

PROMOTING MORE EFFECTIVE STUDENT QUESTIONS THROUGH  
SPECIFIC QUESTIONING STRATEGIES

by

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July, 2011

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## ABSTRACT

This project addresses the question “Do students understand key scientific concepts better with training in the use of specific questioning strategies?” Students were trained specifically in composing questions using the cognitive domain of Bloom’s Taxonomy, as well as in developing experiments, inventions and models using Cothron’s Four Question Strategy. Students engaged in several inquiry activities, both independently and in large and small groups, to practice these strategies and approaches. The results of this research suggest that there is a strong correlation between employing these strategies to improve students’ questioning skills and the students’ understanding of key concepts surrounding questioning and inquiry.

## INTRODUCTION AND BACKGROUND

### Teaching and Classroom Environment

T.W. Kelly Dirigo Middle School is a public school in Dixfield, Maine, serving approximately 250 students in grades 5-8. Students come from the towns of Canton, Carthage, Dixfield and Peru, in the rural Western foothills of Maine. Over 50% of the school's population receives free or reduced lunch through the federal hot lunch program. The industrial base of the towns relies largely on the pulp and paper industry, as well as logging of timber for lumber. Outside of those industries, other major sectors of the economy are the service and the professional sectors.

Students in the community have varied opportunities for outdoor recreational activities, and many have some experience in hunting, fishing, hiking and skiing, among others. However, for whatever reasons, our students have few formalized opportunities to actually "perform" science prior to the grade seven year of school. And what opportunities they have had are often confirmatory or demonstrative in nature, rather than inquiry or discovery.

With this in mind, my action research project is an attempt to find a way to bridge the gap between students' inexperience with scientific questions and pursuits, and the need for them to know how to think critically and independently, how to pursue scientific questions, and how to present their findings to others. Of paramount importance in developing a plan to bridge this gap is a solid foundation built on inquiry methods, support of questioning skills, and a classroom environment that supports higher level thinking and "thinking like a scientist".

It has been my experience that the quality of student-designed inquiry projects and questions is lacking in my seventh grade students. This seems an opportune time to work with them in developing the skills that will help build and foster independent thought, and true inquiry. Research supports an inquiry structure that allows students to address open inquiry questions.

My primary research question is whether students understand key scientific concepts better with "training" in the use of specific questioning strategies. I will use Anderson and Krothwuhl's 2001 reworking of the Cognitive Domain of Bloom's Taxonomy as a model for student training.

I will also examine the following secondary questions: what are the effects of higher order questioning on students' self-assessment of their understanding of scientific content and concepts?; and is the Four Question Strategy (Cothron, Giese & Rezba, 2000) of scientific inquiry an effective strategy to improve student questioning in my classroom?

## CONCEPTUAL FRAMEWORK

To organize my own thoughts around the topic of improving students' questioning processes through the use of inquiry, I have found it useful to look at the literature in three parts: the process of inquiry, supporting student questions, and classroom climate. This review of the literature will proceed in that fashion.

My first goal is to examine inquiry as a process, and look at why inquiry is, seemingly, ubiquitous in science teaching pedagogy. Next, I look into a variety of



approaches taken by researchers in supporting student questions. Finally I look at classroom climate as an ingredient in the improvement of student questioning.

### Inquiry

Inquiry, according to the National Research Council's Inquiry and National Science Education Standards (2000), calls for students to, first, engage in scientific questioning. Evidence collected by students is considered to be of primary importance in the processes of developing and evaluating their own explanations. Students then formulate explanations they have derived from their evidence to address the questions. Their explanations are then connected to their understanding, and students, finally, must communicate and justify their findings and explanations to their peers. These are the skills used by scientists in their everyday lives, but they are also skills any citizen should have in order to be able to effectively evaluate their own beliefs and understandings of everything from politics, to their gardens or their cars, to their relationships with others. Inquiry in the middle grades (5-8) incorporates these principles, but is less complex than inquiry at the high school level (and, fittingly, more complex than the elementary level).

The National Research Council [NRC] (2000), identifies scientific inquiry as the main avenue for students to learn about the natural world and the methods, techniques and habits of mind employed by scientists in learning about the natural world. Scientific inquiry, the NRC says, has a dual nature: it is the study of how science is conducted by others (scientists) and how explanations are derived through the pursuit and the mechanisms of science; but it is also the body of skills and tools, practices and approaches that students acquire by doing the activities through which they learn about

the natural world. Inquiry is not simply doing a hands-on activity in class, nor is it gleaned from the pages of a book. So what makes the pursuit of inquiry so valuable and important to our students?

It is important for students to reflect upon their thinking, for knowledge integration, and for developing their conceptual understanding. Davis (2003), in a study of 178 middle school students, compared the effectiveness of generic prompts in student reflection on science projects and found that students who were prompted more generically than specifically tended to reflect more productively on their work. For the purpose of this study, generic questions were characterized as being asked to "stop and think" during the course of inquiry. A more specific question equates to the teacher giving more hints to direct students toward the desired result.

In small groups, being asked a broad question such as "where are you now with regards to x" tended to yield more productivity from participants than the more specific "have you completed x?" In some cases, says Davis, the specificity of thought is limiting to creative and critical thinking.

The National Science Education Standards (1996) recognize three levels of inquiry that might be pursued in the classroom: structured inquiry, guided inquiry, and open inquiry.

The structured inquiry model involves a high level of teacher guidance in the process. What many people would identify--and incorrectly so--as structured inquiry, would be the textbook/ "cookbook" lab experiences most adults remember from school. The procedure, setup, materials, observations, results and conclusions of everyone performing the lab are expected to be the same, and they are all proscribed by the

cookbook. Conversely, the “real” or authentic model of structured inquiry may be guided by a teacher’s experience and questioning, but allows the students’ curiosity and questions to direct the inquiry.

Guided inquiry requires somewhat more independence. Students receive some guidance from the instructor, but the conduct of questioning and experimental design may be driven largely by the students. In some cases it is logical to start students at the lowest level of involvement (structured inquiry) for a short time to become accustomed to lab procedures and safety, but to move them to the guided inquiry model as soon as practicable. Progression is not necessarily the goal of inquiry but it is desirable to provide students opportunities to pursue inquiry on various levels. So, although a less teacher-involved level of inquiry may seem more desirable due to the level of student autonomy, what level to choose should depend most upon what needs to be accomplished, student needs, and what depth of comprehension is necessary (Banchi & Bell, 2008).

