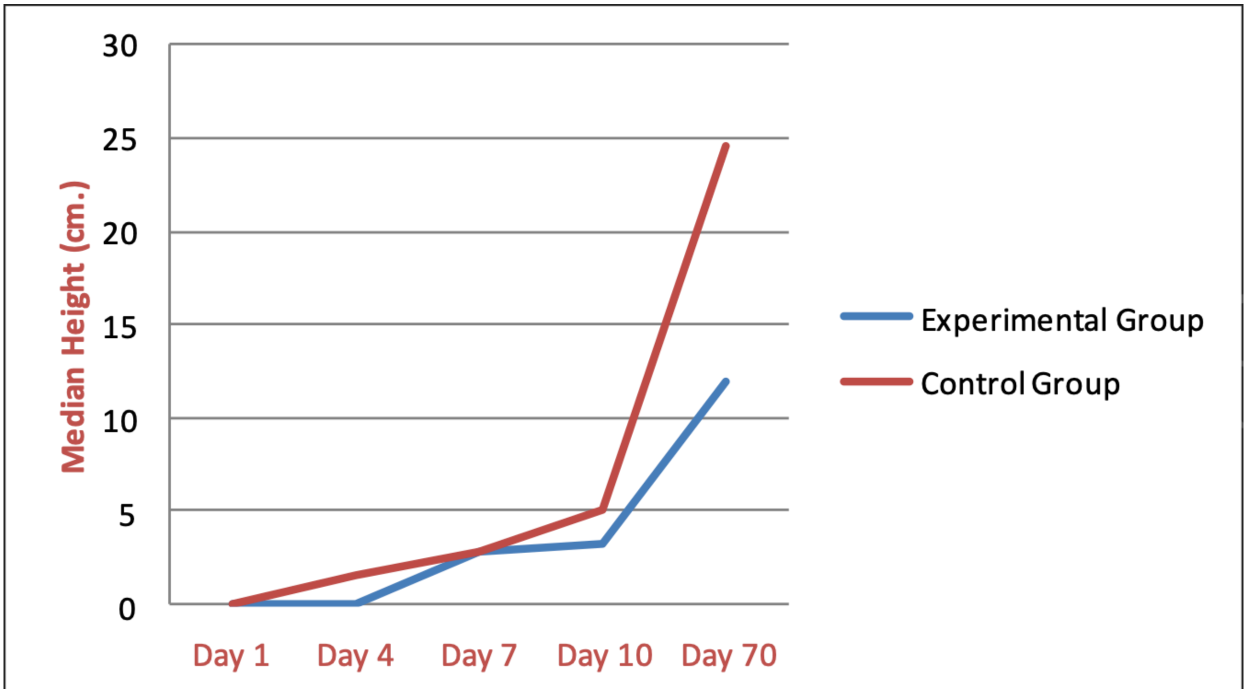
		Observation Day (D-#)													
		D-1	**D-4**	**D-7**	**D-10**	**D-13**	**D-16**	**D-19**	**D-22**						**D-70**
Plant Number (P-#)	P-1	0	0	3.0	3.2										12.3
	P-2	0	0	3.5	3.6										12.8
	P-3	0	0	2.0	2.5										10.7
	P-4	0	0	2.5	3.0										11.2
	P-5	0	0	0.0	1.9										10.5
	P-6	0	0	1.5	1.8										11.6
	P-7	0	0	1.8	2.4										11.9
	P-8	0	0	3.2	3.5										13.2
	P-9	0	0	3.0	3.6										12.1
	P-10	0	0	2.8	3.2										11.9
	P-11	0	0	3.4	3.9										12.8
	P-12	0	0	0.9	2.4										10.2
	P-13	0	0	3.3	3.9										13.5
	P-14	0	0	2.2	2.8										11.0
	P-15	0	0	2.9	3.6										12.7
	P-16	0	0	3.3	3.4										13.1
	P-17	0	0	2.1	2.9										09.8
	P-18	0	0	2.6	3.3										10.6
	P-19	0	0	3.3	3.6										12.7
	P-20	0	0	3.3	3.8										12.8
	Median Height (cm)	0	0	2.85	3.25										12.0
	Average Deviation	0	0	.69	.51										.93

Figure 2. Height of Plants in Control Group (cm) vs. Observation Day – Plants 21 to 40

	Observation Day (D-#)													
	D-1	**D-4**	**D-7**	**D-10**	**D-13**	**D-16**	**D-19**	**D-22**						**D-70**

Plant Number (P-#)	P-21	0	2.7	4.0	6.7										26.7
	P-22	0	2.0	3.5	5.6										25.2
	P-23	0	1.5	2.9	4.7										24.3
	P-24	0	2.1	3.7	6.2										25.4
	P-25	0	1.3	2.9	4.3										22.8
	P-26	0	0.6	1.8	4.1										20.9
	P-27	0	1.8	3.1	5.2										23.6
	P-28	0	2.2	3.6	6.0										26.0
	P-29	0	1.6	2.9	5.6										25.8
	P-30	0	0.7	1.8	4.8										24.3
	P-31	0	1.6	2.4	4.8										24.6
	P-32	0	0.4	2.1	5.3										25.7
	P-33	0	2.0	4.2	6.8										27.0
	P-34	0	1.7	3.3	5.5										26.2
	P-35	0	0.9	1.6	4.0										23.8
	P-36	0	0.8	1.5	3.6										22.4
	P-37	0	1.3	2.1	4.2										24.6
	P-38	0	0.4	0.9	3.3										19.2
	P-39	0	1.7	2.6	4.8										24.6
	P-40	0	1.9	2.8	5.3										25.7
	Median Height (cm)	0	1.60	2.85	5.00										24.6
	Average Deviation	0	0.51	0.73	0.78										1.37

Figure 3. Median Height (cm) vs. Observation Day



30
25
20
15
10
5
0
Median Height (cm.)
Day 1
Day 4
Day 7
Day 10
Day 70
Experimental Group
Control Group