### The Scientific Method?

-The Hypothesis Problem in Student Investigations in High School Science

-MG Miksic, Queens College of CUNY

## **The Scientific Method** [as employed in student research ]

- 1. Pose a question based on observations
- 2. Research the topic: texts and scientific literature
- **3.** Develop a Hypothesis related to the question
- 4. Design an experiment
- 5. Make observations and collect data
- 6. Analyze the data
- 7. Draw conclusions: 'accept or reject the Hypothesis'

- by The Committee of Ten- 1893

#### Scientific Method Questionnaire to Science Teachers

- Recall YOUR own experience with the SM and state BAC.
- What aspects did you remember:
- ...were helpful to learning?
- ...were not helpful to learning?
- What problems did you have with being required to create a Hypothesis?

In your observations of students
 how is the process of student's research
 affected by the requirement of students,
 that 'they must create a hypothesis (H)'
 before they begin their research?

- From your observations of your students.
- What aspects of the SM did students find helpful to their learning?
- Which aspects were not helpful to their learning?
- What problems did they have with being required to create a hypothesis?

- Jim
- "One of the difficulties I have experienced is that students tend to feel that their results need to prove their hypothesis right."
- "...students attempt to do all sorts of dubious "unscientific" means to obtain results that agree with their hypothesis."
- One student said, "How can we come up with a hypothesis when we don't know anything about what we are studying?"
- "how can we know how to set up an experiment if we don"t have a hypothesis?"
- Many students said "of course you are going to try to make your experiment agree with your hypothesis since it"s your opinion."

• Jim

- When asked about doing research of other scientific experiments in the library, one student said, "it"s so difficult to know because everybody who writes a book is trying to support their point of view and there are so many different points of view."
- "The overwhelming perspective was that a scientific investigation was merely an exercise in trying to prove your personal beliefs."
- "These students didn"t understand or believe that science is supposed to be objective."

- Diane
- "...a number of students have reported false data just to make sure that it is consistent with the hypothesis they proposed. This is a very normal and natural tendency. No one likes to be wrong."
- Student 1: "my hypothesis was not correct, I must have had some errors in my experiment."
- Student 2: "I didn"t know what to write for a hypothesis, I had no idea what was going to happen in the experiment."
- Student 3: "The scientific method helps me do experiments in the lab. I especially like coming up with my own hypotheses and seeing if I"m right or wrong."

- Diane
- "Being that this student lacked a thorough understanding of the subject, she hypothesized that the greatest amount of growth would be observed in the plant exposed to green light. Her conclusion read as follows;
- "My experiment proves that the greatest amount of growth took place in the plant that was given green light. My initial hypothesis was correct proving that the experiment was done properly."

• Lisa

- "the majority of the students thought that a hypothesis has to be correct and therefore considered the hypothesis to be a problem every time they disproved it."
- "Some students are led by the Scientific Method to believe that Science is largely that practice of constructing a Hypothesis and proceeding to prove that Hypothesis to be correct. Some students do the experiment first and then make a hypothesis to fit their results. Others understand that is not the case and a hypothesis does not always have to be proven correctly."

• Catherine

"When having to state a hypothesis before doing an experiment, my students will focus on making the data fit the hypothesis. I have seen them redo experiments two and three times to make the fit. At the high school level, they really don"t understand that it is okay for the data not to fit the hypothesis. "

- Catherine
- Student Responses
- "I try to make it fit the hypothesis because it is easier that way."
- "I try to make it fit my hypothesis because I want to at least make some of my guess a little bit right instead of being completely wrong."
- "I think that my hypothesis does sways my opinion of the results of an experiment because it is usually almost the same. What I mean is that the results are almost always the same as the hypothesis."