Open inquiry does not suggest that students should be set adrift on a sea of observation, left to develop investigations without context or guidance. The teacher’s role in this is to facilitate, focus, challenge and encourage students in their investigations. (Zion & Sadeh, 2007). In open inquiry, students are responsible for generating research questions, designing the research that will help them answer the questions, conducting the research, collecting the data, analyzing and interpreting the data, presenting their findings, and following up on new questions that arise from their initial research: in short, students do science. They become the scientists.

Though guided and open inquiry models might be somewhat daunting for teachers to implement, Barrow (2008) provides a workable approach to a four-question

model that helps students to attack inquiry problems. The questions are largely procedural (“What materials are readily available for conducting this experiment?; How can you change the set of materials and the process?; How does baking soda react with vinegar?; How can you measure or describe the response of the baking soda when mixed with the vinegar?”) but go a long way to help students organize their thoughts and their procedure.

Foote (1998), looks at higher order questions and student understanding of concepts. The author suggests that educators' reliance on the constructivist paradigm may be misguided. The research is largely inconclusive that student-developed questions are any more effective in concept attainment than using questions that have been provided by teachers. However, Foote's study does suggest that students will benefit from asking their own higher order questions and working with the instructor as a facilitator in creating these questions.

Cowens (1999) illustrates several specific strategies to employ Bloom's Taxonomy in developing questions. He presents a number of action verbs to be used to access the different cognitive levels of Bloom's Taxonomy in a specific lesson on whales, but then is careful to say that these strategies can be applied to nearly every other topic imaginable. For example, in Knowledge level inquiries, students would use such active verbs as define, label, relate, memorize, record, and recall, among others. Comprehension inquiries might include verbs such as explain, describe, and recognize. Application inquiries might require students to illustrate, interview, or schedule. Analysis inquiries could ask students to debate, compare, or diagram. Synthesis inquiries may have students compose, propose, or organize. Finally, evaluation inquiries could have students predict,

judge, and estimate. This type of approach should lead to students having a stronger grasp of factual knowledge to better cement conceptual understanding.

### Supporting questioning

The main purpose of my action research project is to help students improve their skills in developing scientific questions. It seems sort of a chicken-and-egg question: which comes first, good questioning or solid conceptual understanding? Much of the literature suggests that developing strong skills in the area of questioning can be beneficial to the development of concept attainment and understanding. Student-developed questions around lab activities have been shown to improve student understanding of concepts (Polacek & Keeling, 2005) among college biology students. In this study, students composed three specific, concrete pre-lab questions due before beginning a lab. The professor then provided written comments on the questions, with full credit being awarded as long as the questions weren't "meaningless" in the context of the lab. In the post-lab phase of questioning, students were required to devise one new question that came up as a result of their lab experiment, and propose a way of testing the new question. This practice, according to the authors, "allows students to ask better, more critical questions". Student questions during or after pre-reading about lab activities, coupled with written feedback on their questions from the instructor, resulted in an improvement in the quality of student questioning (Keeling, Polacek & Ingram, 2009). It should be noted that this improvement in questioning ability did not, however, predict improved achievement in the course, based on their lab grades and the final grade for the course.

In order to be able to ask good questions, from a scientific standpoint, students need training. As educators, we may have certain perceptions and misconceptions about our students' experiences and capabilities, and may have higher expectations of their questioning capabilities. Having a structure in place whereby students share their interests and preliminary questions with each other, and then work with teachers and librarians to help them further narrow their questions can be extremely beneficial to developing good research questions (Hertel, 2004). This is achieved by, first, addressing topic focus in both the design and the focus of assignments. Then, students must be informed of ways to find background knowledge prior to topic focus, and suggesting sources to the students. Modeling different question types is another important step in this process. Students should also be educated and forewarned about the uncertainty and frustration of research, along with the caveat that topic focus often changes multiple times during the research process. Finally, it is important for students to hand in a written proposal early in the process in order to identify their research focus.

Though designed to help address the problem for college undergraduates, it is quite apparent that there are aspects to this approach that would be useful even on the middle school level. Both teachers and librarians should be able to point students in the direction of resources that will likely help them find valuable information on their topics.

The idea of improving student questions, and encouraging "higher order questioning" comes from Benjamin Bloom's Taxonomy (1956). Bloom's work suggest that there is a hierarchical nature to the cognitive domain of learning, beginning with knowledge of simple facts, and moving upward in complexity through comprehension, application, analysis, synthesis, and evaluation. While Bloom's Taxonomy moves beyond

just the cognitive domain (affective and psychomotor domains are also discussed), this action research project applies solely to the cognitive domain.

In later years, Bloom's associates, Anderson and Krathwohl (2001) re-worked the cognitive domain. Some relatively small changes were made: the activities associated with Bloom's cognitive levels were re-stated in verb form, thus becoming easier to assess; and the two top levels, synthesis and evaluation, were switched, with the explanation that creation requires a higher level of cognitive attainment than does evaluation. But perhaps the most important change made by Anderson and Krathwohl to Bloom's original vision was the incorporation of the dimensions of knowledge (factual, conceptual, procedural and metacognitive) into the cognitive processes. Though this action research project does not address the dimensions of knowledge, they further flesh out the picture of cognition, allowing educators to see more varied shades of understanding in their students. This aspect of Anderson and Krathwohl's work bears further attention as a means of better assessing student understanding.

An exploration into inquiry and questioning looked at a program called Biomind, where students were trained in four models of inquiry, and then asked to carry out open inquiry projects (Zion & Sadeh, 2007). The researchers found that different students functioned more effectively with different types of models. Some students, generally more curious and confident in their inquiry skills, seemed to produce good results when they used sequential and semi-sequential models of inquiry, i.e., starting with one research question, performing an investigation, and developing one or two new questions. On the other hand, students who were less curious, or possibly less confident in their science abilities, seemed to do better with a parallel or semi-parallel model, whereby they

began their investigations with multiple questions, which could lead to multiple secondary questions. Preliminary results suggest great potential in this approach for differentiation among students.

A classroom climate where students are encouraged to think, discuss, explore, justify and present their own thoughts about science, and where the teacher models the attributes of scientist and scientific inquiry, will encourage critical and creative thought. Students who have the benefit of this type of class setting will better understand the context in which real science occurs, and the procedures carried out in the pursuit of science.

