Refining the Why? Turning Student Questions into Research
(as exemplified by an investigation of the human body)

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Overview: Too often students don't realize that science is a process of questioning... and that their own interests and curiosities, with careful consideration, can be looked at as scientific endeavors. This lesson introduces students to the practice of scientific inquiry, in a research context, using a guided approach to balance and maximize both student input and teacher control. Originally designed with Christa Salmon at Lansing Middle School to fit within her 7th grade unit on the Human Body, the concepts and structure of this lesson can be applied to any subject matter about which students ask questions from their own observations and experiences.

Subject: Primarily, an explicit and experiential look at the process of inquiry. *Secondarily, in the italicized passages, examples and narratives are given applying this model to a curriculum focusing on the systems and functions of the human body.*

Audience: Suggested 7th grade through high school. The activities were designed for a 7th grade Life Sciences class, but the general principles could be applied with any group endeavoring to introduce and practice the skills necessary for scientific inquiry. Adaptations are noted throughout that may allow for the tailoring of procedures for more experienced classes, or for schedules allowing a bit more time.

Time Required: 4-6 class periods, need not be contiguous

Posing Questions (1 class)
Refining Questions (1 class)
Clarifying Methods and Conducting Research (1-2 classes)
Interpreting Data and Understanding Results (1-2 classes)

Background: School reforms call for authentic inquiry, but conducting a student-generated inquiry project can be a complex process daunting to students and teachers alike. Studies show that a gradual approach to the concepts and skills necessary for research can build confidence among teachers and students, and thus facilitate future inquiries. This lesson outlines a guided inquiry activity, where students are given the authority to ask and develop questions, but allowing teachers to direct student questioning in ways that fit both lab resources and curriculum needs.

Research also suggests that students most effectively learn the process of inquiry when inquiry skills are taught explicitly, and when students can both practice the skills and reflect on the inquiry process. This lesson emphasizes the skills of identifying and asking testable questions, evaluating possible research methods, and understanding how methods influence results. At the same time, students can gain an understanding of the subject matter around which the inquiry is focused.

As applied in the examples that follow, students ask questions to introduce and integrate a unit on the Human Body. This subject matter was easily applicable to the questioning model, as students had a lifetime of experiences with their own body from which they could generate questions. The idea for this project stems from descriptions of classroom research focusing on observations of the moon (Van Zee et al, 2001)[1]. Other subject areas with which students have familiarity (a local park, weather patterns, etc.) could easily follow this model.

Learning Objectives

Students will:

1. Generate authentic questions based on their experiences (understand that science involves making observations and asking questions)
2. Rephrase questions to address testable factors, and suggest basic methods (be able to explain what makes a question testable in a scientific context)
3. Critically review research methods and come to consensus about changes (recognize that research methods will affect results)
4. Conduct, as a group, the agreed-upon investigation
5. Evaluate compiled data to explain both results and limitations (be able to identify unexpected factors that impacted data collection)

National Science Education Standards Addressed

Content Standards

- Science as Inquiry **(A)**
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- History and Nature of Science **(G)**
  - Science as a human endeavor
  - Nature of science

Teaching Standards

- Teachers of science guide and facilitate learning **(B)**
  - Focus and support inquiries while interacting with students
  - Encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science
- Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning **(E)**
  - Nurture collaboration among students

[1] van Zee, E. H., M. Iwasyk, A. Kurose, D. Simpson, and J. Wild. 2001. Student and teacher questioning during conversations about science. *Journal of Research in Science Teaching* 38: 159-190.

Model and emphasize the skills, attitudes, and values of scientific inquiry

In addition, the human body example addresses Content Standards grades 5-8 in the areas of Structure and Function in Living Systems and Regulation and Behavior.

Assessment Strategy: Individual and group progress can be tracked by looking at the work students produce. The procedure for this lesson involves a step-wise process, which, if students begin to grasp the skills, will allow students to demonstrate their advancing understanding in each phase of the project.