- Lisa
- Responses from Students
- "The hypothesis wasn"t helpful because it was always wrong"
- "I didn"t have any problems with creating a hypothesis because I actually think that"s the easiest part. Because there is no right or wrong answer, but I still don"t think it"s really important"
- "You have to fully understand your experiment in order to get a correct hypothesis"
- "Even though the hypothesis is an educated guess, I got the hypothesis wrong and I had to prove it wasn"t wrong"

- Ernest: Student Responses
- "My hypothesis was\_If you stand too close to the microwave you will get cancer from radiation. The problem is how to about testing the hypothesis? I would love to take an animal of some kind and give it microwaves and see if it dies. I believe that this would be a good experiment on some of my friends to see how they handle stress. Until I learned the scientific method I never realized that I could use it in my life...."
- "I can barely understand what they mean by homeostasis and they want me to create an experiment to find out more about how a cell works. It doesn"t make sense. Even if I make a problem, how am I supposed to know how to answer it with a hypothesis when I don"t know anything."

• Darlene – recalling her student research

• "The scientific method seemed to work for me sometimes as a student because we could often "fake" the data to meet what we thought our conclusion should be. ... My classmates and I would sometimes then work backwards in the lab since we knew what the end product would be. It was almost as if we made up backwards instructions for the lab assignment so that we would get a good grade in the lab."

• Darlene – interviewing a colleague

• "Kirk (a 26 year old chemical development engineer) says; "in theory the scientific method is suppose to work...a problem I see many times in the industry is that a research chemist will formulate a hypothesis, with a certain conclusion already he has in mind...

Whether done on purpose or not, many times the data and analysis will be performed and modified in such a way as to support the original hypothesis."

- Stephen interviewing a colleague
- One high school physics teacher (Teacher E) explained that in his school, he was asked to formulate hypotheses before every experiment.
- "It felt stupid, most of the time, really. You just picked something you think could possibly happen and then try to make it happen. If you picked it right, you felt good. If you didn"t, you felt like an idiot for not knowing any better."
- He went on to explain that some students felt embarrassed if their hypothesis was wrong, and many would later change it when writing the lab reports."

- Christine
- "All teachers I spoke to believe that the scientific method helps to promote student learning in the science classroom."
- "...they felt that the hypothesis serves as an educated guess."
- "My own evidence is that creating a hypothesis leads students into believing that they must prove the hypothesis to be correct."
- Student responses:
- "I just cannot figure out the purpose of forming a hypothesis."
- "there"s no use for what you think the outcome is...,"
- "My prediction does not help me in any kind in my project. It just shows whether I'm right or wrong at the end."
- "if I never did the experiment, how would I know the results.?"
- "trying to predict what will happen, I think it"s useless."

- Christine
- "Based upon my interviews with the students, I would like to question one student further. He said that "experimenting and determining the answers to my questions helps me to learn." He did not say anything about following a procedure. I think he meant actually exploring on his own and not necessarily following the scientific method."
- "He also said that the hypothesis was least helpful because "it does not change any part of your experiment."
- "These statements, I believe deserve and need further explanations. These statements contradict some of the benefits of the scientific method that the teachers say exist."

Some Conclusions

- The requirement of the H in many student investigations is damaging to student's learning in science and about how science is really done.
- Student Investigations may be helped by using an "Inquiry Question (Q)" to drive their experiments and by dropping the H requirement.
- Teachers need to know much more about the processes of science research methodology.

# **NSES Science Content Standards for Grades K - 12**

- Unifying concepts and processes in science.
- Science as inquiry.
- Physical science.
- Life science.
- Earth and space science.
- Science and technology.
- Science in personal and social perspective.
- History and nature of science.

# **Science Inquiry** for a Student Researcher (SR) SR makes observations of phenomena SR poses an Inquiry Question to investigate SR designs an investigation, determines what constitutes evidence and collects data SR summarizes and analyzes data and formulates an explanation SR examines other resources and forms the links to explanations

SR forms logical arguments to communicate explanations

- Is The 'Hypothesis' Harmful and Unnecessary for Student Research?
- Answer: Probably Both

 Harmful: it may lead to belief in pseudo science: experiments are done to verify a previously conceived 'hypothesis', a fallacy that even reputable scientists have sometimes falsely accepted. • Is The 'Hypothesis' Harmful and Unnecessary for Student Research?

• Unnecessary: because both the SM and SI except for the 'Hypothesis" follow very similar protocols and

• any Hypothesis can be converted into a neutral Inquiry Question.

- *"…..For whatever is not deduced from the* phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phenomena, and afterwards rendered general by induction.
- -Isaac Newton, "Principia" 2<sup>nd</sup> ed. 1713