## METHODOLOGY

The purpose of this project was to determine whether students would understand key scientific concepts more effectively with direct training in two specific questioning strategies. Specifically, my students were trained in the cognitive domain of Bloom's Taxonomy (1956), with special regard to the work of Anderson and Krathwohl (2001) and the factual, conceptual, procedural and metacognitive dimensions of knowledge. The other strategy I used to train students in higher order questioning was the Four Question Strategy (Cothron, et.al, 2000), where students designed experiments based on the materials and equipment they had at hand, and established how variables could be manipulated to find out more about the natural world.

It was my assumption that Anderson and Krathwohl's (2001) re-working of Bloom's work would be useful in giving students the terminology needed to describe what they were doing. Being able to identify the steps and levels of their own cognition



would give them a common language with which to communicate about their thinking and their questioning. My thought was that these are important first steps for students in learning about their own thinking: looking at the questions they ask, and seeing what actions they are using in their questioning, they should then be able to take inventory of the types of questions they are asking, and, where appropriate, find ways to ask more substantive and useful questions. As students began their individually chosen Free-Form Friday projects (see Interventions section for further explanation), during their early cycles of independent inquiry projects, they all received training in the cognitive domain of Bloom's Taxonomy. They learned about the levels of questioning, and the action words that describe or indicate them. As part of their training, they were asked to sort and characterize pre-written questions into Bloom's levels, as well as look for the specific cognitive levels in questions written by their peers.

The Four Question Strategy as outlined by Barrow (2008) is a procedure whereby students designed their inquiries around four questions:

1. What materials are readily available for conducting experiments on my subject?
2. How can I change the set of materials to affect action?
3. How does my subject act or react?
4. How can I measure or describe the response to change?

The main benefit of this approach to students was realized in facilitating student discussions about their inquiry activities. It does not seem a stretch to think that these improved discussions might also have improved the levels of cognition at which students designed their inquiries and asked their questions, with prior training in cognition, experimental design and methods of inquiry. Although the assessment of their use of this strategy occurred in March, they had already used this strategy indirectly, beginning early

in the year. In fact, many of our class investigations incorporated this strategy, but it is likely the first time most of them had employed it on their own. The Four Question Strategy training was implemented more directly through the students' Free-form Friday projects, as outlined later on in this paper in the Interventions section.

My intention was for the students to employ the Four Question Strategy in the design of an experiment, invention or model that would help them better explain an aspect of the natural world. Their findings were presented to their classmates as a culminating event for this module.

### Participants

My seventh grade science students were the focus of this action research project. Many of them participate in various activities concerned with the natural world, including hunting, camping, canoeing, skiing, and gardening or farming with their families, among others. However, as a result of intensified concentration on reading and mathematics in the elementary grades in recent years, these students have had little experience with the conduct of science or even informal experimental skills.

Because I am interested in improving the questioning skills of all my students, the participants in this project were chosen from a representative sample of my students, covering a span from students in a life-skills program who come to class with educational technicians, to students who are members of the pre-Algebra class, to students identified as gifted and talented in science, and everyone in-between. The only effort outside of class that I asked of participants was the initial orientation meeting for the project (10-15 minutes), and follow-up interviews after each of the treatments, where participants were each interviewed once, for a total of about ten minutes. All of my students, whether

participants in the research or not, completed the same trainings, assessments, self-surveys, and class assignments. All of the treatments and activities associated with this study were incorporated in my curriculum.

I hoped to have about twenty-four participants drawing equally from my four sections of seventh grade classes, but ended up with fifteen volunteers. All students were invited to volunteer to be participants in this research project, so the population of the sample represented just over 20% of my students. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

### Interventions

This project aimed to test the effects of training students in Bloom's Taxonomy on the cognitive level of their questioning. My students first completed a self-inventory to determine baseline levels of their ability to ask useful scientific questions on each of the levels of the cognitive domain of Bloom's Taxonomy. After this assessment, we completed a mini-unit on the cognitive levels and applied that to the types of scientific questions they ask. Students viewed several demonstrations and videos chosen to elicit scientific thought and questions, such as time lapse videos of decomposition and glacial movement. Then they developed questions on different levels, and learned to sort and categorize different types of questions, based on the levels of cognition they required to be answered and their scientific value.

Also for this project, I taught my students the Four Question Strategy of inquiry to help them approach scientific inquiry in a more focused manner and to organize their

inquiries. After having completed the previous module on cognitive levels and levels of questioning, students completed a module where they designed their own inquiry activity using the Four Question Strategy. There is already a structure in place in my classroom that allows for open inquiry on the parts of my students, and for them to use this structure. In my Free-Form Friday program, students are free to choose scientific topics that interest them, regardless of what we are studying at a given time. It has always been a goal of mine to require each student to design an experiment or invention or create a model through the Free-Form project, and this seemed to be an ideal opportunity to employ this strategy.

By this time in the year, each student had already completed at least one Free-Form Friday project, where they had: identified a scientific topic of interest to them; developed three to five research questions they hoped to resolve about their topic; researched their topic, which may or may not have included designing experiments, building models or invention; kept a log, or journal about their project; created a presentation to share their findings with their classmates; and presented their findings, along with answering their peers' questions about their findings.

At this point, students should have had familiarity with the process of the conduct of inquiry, and had had varying levels of success with their projects. Some had frustrations in designing experiments, and some may have had an easy ride, due to the questions they asked. During the cycle on which they were assessed for this study, students were trained explicitly in the Four Question Strategy, and were required to either conduct an experiment, create a model, or create an invention, using the steps of the strategy as their guidelines.

After each of these treatments, students re-took the original assessments. Though not all of my students' responses to these assessments were used for reporting purposes, they were an important part of the learning process for every student, and also for informing my practice. Therefore, all students were required to complete them and they were used by me, outside of the purview of this project, for classroom assessment purposes.

## DATA AND ANALYSIS

My methods for determining the effectiveness of these interventions largely relied upon establishing baseline measurements before treatment, administering the treatments, and then re-taking or comparing a second administration of the original measurement tools as the post-treatment assessment. The pre- and post-treatment measurements were administered to all of my students, and the participants were also interviewed about their attitudes toward their own efficacy, confidence, and understanding of the content. The participants in my action research project were a representative sample of students from all of my classes, selected from a pool of volunteers. Table 1 summarizes the data collection strategies I used in this project.