Teaching Tips/Potential Problems: An element of age-appropriateness needs to be considered when choosing the research subject matter. There will inevitably be a subset of silly questions, but I've seen bits of honest curiosity even in the questions that sound at first purely provocative.

In the implementation of this project, we compared student responses when asked to work alone or in groups. Observations suggest that students who are told to generate questions as a group activity, at least with this subject matter, hesitated to begin questioning. Students who were instructed to develop questions individually showed no such hesitation, and spontaneously began sharing their questions at their table group. From these observations, I would suggest a period of individual questioning followed by group sharing and brainstorming. The discussions generated within dynamic groups can be fostered for a deeper connection to and understanding of the process.

Note that this project's strength lies in the ability to facilitate student ideas and discussions. The more students recognize that their voices have an impact on both the process and the outcome, and the more they hear their voices included in the planning and implementation, the more they will begin to trust their role as researchers and take responsibility for the project. This requires being both patient and open to student ideas and being adamant about channeling those ideas appropriately into the process. A worthwhile and rewarding balancing act!

POSING QUESTIONS (1 class)

Objective: Students begin to recognize patterns of observations, generate questions from those experiences, and recognize their capacity to find answers to those varied questions.

Background: The scientific endeavor involves finding answers to questions that arise through individuals' observations and experiences. Some questions can be answered by seeking out a source of information, such as books in a library, while other questions can be answered through experimentation. We ourselves can put a

scientific question to the test, but must recognize the capacity that we have to do so with the resources at hand.

Materials: index cards or small sheets of paper, pen/pencil

Procedure:

1. Ask students to focus attention on their observations of the research subject. *Each of us has had a lifetime of experience with our body, and the use of its systems. Think, for example, of the systems you have used today from the time you got out of bed this morning (muscular, respiratory, digestive, etc.).*
2. From those observations and experiences, ask students to notice patterns and think about natural questions. It may help to model those skills for the students. *Think about ways that you have noticed that your body works on a regular basis, things that make you wonder why they happen that way. Wondering about these patterns can be expressed as a question, for example, "Why do I always sneeze when I go out in the sun?"*
3. Give students a stack of index cards or small pieces of paper, and have them use a new piece of paper for each question that they write. This may be accomplished either individually or in groups (see "Teaching Tips").
4. After a set time, or when the initial pool of questions seems to have been exhausted, have students read over each question to determine whether it could best be answered by going to the library or conducting an experiment. Have them label "L" on the back of the library questions and "E" on the back of the experiment questions. Additionally, for the experiment questions, have them circle the "E" if they think that they can accomplish an experiment on that topic within the classroom.
5. After class, compile and list the students' questions. Many of the questions can be categorized as dealing with similar subjects. Before conducting the next segment of this project, pull out the categories around which you can design a simple classroom research project. Your criteria for this decision will be unique to your class: the amount of time you wish to spend, the topics you wish to cover, and the resources you have available. Leave room for some flexibility, however, as the students will have one more opportunity to shape the direction of the next step.

Taking a critical look at the questions, as phrased on the index cards, is a peek into the functioning of the minds of the students. This can be the initial phase of tracking the students' questioning skills. Implementing this project with 7th graders, the majority of the questions began with the word "why." Because of this observation, we structured the next phase of the lesson to address the need to refine and clarify research questions.

Example student questions:

Why does food taste different when you plug your nose?
Why do we get dizzy after spinning?
Why do we have less balance with our eyes closed?

Why does my stomach make noise when I'm hungry?
Why can't we swallow after we swallowed before?
Why are yawns contagious?

REFINING QUESTIONS (1 class)

Objective: To choose a classroom research topic, and refine the topic into a testable question.

Background: Questions can describe an interest or curiosity, but may not be testable unless they are carefully phrased. Questions beginning with the word "why," for example, encapsulate too many factors to test with one research project. *The question, "why do I sneeze when I go out in the sun?" is too broad… a research project would have to address all possible factors, such as allergies, weather, sinus problems, family history, etc., before being able to answer the "why."* A testable question identifies the specific factor or factors to be addressed in the research methods. *A more testable question would be, "Do I sneeze when I squint in the sun?" This is because a research method could be developed to compare sneezing reactions when squinting and not squinting.*

Research methods can vary. Students may envision a scientific experiment as something that takes place in a laboratory with white coats and microscopes, while they may think of research as happening in a library. However, research can take a variety of forms, including surveys, repeated observations, or experiments with treatments and comparisons. It refers broadly to the process of identifying and investigating a specific question.

