Success in Science

A Manual for Excellence in Science Education

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Introduction

The Purpose of this Book

Science is a subject near and dear to our hearts. Brad loved the hands-on research experiences that he had in high school so much that he went on to pursue a double major in the sciences as well as a masters in biology, while Paige was so impacted by her chemistry courses in high school that she decided to go on to pursue a bachelor's degree in biochemistry. Our experiences with science have been overwhelmingly positive, but the sad reality is that, for many people this is not the case. Most of the population cringes when you mention words like chemistry or physics. For years, science has been looked at as a lofty subject that few really understand.

The truth is that science is the explanation for what we see going on around us every day. Science explains why the ice in our glass melts quicker on a hot day than a cold one. Science gives us the reasons for how our body works and why the weather is what it is. Science surrounds us daily and it helps us to really understand what is going on in our environment.

Every student is normally required to take several science classes in high school because every major university requires that a student has taken several of these courses before he can apply for admissions. But beyond the academic reasons,

science education can be beneficial for every student. We believe that there are two main purposes for teaching science.

First, science will give the student a better awareness of the world around him. Science is all around us; it's in the metamorphosis of the butterfly, in the changing colors of the leaves in autumn and in the apple falling off the tree. The fact that you can walk upright and digest your food can all be explained through science. When you teach science properly, the student learn the why's behind the things that take place every day around him, resulting in a deeper appreciation of life.

The second purpose for teaching science is because it helps to train the brain to think logically. The scientific method is the formula that all scientists learn to use when approaching a problem. The scientist has a question, researches about that question's topic, predicts the answer to his question, does a test and then analyzes what he has found to determine what the answer to his question could be. This method is a logical and thorough process that the scientist will use over and over again. Being familiar with the scientific method will train the brain of the student to approach any question or problem in a logical manner.

In this book, we will provide you with a framework for teaching science to the various grade levels as well as lay a foundation for why we feel you need to place an importance on science education. Our desire is to see all students excel in their study of the fields of science. Our hope is that this book will give you the tools you need to see your student shine as he studies those fields.

Part 1: The Foundation of Science Education

1
The Most Important Concept

The study of science helps to develop the student's ability to think logically and critically. By analyzing problems and determining how to follow the scientific method, the student gains confidence along with a foundation for logical thinking. According to Carl A Rotter...

> *"While teachers can do nothing to increase a student's mental capacity they can modify their instructional strategies to make concepts easier to comprehend. This may be accomplished through the use of concrete models, illustrations and diagrams and hands on experiences. A student's cognitive developmental growth will increase through exposure to activities requiring them to reason formally. Students, who use integrated science process skills during science activities, increase the level of their cognitive development."*

Another study by Süleyman Yaman found that science education trains people to "discover, explore, make right decisions, solve problems and continuously learn".

We have seen that teaching science well promotes excellence in our students, but to truly understand science, one must be familiar with a single key concept: the scientific method. No high school student should graduate without a firm grasp on this concept; simply memorizing the method is not enough. The student needs to have used the scientific method over and over in experiments until it has become a natural habit. It will take years for a student to fully etch the scientific method into his mind. So, the scientific method is something that you need to begin teaching from the very start.

What is the Scientific Method?

In a nutshell, the scientific method teaches the brain to logically examine and process all the information it receives. It requires that one observes and tests before making a statement of fact. It is the main method scientists use when asking and answering questions. The main steps of the scientific method are…

1. Ask a Question
2. Research the Topic
3. Formulate a Hypothesis
4. Test with Experimentation
5. Record and Analyze Observations and Results
6. Draw a Conclusion

Using the scientific method will teach the student to look at all the evidence before making a statement of fact. It sounds like a lofty idea, but in reality it is an integral part of science education. If we want our students to be prepared for higher education science, they must be comfortable with this most fundamental process.

Though this all sounds intimidating, it's really not. You are simply teaching the student to take the time to discover the answer to a given problem by using the knowledge he has as well as the things he observes and measures during an experiment. The scientific method is a simple, yet logical process that follows the same steps every time.

The Steps in Detail

In the remainder of this chapter we will look at each of the steps in the scientific method in more detail in hopes that you will become more comfortable with teaching the process to your students.

Step 1: Ask a Question

The scientific method begins when a scientist observes an occurrence that makes him wonder what is happening. He then creates a question relating to what he has perceived. When crafting the inquiry, the scientist makes sure that the question is worded in such a way that he will be able to measure whether or not he has obtained the answer. Good questions begin with how, what, when, who, which, why or where.

For example, let's say the student is fascinated by the growth of the plants that he observes, but he doesn't know why this is happening. So the question he could formulate would be, "Why do plants grow?", but this will be time-consuming to measure, so, you will want to help him narrow down the question. Some options are: "How does the lack of sunlight affect the growth of house plants?" or "Which soil is best for house plants to be grown in?" Each of these questions is more specific, making them far easier to measure.