Table 1  
*Triangulation Matrix*

Primary Question: Do students understand key scientific concepts better with training in the use of specific questioning strategies?			
Secondary Questions	Data Sources		
1. What are the effects of training in higher order questioning on students' understanding of scientific content and concepts?	Pre-treatment assessment: pre-test of ability to generate useful scientific questions at all levels of the cognitive domain of Bloom's Taxonomy	During instruction: Teacher observations of sorting and classification activities	Post-treatment assessment: self- and instructor assessment of pre-test questions  Student interviews
2. Is the Four Question Strategy of scientific inquiry an effective strategy to improve student questioning in my classroom ?	Pre-treatment assessment: pre-test of ability to generate testable and worthwhile questions	During instruction: Teacher review of student progress logs	Post-treatment assessment: teacher assessment of ability to generate testable and worthwhile questions  Student interviews

In addition to the pre- and post-treatment surveys students completed as part of the Bloom's Taxonomy training, I also observed their input and their participation in the sorting and classification activities. My observations were anecdotal and qualitative in nature, as I looked for evidence of ongoing growth and improvement in the students' questioning skills. These observations occurred during class brainstorming and discussion activities centered around activities in which students sorted and classified each others' questions by the types (levels of the taxonomy they addressed), and the usefulness (whether it was new and/or useful, versus being readily looked up in a reference library

or online) of their questions. One entry from the blog I created for reflective practice directly mentioned the changes I observed in my students:

There have been some interesting outcomes of this activity. First, and merely anecdotally, I have already noticed some improvements in the cognitive processes of my classes. Today's activity had my students watching time-lapse videos of Alaskan glaciers receding. Some examples of questions students asked were:

- what temperatures do glaciers need to be in order to melt?
- what was the general temperature over the time period of the videos?
- what causes a glacier to change shape/form?
- how does the melting of glaciers affect wildlife?
- is there a way to slow the melting process?
- can we create scale models of glaciers to understand them better?

(Reflective journal entry, 3/2/11)

The questions I asked students to answer prior to and following the Bloom's Taxonomy training they received were designed to do two things. First, I wanted to know how the training affected their ability to ask questions on each level of the cognitive domain. I provided them a list of topics from which they could choose, and about which they would ask one scientifically important question about which they would like to find an answer. They also had the option of choosing their own topics. In either case, the questions generated needed to pertain to whichever topic they chose. Then I listed each of the levels of the cognitive domain, with a brief and simple description of what is associated with that level and an example of a question on that level, i.e., "remembering

deals with facts, lists and definitions; asking someone to list the parts of a microscope would be a ‘remembering’ level question”.

I also hoped to assess whether the Bloom’s Taxonomy training affected their ability to examine and refine their own questions. Therefore, for the post-treatment assessment on the Bloom’s Taxonomy module, I asked them to look at the original assessment they completed and reflect on their original questions. They were asked to determine whether each of the questions they asked: 1) fit the cognitive level it had been written to address; 2) was a scientifically important question, and: 3) what improvements or changes they would make (if any) to satisfy the first two questions.

The next module we completed was in the Four Question Strategy. As I outlined previously in the Interventions section of this paper, my students already had some experience in designing scientific questions and procedures, in varying degrees. At this point, students were trained specifically in the use of the Four Question Strategy. This strategy asked students to observe a condition of interest to them and consider a question they could address. Then they were asked to look at the materials available to them, and to consider how they could use those materials and/or change the condition, by designing an experiment, an invention or a model. Finally, they were asked to present their findings and explain to their classmates what they observed and discovered.

### Analysis

This study examines whether, through the use of specific strategies that focus them on cognitive levels of their scientific questioning and on a simple and specific



approach to designing experiments, inventions and models, students would improve their understanding of these key scientific concepts.

### Impact of Bloom's Taxonomy Training on Students' Questioning

My first focus question was to determine whether specific training in the cognitive domain of Bloom's Taxonomy, and the activities associated with that training, would improve my students' ability to ask appropriate and useful questions on the different cognitive levels.

On five of the six cognitive levels, students showed positive percentage changes of at least 24% in the "Above and beyond" and "Fully acceptable" categories combined. The only cognitive level registering lower (actually a -1.4% change) was the understanding level. Beyond that, for each of the cognitive levels, eight to eleven of the students either: kept a good question; changed their questions to be more appropriate or effective; or made insubstantial changes to maintain already appropriate or effective questions. Conversely, either three or four students failed to improve a question that should have been improved, or inappropriately changed a question to become less appropriate or effective. Only question two, regarding the understanding level, was inconsistent with the trend, and showed a small (1.4%) decrease in appropriate responses between the pre- and post-treatment assessments. It is entirely possible that, having concentrated so heavily upon this cognitive level, that students looked at their initial responses and were overly confident. It is conceivable that they unconsciously chose not to make needed changes on the understanding level because they felt a more urgent need

to change questions on the higher cognitive levels. Table 2 and table 3 summarize these results.

Another possible explanation for this decrease on the remembering cognitive level from pre-treatment to post-treatment assessment is that students may have already been asking effective questions at that level prior to the assessments. If they were already proficient at asking understanding level questions prior to the assessments, a very small decrease from pre- to post-treatment assessment doesn't seem unreasonable. And the change is small enough as to be almost insignificant.

Table 2  
*Pre-Bloom's Taxonomy Treatment Assessment*

Cognitive level of questioning	4-Above and beyond	3-Fully acceptable	2-On the road	1-A little lost	0-Failure to launch	Mean Student Score on Item
Remembering	2	5	6	2	0	2.47
Understanding	4	8	2	1	0	3
Applying	2	5	6	2	0	2.47
Analyzing	1	7	5	0	2	2.33
Evaluating	2	5	5	3	0	2.4
Creating	3	3	4	5	0	2.27

Table 3  
*Post-Bloom's Taxonomy Treatment Assessment*

	Main- tained a good question	App- rop- riately im- proved ques- tion	In- sub- stan- tial change to ques- tion	Chan- ged ques- tion in- approp- riately	Should have changed question but didn't	% Fitting Criteria, Pre- treatment	% Fitting Criteria, Post- treatment	%Change ( ) denotes negative value
Remember- ing	5	3	2	1	3	46.7	71.4	24.7
Under- standing	6	5	0	0	3	80	78.6	(1.4)
Applying	4	4	2	1	3	46.7	71.4	24.7
Analyzing	4	5	2	0	3	53.3	78.6	25.3
Evaluating	8	0	2	1	3	46.7	71.4	24.7
Creating	5	4	2	1	2	40	71.4	31.4