Materials: list of selected student questions, index cards or scrap paper, pencil/pen

Procedure:

1. Have students read the compiled list of questions as chosen from the previous day's work. Remind them that these questions were generated from their own interests.
2. Discuss what is involved in writing a testable question, and use an unlisted example question to walk through the process of refining a vague question into a testable one. *Students in the 7th grade life sciences class were asked to take note of commonalities between the listed questions: they all began with "why."*
3. Inform students that research methods should be considered in planning the question, and remind them that there are a variety of research methods that can be used.
4. Have students vote to choose the focus question for the remainder of this project.
5. Instruct each small group to work together to clarify that particular research topic into a new, refined question. Have each group include the type of research method they think would be appropriate for that question (e.g., survey, observation, or treatment).
6. Collect and read out loud each group's question, one at a time. Give each group time in between to respond with constructive comments about the

question as phrased or the methods suggested (i.e., still phrased as a "why" question).

7. Be certain to track the students' comments on each question made during the process of peer review. The collected questions, and their associated comments, are a measure of the students' understandings of the process skills for refining research ideas.

Several classes chose the research topic, "Why is yawning contagious?" They had many ways of refining the question. Example "peer review" comments (comments from other students) are given in parentheses.

> *Do you yawn when another person yawns because it reminds you how tired you are? (think this should be a survey; every time you yawn look around and ask why)*
>
> *After you hear one person yawn, how many people will yawn? (someone could fake a yawn; you shouldn't know they're yawning)*
>
> *Survey: Do you yawn when someone around you yawns? (if you asked this in a survey it would answer a different question)*
>
> *Does seeing people yawn make you yawn? (trying to make this happen is not natural; an issue of trust)*
>
> *Is yawning contagious by seeing or hearing it? (could be both; must test one at a time)*

At this point, depending on the skill level of the students and the time allotted, students can be involved in the design of the research methods. I would suggest following a similar process as above, allowing small groups to each generate a testing procedure, and then allowing time for peer review. If giving students this responsibility, be certain to voice any concerns or constraints in the areas of material availability and safety. This process would likely take an additional class period.

Because of time constraints and the novelty of this process for the seventh-grade students, the teacher and I chose to retain responsibility for constructing the methodology, staying as true as possible to the submitted questions and peer review comments. Create an overhead or handout outlining the rephrased question and basic methods, design a datasheet for individual/group record keeping, and gather all materials in preparation for conducting the research in class. Students will be given one final opportunity, in the next class period, to review the methods and make changes in the methods before collecting data.

CLARIFYING METHODS AND CONDUCTING RESEARCH (1-2 classes)

Objective: Students will understand that the methods they choose may influence their research results.

Background: Scientists often work in collaboration and utilize many people's feedback and ideas to inform and improve their research. Peer review can be a constructive way to critically identify important details that one person may not think of in a research design. Even seemingly small factors can affect whether the collected data will accurately answer the research question.

Materials: all necessary materials for collecting data with the outlined methods, data sheets appropriate for the project

Procedure:

1. Display and describe the refined question and outlined methods.
2. Open the floor to hear student questions, concerns, and clarifications of the research methods, at first just listing these in a visible place.
3. Once a list has been established, help the group to address each item and decide upon appropriate ways to incorporate the comments into the methodology. This takes careful facilitation to keep the group process-oriented and productive.
4. Once the comments are adequately addressed (as decided upon by the students or the time), allow the students to conduct the research following the revised methodology.
5. As additional questions will inevitably arise during the process, have students take note of these and any other new concerns on the back of their individual data sheets.
6. Student understandings can be tracked by looking at comments made both before and during the data collection process. Their thoughts on what may affect data accuracy will likely provide insights into their understandings of the process as well as any group dynamics that may not have initially been evident. Compiling these comments will be important for preparing the final section of this project.