Step 2: Research the Topic

Next, the scientist researches about the topic from the question so that he will have some background knowledge about the subject. This keeps him from repeating mistakes that have been made in the past, but also gives him a basis for formulating his hypothesis. It is very hard to predict what is going to happen in an experiment without knowing something about the principles at work.

The student from the example in step 1 would start by reading about plants and researching how they grow. He can begin with the encyclopedias or reference books that he already has on hand. Next, the student should look at the library for any books relating to plants. Finally, he can search the internet for scientific articles relating to his topic. The student will glean a lot of information from his research, so you will need to assist him in determining which information is useful for answering his question and which material can be tossed.

Step 3: Formulate a Hypothesis

In step 3, the scientist formulates his hypothesis, which is a fancy word for an educated guess about the answer to his question. The hypothesis must always be able to be measured as well as provide the answer to the original question that was asked. Hypotheses are normally simple "if-then" statements that are not more than one sentence long.

For example, the student has chosen the question, "How does sunlight affect the growth of house plants?" He has done his research and found out that sunlight is transformed into energy by the chlorophyll found in the plant cells. So, his

hypothesis could be, "*If a plant receives less sunlight, then it will stop growing.*" or "*If a plant receives more sunlight, then the plant will grow more.*"

Step 4: Test with Experimentation

The next step in the scientific method is for the scientist to develop an experiment that will test whether his hypothesis is true or false. It is important for the test to be fair, so the scientist will only change one variable at a time and he always has a control group. He generally has more than one sample in each group so that the findings will be reliable. The scientist may also find that several experiments are necessary to thoroughly prove whether his hypothesis is correct or not.

In our example, the student will need to design an experiment that tests whether or not a plant will grow if the presence of sunlight is changed. This is a relatively easy hypothesis to test, since it only contains one independent variable, the amount of sunlight. His experiment could have nine house plants that are allowed to grow on a shelf in a relatively sunny room. After 5 days, 3 of the house plants can be moved into a completely dark room, 3 of the house plants can be moved into the full sun on a window sill and the other 3 house plants are left on the shelf for 5 more days. He will need to water each one as necessary, so that the amount of water does not become another variable in his experiment.

A Word About Variables

Each experiment seeks to test a variable, which is an event or factor that you are trying to measure. There are two

main types of variables, independent variables and dependent variables, which can be found in every experiment. The independent variable is the factor that is controlled or changed by the scientist performing the experiment, such as the amount of sunlight the plant receives in the above experiment. The dependent variable is the factor being tested in the experiment, like the amount that the plant grows in the experiment that we have been discussing. The dependent variable is what the scientist measures to determine the effect of the changes to the independent variable. In other words, the dependent variable depends upon the independent variable.

It's also important to mention controlled variables. A controlled variable is a factor that is not being examined in the experiment. The scientist will keep the controlled variable constant so that its effect on the experiment will be minimized. The amount of water would be an example of a controlled variable in the experiment that we have been discussing.

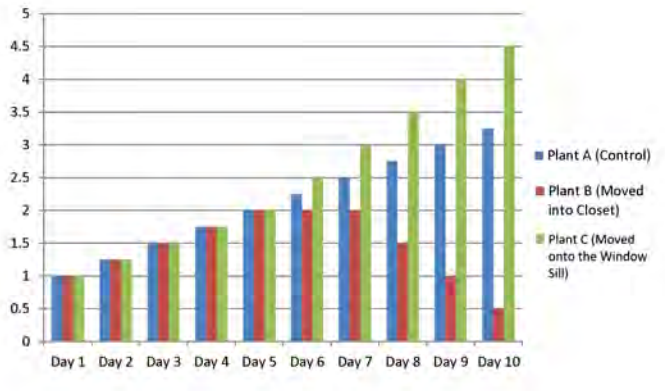
Step 5: Record and Analyze Observations and Results

During the experiment, the scientist will record all his observations and measure his results. Observations are a record of the things he has seen happen in the experiment, while results are the specific and measurable data that he has collected during the testing. Once the experiment is complete, he will analyze the observations and results to see if his hypothesis was true or false.

So let's say that the student we have been discussing has kept a journal of his observations during the experiment. His journal contained entries like:

"Day 7: The plant on the window sill is green and tall. The plant on the shelf is green, but a little shorter than the plant on the window sill. The plant in the dark is turning yellow and has not grown in days."

He has also measured how much the plants grew each day and then plotted each of his measurements on a graph that looks like this:



Now the student can easily see from his journal entries and from the graph he created that his hypothesis was true. He has found the answer to his question.