Table 4  
*Individual Students' Pre- and Post-Bloom's Questions*

Pre-Bloom's Treatment Question	Post-Bloom's Treatment Question	How change was characterized by scorer
What is the difference between a flash drive and an SD card? (understanding)	Is there a difference between a turtle and a tortoise? (understanding)	Maintained a good question
How can people make the internet an easier place to navigate? (creating)	How can we prevent turtles from thinking plastic bags are jellyfish? (creating)	Changed question inappropriately
What is the difference between a deciduous forest and a tropical rain forest? (understanding)	What are the differences between a deciduous forest and a tropical rain forest? (understanding)	Insubstantial change to question
Could I analyze materials and see how much sunlight they take in? (analyzing)	How can solar energy be used to make everyday life better or easier? (analyzing)	Appropriately improved question
How can I find and measure the amounts? (creating)	How can I create a small scale model solar panel to get the effect of a full solar panel? (creating)	Appropriately improved question
How can I create my own ecosystem in my own back yard? (creating)	How can I create an ecosystem in my back yard? (creating)	Should have changed question but didn't

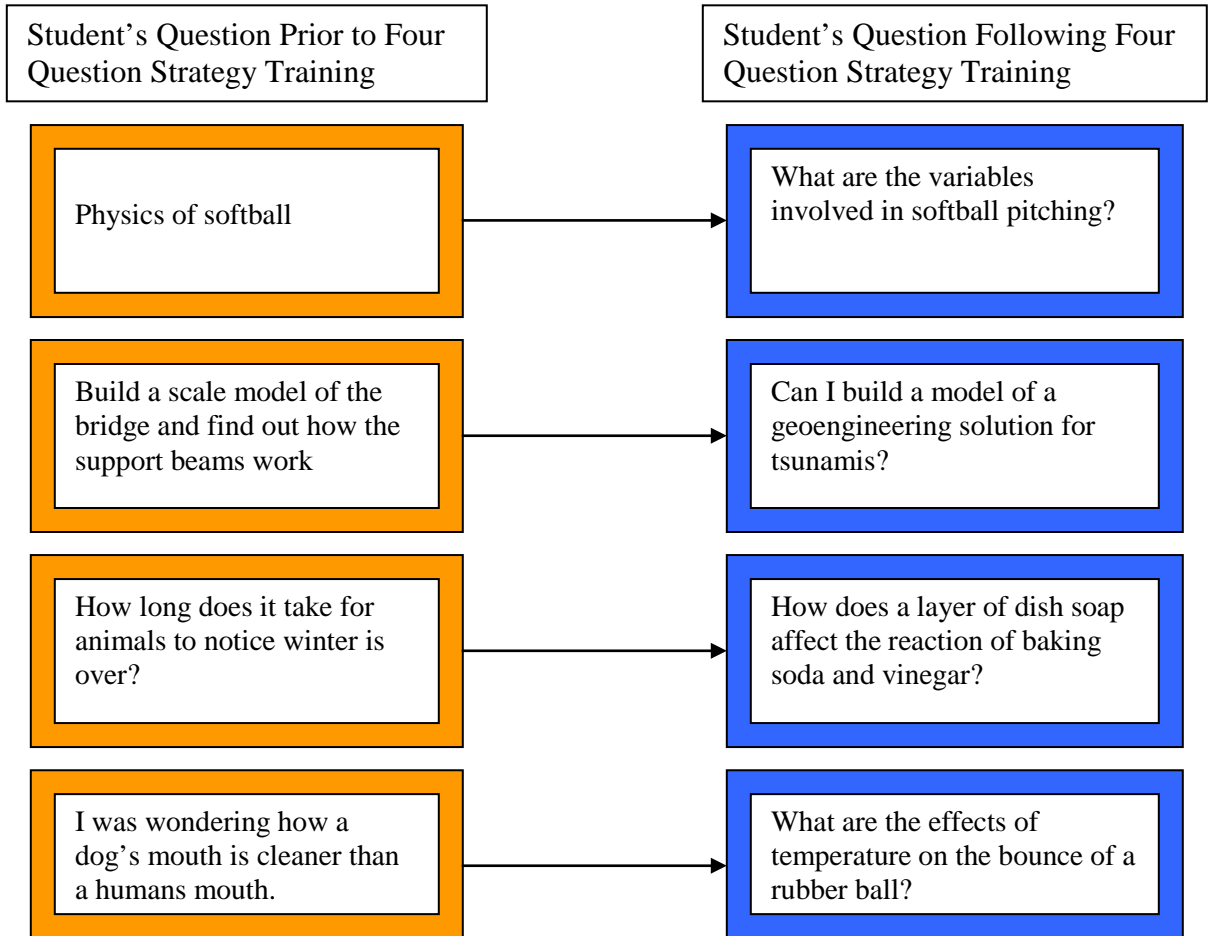
In Table 4, responses from individual students' pre- and post-Bloom's Taxonomy assessments are shown side-by-side. The third column of this table is included to illustrate the designations or assessments that I assigned to the changes they made. It is useful to note that some students maintained their original topics, while some changed them from the first assessment to the second.

It is evident that specific training in the cognitive domain of Bloom's Taxonomy, and the activities associated with that training, improved my students' ability to ask appropriate and useful questions on the different cognitive levels. Questions 1, 3, 4, 5 and 6 from the pre- and post-treatment assessments strongly corroborate this statement, with positive percentage changes of at least 24% on the highest two designations ("Above and beyond" and "Fully acceptable").

#### Student Use of the Four Question Strategy

My second focus question was to determine whether providing students training in the Four-Questions Strategy would help them to improve their understanding of designing a useful experiment, inventions and models, and to improve student questioning and inquiry.

Between the pre-treatment assessment, where students identified an experiment, invention or model they thought they could reasonably perform, and the post-treatment assessment, where they actually presented the results of their efforts, students demonstrated appreciable improvement. In the pre-treatment assessment, many students' perceptions of projects they could actually perform were skewed. Some examples included building a model of the bridge spanning the Androscoggin River, between Peru and Mexico, Maine; comparing the cleanliness of a dog's mouth and a human's mouth; creating an experiment to explore the physics of a curveball; and creating a model of a gymnast's body to demonstrate the physics of the parallel bar. Some of these were more attainable than others, but students most definitely streamlined their procedures and thought processes after having worked with the Four Question Strategy.



*Figure 1.* Comparison of Pre- and Post Treatment Questions for Four Question Strategy.