One of the 7th grade classes chose to look at the issue of food tasting differently with your nose plugged (the students' terminology). The research question and methods are listed as presented to the students, and some of their comments follow.

Does food taste different with our nose plugged than it does with our nose not plugged?

1. *Plug your nose*
2. *Taste the food offered on a toothpick*
3. *Repeat steps one and two for all three food items*
4. *Repeat steps two and three for all food items with nose unplugged*

Pre-data comments:

Make sure nose is fully plugged
Move food around to hit all parts of tongue
Cover eyes… later discussion: the whole time? No, because we need to write
Grind it up
Might have never tasted the food before to be able to identify it
How many people have colds? That can affect taste…
Many questions about what kinds of foods… class decision to keep it totally secret
Second round: teacher initiated discussion about whether the order should be changed. Class decided to have it kept a secret and not be told, but there were good points raised about being able to compare, vs. being biased by initial thoughts

Data sheet comments:

I could feel the food
Could look at color on end of toothpick
Different ways of chewing/tasting
People could have had their eyes half closed

To expedite the project and to keep students critically focused on the process, the teacher and I compiled and graphed the data before the next session. Looking at the data in a variety of ways and creating several different kinds of graphs will give students material from which to interpret results. A more advanced class with more time and/or experience could approach this step with more guidance or independence.

INTERPRETING DATA AND UNDERSTANDING RESULTS (1-2 classes)

Objectives: Students will: (1) examine graphical representations of their data and interpret the results in light of comments on the research experience, and (2) evaluate different graphing techniques to understand that different kinds of graphs are appropriate for describing different sorts of data.

Background: Interpreting data is what finally allows scientists to answer the initial research question. The way that information is graphed can affect how we understand the results, and graphing techniques can be used appropriately or inappropriately to make sense of data. As scientists, we must always be aware of the limitations of what we can conclude from our data, and as part of this must identify ways to improve future studies.

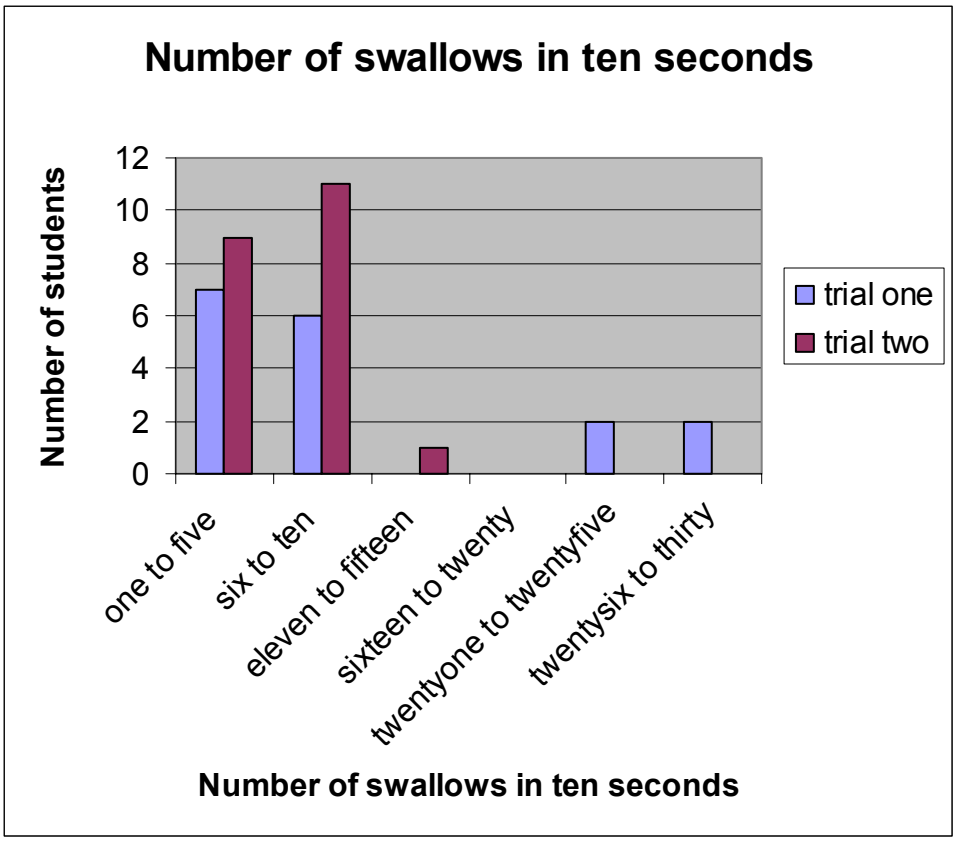
Materials: Several different graphs as handouts for students (create bar graphs, line graphs, pie graphs, etc.), overheads or slides of the graphs to display to the class, graph evaluation handouts enough for each group to review each graph *(sample handout below)*