Step 6: Draw a Conclusion

Finally, the scientist can use what he has discovered to make a statement about whether or not his hypothesis was true. This statement will communicate his results to other scientists and hopefully answer his original question. The scientist may find that his hypothesis was false or that his experiment design

did not really answer his question. If this is the case, he will formulate a new hypothesis and begin the process again until he are able to answer his question.

In our sample experiment, the student saw that the plant in the dark room stopped growing and began to shrink, while the plant on the window sill grew faster than the one on the shelf. He can easily theorize that, "*The more sunlight a plant has, the better it will grow.*" However, more testing is needed to see if other independent variables play a role in plant growth before he can make a statement of fact about the relationship of plant growth and the presence of sunlight.

A Quick Word about Theory vs. Fact

If you noticed in the last paragraph, we stated that the student could theorize, but he could not make a statement of fact. The student is able to make an educated prediction that an increase in exposure to sunlight will cause an increase in the plant's growth. However, the student cannot make a statement of absolute truth because he has not examined all the factors that affect the plant's growth and how those factors relate to an increased presence of sunlight.

So what is the difference between a theory and a fact? To answer this question, we must examine the origins of the words themselves. The word theory comes from the ancient Greek word *theoria*, which means "a looking at, viewing or beholding". In science, a theory is an analytical tool used for understanding, explaining or predicting cause for a certain subject matter. The word "fact" comes from the Latin word *factum*, which means "a thing done or performed". In science, a

fact is an objective truth that can be seen in nature or confirmed through repeated experiments.

So, we can say that theories are meant to be tested by experimentation and observation to determine if they are fact, while facts are truths that can be verified through repeatable experimentation or by real-time observations.

Conclusion

Whether you are creating a theory or proving a fact, the scientific method is the tool that every scientist uses to determine the findings. The scientific method is integral to understanding science, but it has benefits that are useful beyond the study of how the world works. It is a technique that trains the student how to answer a question in a logical manner. It also teaches the student to analyze and process the information he is receiving. The scientific method teaches the brain to logically examine and process all the information it receives. This is why we believe this process is the most important concept in science education.

In the next section of this book, we will lay out our plan for teaching science throughout the preschool, elementary, middle school and high school years.

Part 2: What Science Education Should Look Like

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The Preschool Years

The preschool student is learning daily about his environment. He is constantly absorbing information about the world around him through hands-on experiences. He enjoys seeing how things work and loves being introduced to new things. The preschooler is more than ready and willing to learn, but his motor muscles aren't quite ready for all the writing that formal education entails.

Why Teach Science to a Preschooler?

Typically, the preschooler is taught the basics, such as colors, the alphabet and the numbers 1-20 through simple worksheets. We also provide him with structured play, such as a kitchen set or a dress up station. We make sure that he has time to build his motor skills through creating art and exploring music. However, all too often, we neglect to introduce the youngest student to the wonder of science because we think it is too difficult of a subject for him to grasp. While some concepts in science will go way over a preschooler's head, we can introduce him to the subject as a whole by presenting him with the way that things work in his environment.

The preschooler is naturally wired to be curious, and thus, he is fully prepared to learn about science. These early years are a good time to introduce him to the way things work in his environment, because an early introduction to the subject will create an interest that you can build upon once he reaches the elementary years. By showing him the miracle of the scientific processes going on around him, you are constructing a basis for future learning.

Your Goal

The goal for preschool science is simple:

1. To introduce the student to the world around him.

The preschool student is a completely blank slate, so during these years your goal will be to introduce him to various concepts and ideas found in science through a hands-on approach. This will help him to build a basic framework, or bucket, that he can fill during the elementary years.

The Components

There are four basic components to preschool science education that will help you to accomplish your goal. They are...

1. The Weekly Topic
2. Practical Projects
3. Read-Alouds
4. Coordinating Activities

What you accomplish each week will vary because the student's interest will vary. Some weeks a preschooler will want to spend every waking minute learning something; some weeks he will

only want to spend 5 minutes on educational topics. So look at the following components as a buffet of ideas that you can use to introduce the student to the world of science rather than a list of things to do each week.

Remember that science during the preschool years needs to be very hands-on and teacher directed. During these years, science should also be strictly enjoyable for the student. If he does not enjoy reading books about science (or any of the other components), don't force him to do so, as this will be counter-productive to your goal. There will be plenty of years for him to learn what he needs to in the not so distant future.

A Closer Look At The Components

The four components for your preschool science buffet are the weekly topic, hands-on projects, read-alouds and coordinating activities. A good science curriculum for the preschool years will give you options for each of the following components.

The Weekly Topic

The main purpose of having a weekly topic is to create a focus for your studies for the week. Once you choose your weekly topic, create a main idea that relates to the topic. This main idea should put science into words that a preschooler understands, such as, "*Rain is water falling from clouds in the sky.*" Next, you will determine a way to introduce the topic to the student. These should be simple explanations, demonstrations and/or guided observations that the student will understand.