It is apparent from the student examples, found in figure 1, that some of the initial questions were a bit of a reach, either intellectually or from the standpoint of available resources. They each have their own scientific value, and reflect interesting thought processes, but for the time and technological constraints of these projects (of which the students were aware from the outset) the students were a little off the mark.

After some firsthand experience in using the Four-Questions Strategy in classroom activities, the students seemed to grasp the importance of developing questions that are “doable”. One of the classroom activities illustrating how to use the Four - Questions Strategy was a team activity where students were given five sheets of 8.5”x11”

paper and a foot of Scotch tape. They were asked to design and build a free-standing tower as tall as they could (Figure 2).

When presented with the materials for this activity, I asked students the question: what materials do we have to make a paper tower? Then I asked the students to think about ways they could change or alter the materials they had to help them build a paper tower, and, as a group, decide the ways they would alter their materials. The groups came up with various ways they could fold, cut, tear, crimp and connect the paper, as well as universally deciding that one foot-long piece of tape was less desirable than numerous smaller pieces. Finally, the groups tested their ideas and measured the results of altering their materials. This was a fun and engaging way to employ the steps of the Four Question Strategy, and to see that the approach could be effective and useful.



*Figure 2.* Paper Tower Activity.

Following the treatment, I conducted interviews with half of my respondents ( $n=8$ ) to determine their thoughts about the efficacy of the Four Question Strategy. The first question I asked was “Before this project, had you ever made an invention, designed an experiment or made a model of anything before? (If so, please describe what you did.)” In general, students had some limited experience in creating inventions, or performing experiments. The most extensive prior experience with creating models that students related was having created the old standby, baking soda and vinegar volcanoes. Most of the inventions and experiments students had created and performed were of the household variety: making items that would help with a chore around the house, or comparing consumer products. It is encouraging that students are getting some opportunities for these activities either in school at younger grades, or at home. It is discouraging, however, that students don’t seem to recall any of these opportunities happening beyond fourth and fifth grades.

The next question asked “Did you worry about doing this project when you first heard about it? (If so, please explain what your worries were.)” Students’ answers to this question indicated some mild initial anxieties, mostly based in their worries that their inventions, experiments or models wouldn’t work when they were completed. Overall, the attitude toward this project was positive and mild excitement. Some students indicated the Four Question Strategy alleviated some of the anxiety they experienced at the outset; having a focused approach seemed to help their confidence.

When asked “How do you feel about inventing, experimenting or making models? Have your ideas improved? Do you understand how to set these things up better now?”, students’ attitudes toward inventing, experimenting and creating models was generally



positive. They credited the Four Question Strategy with helping them make their ideas more specific, helping them with experimental design, improving the creativity of their ideas, and with improving their understanding.

Finally, when asked “Do you think you’ll use what you’ve learned about the four question strategy and designing experiments, inventions and models in your future?”, a number of students indicated an interest in pursuing career paths that would utilize experimental design, invention, or modelling (notably architecture, engineering and radiology). They readily recognized the utility of this approach to their future goals. Others also saw that, even though they were not considering future careers in STEM fields, they would still be involved in science classes, and that the Four Question Strategy would be of use to them.

After completing the Four-Questions Strategy training, each of the students’ post-treatment questions was adequately developed, and resulted in an experiment, invention or model that reflected a deeper understanding of the topic they had chosen. This was evidenced by the students’ presentations of their projects to their peers. Each student ended up presenting an experiment, invention or model that was adequately and appropriately developed from the standpoint of identifying appropriate topics, isolating variables, measuring the effects of manipulating variables, and presenting their findings to their classmates.

## INTERPRETATION AND CONCLUSION

The purpose of this project, once again, was to find out whether specific training in questioning strategies would help my students understand key science concepts better.

I also hoped to find out whether learning about, and being able to identify, questions at different levels of the cognitive domain would help students to ask more effective questions. Further, I attempted to determine whether employing a specific inquiry strategy—the Four Question Strategy—is an effective practice for student inquiry.

Student responses from the post-treatment interviews supported the assertion that the training in Bloom’s Taxonomy improved their ability in asking appropriate and useful scientific questions. The second question, in particular, was very telling. I asked “Do you feel your questioning skills improved from learning about the cognitive levels?” Student replies were unanimously affirmative, to different degrees. Some thought the improvement they experienced was relatively small (“I think they improved a little but not that much”), while others were described a more marked change (“Yes, a lot. I can actually ask useful questions.”)

From the beginning of the year, I mentioned that my action research project would be a part of what we did during the school year. I told them up front that I would be conducting research into the effects of some different strategies on improving their questioning. It is conceivable that their knowledge of this process helped to focus their attention on questioning, which might have inflated the effects we witnessed. Either way, I don’t suspect this is an outside influence or “noise”. It is a part of the preparation and the classroom program, so when viewed in that light, it is just another effect of the treatment.

Students’ performance on the second item of the Bloom’s post-treatment assessment temporarily caused me to question my results, where students’ understanding questions were slightly less appropriate in the second round than they were in the pre-

treatment. The percentage change was negative, but just over 1%. Not a big change, but very different from the other five cognitive levels' positive percentage changes of at least 24%. My suspicion is that they let down on this lower level, concentrating on the higher order questions.

My observations of and conversations with students during the process of creating this project bore out the assertion that the Four Question Strategy helped them focus, hone, and simplify their projects. They were able to identify their assets, look at how they act, identify ways they could alter how they act, and measure the difference in how they acted when those changes were made. My discussions with students, and questions they asked me while they were preparing their projects illustrated to me how their approaches to performing science were improving.

It is also apparent that providing students training in the Four-Questions Strategy helped them to improve their understanding of designing useful experiment, inventions and models, and to improve student questioning and inquiry.

It is clear to me that the treatments I used in my classroom—specifically, training in the cognitive levels of Bloom's Taxonomy and the Four Question Strategy—were successful in improving my students' understanding of key scientific concepts and in helping them focus on valuable scientific questions. What is unclear at this point is whether there are more effective approaches, and whether there are more effective ways to present these tools. These treatments have been a point of embarkation on what promises to be a very long journey. I suspect I'll be using some combination of these strategies for the rest of my days in my classroom, and building upon the findings of this action research project throughout my career.

In retrospect, I might choose to use different methods of data collection; it would be nice to have some more quantitative data to further verify that the treatment was successful. But, overall, I am confident for my own purposes that what I have observed and what my students have reported is an honest and accurate assessment. We—my students and I—are in agreement that the Four Question Strategy served them well in improving their questioning skills.