Procedure:

1. Have students work in small groups. With six small groups and two copies of each of three graphs, we did a rotation system so that each group had only one graph at a time on which they needed to focus their attention.
2. For each graph, have students answer some guided questions (on a graph evaluation handout) about the data and the graph itself.
3. After each group has a chance to see all graphs, display one graph at a time (using overheads or projector) to the class to hear comments. With the given comments, class discussion can bring about an understanding of what can be concluded from the data.
4. Student comments in evaluation of each graph will highlight the students' ability to synthesize their understandings of graphing techniques with their understandings of the research process. The most effective discussions occur when students can visually connect patterns in the data with their previous critiques of the research process.

At the beginning of this class, students may need a reminder that the data, as graphed, are what will help them finally answer the initial question that they chose as a group. The participation level when students heard this was much more dynamic than groups who perceived this as just another activity with graphs, numbers and handouts.

One of the 7th grade classes pursued the joint questions: "How many times can you swallow in ten seconds" and "What is happening when we swallow?" Their research involved counting the number of swallows in a ten second period and describing the physical activity of swallowing. There was much discussion in the class after the first trial because of huge discrepancies among student numbers, and the way that students were swallowing. The graph and comments below illustrate students' abilities to make connections between their methodologies and their results.



Comments:

Some people were swallowing air and some people didn't do a second trial
First trial people were swallowing air, second were swallowing saliva
Some people could have messed up on the first trial

Handout: We used the following set of questions to help students evaluate the graphs. Questions and approaches can be changed to make this handout appropriate for different age levels and research topics.

Graph: _____

What does the x axis show? _____

_____

_____

What does the y axis show? _____

_____

_____

What are the two axes comparing? _____

_____

_____

*What patterns do you see in the graph?*_____

_____

_____

*What does this pattern say about the research question?*_____

_____

_____

*What is confusing or misleading about this graph?*_____

_____

_____

What factors in our data collection yesterday could be affecting what we see in this graph? _____

_____

_____

SUMMARY

This lesson plan was designed to help facilitate a first step towards classroom inquiry in the form of a research project. This procedure, as designed for a seventh-grade classroom, offers a balance between teacher guidance and student freedom, which allows students to take ownership for the process while allowing the teacher to maintain control of the project's direction and logistics. This balance can be shifted to meet the needs of classes at different levels, providing for more student voice or more teacher direction.

Again, while the case-study classroom for this lesson plan focused on the human body, this format is adaptable to almost any subject area. Additionally, class time focusing more directly on content can be allotted throughout the project, or interspersed between days. For example, Ms. Salmon assigned homework that led students through an exploration of different body systems, and spent time reviewing content for a few minutes each day.

It is important that the process of inquiry be taught in an explicit manner. This project gives students the opportunity to focus on the stepwise elements of inquiry, from questioning to peer review to data analysis. As the lessons take place in the context of a curricular subject matter, classrooms can concurrently address multiple standards. This layering approach may help teachers alleviate the increasing pressures of standards, and facilitate the incorporation of inquiry in an already busy classroom year.