### VALUE

While reflecting on the value of this action research project, I was naturally drawn back to the essay I wrote three years ago, as a prospective student for the MSSE program. It traces my own personal journey from the wide-eyed wonder I experienced as a young child, through formalized education, where the book became important, to where I was as a science educator at the time of writing the essay. One line stood out most to me as the reason for why I chose this topic, and for why it is so important to me: "In junior high school, science became more academic, and the lessons that endured were not necessarily the ones my teachers intended to leave us with."

This is the part of a student's journey in science that I try hardest to avoid: leaving students with the feeling that what they do doesn't matter.

I am certain that there are unintended lessons that crop up in my class, and I have no doubts that some of the things my students remember best will not be the curriculum. But what is important is the teaching of a thought process; a way to approach questions and problems that will serve students throughout their lives. Whether they choose to enter

a field of science or not is largely inconsequential. Of greater importance is whether they can glean enough information to make informed choices and be informed citizens.

Through my pursuit of this action research project, I have witnessed my students beginning to approach problems and questions in new and more pertinent ways. When seventh graders come to me, they already have some fairly deeply ingrained ideas, and a hefty amount of misconceptions. It verges on the impossible to undo all of the erroneous information and falsehoods they've absorbed by seventh grade. However, training students in questioning using Bloom's cognitive levels and teaching them to set up experiments, inventions and models with a focused approach such as the Four Question Strategy allows them to overcome the intimidation of daunting projects, and allows them the satisfaction and gratification of learning something from what they do.

I teach my students little bits about brain chemistry, and how the brain seeks patterns and releases endorphins as we learn, creating a pleasurable experience; that learning is actually fun, and something the brain wants to do. It is usually when school tasks are tedious, meaningless or excessively stressful that education becomes painful. By learning to use these tools they were taught as a result of this action research project, my students have more pathways to avoid the pitfalls of academia.

In order to maximize the chances that these practices will become more ingrained, I plan to implement these strategies much earlier in the year. In past years I have begun with a mini-unit on Multiple Intelligences theory. It might be a perfect vehicle for teaching Bloom's Taxonomy, while pointing out different cognitive levels of questions along the way: name the different intelligences; how can you create a visual

representation of the different intelligences present in this class?; how do the different intelligences support each other, and function together?, etc.

I will probably then present the Four Question Strategy, using very simple objects to demonstrate the principles, and employing the four questions to guide their inquiry. Beginning the year by using these two approaches, and consistently returning to them throughout the year, may provide students a solid framework for future pursuits in science, whether it be as high school students, college students, professionals in a scientific field, or simply as well-informed citizens.

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APPENDICES

APPENDIX A

PRE-TREATMENT ASSESSMENT: COGNITIVE LEVELS OF QUESTIONING

## Appendix A

### Pre-treatment Assessment: Cognitive Levels of Questioning

This assessment is to look at your ability to ask important scientific questions on different levels. You will choose one of the scientific topics I have provided, or a topic that you choose.

Try to write useful scientific questions (something that would give us important information about the topic). You will also be writing these questions on different cognitive levels. Questions at different cognitive levels require a person to think in different ways and on different levels to answer them.

For each type of question, I have provided an example of a question of that type.

Choose one of the following topics to be the focus of your questions and circle it, or fill in your own topic in the blank space:

-photosynthesis

-ecosystems

-the water cycle

-water quality

-other (please write in the blank)\_\_\_\_\_

Note: all of the questions you write should be about the topic you have chosen.

Directions: Please write one useful scientific question about the topic you have chosen for each cognitive level.

#### Cognitive Level 1: Remembering

Remembering deals with facts, lists and definitions.

“What are the different parts of a microscope?” would be a “remembering” level question.

#### Cognitive Level 2: Understanding

Understanding deals with making meaning from different pieces of information; actions include classifying, comparing, interpreting, summarizing, inferring or explaining.

“What are the differences between a compound light microscope and a stereoscope?” would be an “understanding” level question.

### Cognitive Level 3: Applying

Applying deals with carrying out a procedure, or implementing a plan.

“How can I use a compound light microscope to examine the bacteria in my bathroom sink?” would be an “applying” level question.

### Cognitive Level 4: Analyzing

Analyzing deals with breaking concepts and materials into parts, and seeing how those parts work together in a system, or for a purpose; actions include organizing, distinguishing between parts, attributing, and organizing.

“How can various protozoa be organized by their roles in the food web?” would be an “analyzing” level question.

### Cognitive Level 5: Evaluating

Evaluating deals with making judgments based on standards and criteria. Some of the actions associated with evaluating are choosing, deciding, comparing, concluding, or inferring.

“Which protozoa are best suited for survival in our local freshwater streams?” would be an “evaluating” level question.

### Cognitive Level 6: Creating

Creating deals with putting pieces together to create a complete, functional whole.

Actions include reorganizing, designing, assembling, constructing, or developing.

“How can I create a self-sustaining habitat that supports a variety of protozoa?” would be a “creating” level question.

APPENDIX B

POST-TREATMENT ASSESSMENT: COGNITIVE LEVELS OF QUESTIONING

## Appendix B

### Post-treatment Assessment: Cognitive Levels of Questioning

Now that you have completed some training in Bloom's Taxonomy and levels of cognition, you probably have a better understanding of the levels of questioning, and of what makes a useful science question.

You are now being asked to assess the questions you wrote before starting this module. In the spaces below, you will be asked to re-write the questions you came up with before we studied Bloom's Taxonomy. Then you will be asked to determine whether your questions fit the cognitive levels they were written to address, and were scientifically important or useful. Then you will be asked to describe any improvements or changes you would make to your questions to make them fit the cognitive level better, or to be more scientifically useful or important.

#### Remembering Question

Write your original "remembering" level question here:

Did your original question fit the "remembering" level of cognition? (Just answer yes or no; you can provide details in the next question):



How could you improve your “remembering” level question to better fit the cognitive level, and/or be more scientifically useful or important?

#### Understanding Question

Write your original “understanding” level question here:

Did your original question fit the “understanding” level of cognition? (Just answer yes or no; you can provide details in the next question):

How could you improve your “understanding” level question to better fit the cognitive level, and/or be more scientifically useful or important?

#### Applying Question

Write your original “applying” level question here:

Did your original question fit the “applying” level of cognition? (Just answer yes or no; you can provide details in the next question):

How could you improve your “applying” level question to better fit the cognitive level, and/or be more scientifically useful or important?

### Analyzing Question

Write your original “analyzing” level question here:

Did your original question fit the “analyzing” level of cognition? (Just answer yes or no; you can provide details in the next question):

How could you improve your “analyzing” level question to better fit the cognitive level, and/or be more scientifically useful or important?

### Evaluating Question

Write your original “evaluating” level question here:

Did your original question fit the “evaluating” level of cognition? (Just answer yes or no; you can provide details in the next question):

How could you improve your “evaluating” level question to better fit the cognitive level, and/or be more scientifically useful or important?

### Creating Question

Write your original “creating” level question here:

Did your original question fit the “creating” level of cognition? (Just answer yes or no; you can provide details in the next question):

How could you improve your “creating” level question to better fit the cognitive level, and/or be more scientifically useful or important?

APPENDIX C

POST-BLOOM'S TAXONOMY INTERVIEW QUESTIONS

## Appendix C

### Post-Bloom's Interview Questions

As a part of agreeing to be a research subject for my project, you indicated that you would be interviewed following one of the activities we completed. I am now asking you to answer the following questions as completely as you can, and get your answers back to me. You may choose to do this interview in a variety of ways:

- you may type your answers and send them back to me in an e-mail
- you may answer them in a PhotoBooth video and send the video back to me as an attachment
- you may answer them in a voice recording and send it back to me
- you may schedule a time to do the interview face-to-face

I really appreciate your help with this project! It will definitely help me become a better and more effective teacher. Also, keep in mind that you may opt out of this project at any time, with no penalty.

Mr. Buck

Did you think your questions needed to be improved before we began learning about the different types of questions?

Do you feel your questioning skills improved from learning about the cognitive levels?

Do you think you ask more important or useful questions now, after learning about different levels of questions?

Do you think it was useful or important to concentrate on the types of questions you ask?

How much do you think your science skills have improved as a result of your training in cognitive levels?

In your opinion, are all of the levels of questions as important as the others? Explain your answer.

APPENDIX D

PRELIMINARY PLAN: FOUR QUESTION STRATEGY

## Appendix D

Preliminary Plan: Is the Four Question Strategy an effective strategy for improving student questioning?

This month in Free-form Friday, you will be using a strategy called the “Four Question Strategy” to help you design your projects. These questions are to help you focus on a possible topic for your March FFF project, and to help me know how you are doing on putting together projects.

Identify something in your everyday life that you would like to know more about. This could be a question you have about things you see, a problem you encounter day-to-day, or something you’ve just seen from time-to-time, and wondered how it worked.

Write an idea for a project you could design to learn more about your topic. Would you choose to do an experiment to try to answer your question? Would you try to design an invention to help you do a job or overcome a problem? Would you make a model to help explain how something works?

Think of the things you have at home, or the equipment you have available to you in class. What are some ways you could use those objects and equipment to put your project together?

In what ways can you change the materials in your experiment, invention or model to show others what is happening?

How would this project help to answer, solve, or explain your question? In other words, explain how you think your project would work.



APPENDIX E

POST-TREATMENT ASSESSMENT: FREE FORM FRIDAY RUBRIC

## Appendix E: Free Form Friday Rubric

	4 (Exceeds Standard)	3 (Meets Standard)	2 (Progress Toward Standard)	1 (Does Not Meet Standard)	Comments and Initials
The Question	<p>Questions are of high scientific value</p> <p>Strong attempt to answer Questions</p> <p>High quality/depth of questioning</p>	<p>Questions show some scientific value</p> <p>Partially answers Questions</p> <p>Some advanced level questioning</p>	<p>Questions are of low scientific value</p> <p>Inadequately answers Questions</p> <p>Only low-level question(s)</p>	<p>No questions</p> <p>No attempt to answer Questions</p> <p>No guiding question</p>	
Progress Log	<p>Consistent, frequent, highly reflective entries</p> <p>Log guides process</p> <p>"Next steps" responsive to progress</p>	<p>Consistent and frequent Entries</p> <p>Log is a part of process</p> <p>"Next steps" listed consistently</p>	<p>Entries incomplete and/or Infrequent</p> <p>Log refers to process in Passing</p> <p>"Next steps" inconsistent</p>	<p>No entries in log</p> <p>No reference to process in log</p> <p>No "Next steps" listed</p>	
Research	<p>Sources cited completely</p> <p>5+ sources used</p> <p>Research is "deep"</p>	<p>Sources cited completely</p> <p>5+ sources used</p> <p>Research is "deep"</p>	<p>Sources cited with error</p> <p>1-2 sources used</p> <p>Not enough research</p>	<p>No sources cited</p> <p>No outside sources</p> <p>No research conducted</p>	
Resources	<p>3+ types of resources</p> <p>Fully and clearly explains resources used</p> <p>Highly valuable and appropriate graphics</p>	<p>2 types of resources</p> <p>Full or clear explanation, but not both</p> <p>Graphics useful in supporting project</p>	<p>One type of resource</p> <p>Explanation present, but neither clear nor full</p> <p>Graphics present, but not useful or appropriate</p>	<p>No variety of resources</p> <p>Does not explain use of Resources</p> <p>No graphics, or inappropriate</p>	
The Product	<p>Fully edited and Proofread</p> <p>Very clear and concise</p> <p>Shows extreme care</p>	<p>Evidence of editing, but some errors present</p> <p>Mostly clear and concise</p> <p>Shows lots of care</p>	<p>Numerous errors but some evidence of editing</p> <p>Some unclear passages</p> <p>Shows some care</p>	<p>Unedited and not Proofread</p> <p>Unclear and rambling</p> <p>Shows very little care</p>	

APPENDIX F

POST TREATMENT INTERVIEW QUESTIONS: FOUR QUESTION STRATEGY

## Appendix F

## Post-Treatment Interview Questions: Four Question Strategy

Before this project, had you ever made an invention, designed an experiment or made a model of anything before? (If so, please describe what you did.)

Did you worry about doing this project when you first heard about it? (If so, please explain what your worries were.)

How do you feel about inventing, experimenting or making models? Have your ideas improved? Do you understand how to set these things up better now?

Do you think you'll use what you've learned about the four question strategy and designing experiments, inventions and models in your future? (If you're planning to pursue science in a future career or in school, you can talk about that. Even if you're not, how might you use this strategy in your future?)