CoRe: Content Representation Tool
(Loughran, Mulhall, & Berry, 2004)

Big Ideas/Concept: Science is subjective (biased)

1. **What you intend students to learn about this idea**

When scientists attempt to interpret scientific evidence/data, they can be biased in their conclusions (AAAS, 1990). If a scientist holds strong beliefs about the outcome of his or her research, it can prevent him or her from detecting more accurate, unbiased conclusions (AAAS, 1993). What scientists want to observe can often affect what they actually do observe (NSTA, 2000). The idea that scientists differ in their interpretations of scientific data is nothing new to science (NRC, 1996). The observations scientists make, the questions they ask and their conclusions about scientific research are all influenced by the scientists' expectations, past experiences, existing scientific knowledge and social and cultural influences (NSTA, 2000).

2. **Why is it important for students to know this**

Students often see scientists as rigid people with no imagination or personality. Students need to know that scientists are regular people and their work is influenced by their everyday lives. This idea allows students see that all scientists think differently, and their personal backgrounds and expectations affect their work. This is important because students will not enjoy science unless they can see themselves (personality, imagination, etc.) involved in the process. Because all students have different perspectives and backgrounds, students will begin to see how vital their participation can be when discovering and understanding new conceptions.

This idea also fits well in Driver's democratic argument for understanding science. The democratic argument states that "everyone should understand science in order to be able to participate in discussion, debate and decision-making about" issues concerning science and technology (Driver, 1996, p. 11). Students must know how to critically analyze scientific work knowing that the scientists will have some personal bias towards his or her research. Understanding these ideas will allow students to be more informed citizens in a society which greatly affects current scientific research.

3. **What else do you know about this idea (that you do not intend students to know yet).**

Karl Popper's philosophy states that science advances through conjectures and refutations. Scientists should propose laws and theories as conjectures and then actively work to disprove or refute those ideas. Falsification allows scientists to avoid biases in their work because they are forced to look outside their own research for alternative theories for why nature acts as it does. If scientists are constantly developing ways to falsify their own work, they will not fall into the trap of accepting their ideas as they are (Chalmers, 1999).

Induction/empiricism does not hold up; observations are theory-dependent. Scientists cannot observe nature with a blank mind. Scientists use a foundation of past experiences and

expectations to make sense of their current observations. Because all people have different perspectives and past experiences, their understanding of observations will be subjective (Chalmers, 1999).

Thomas Kuhn stated that scientists work within a paradigm (the rules and standards for scientific practice). Scientists spend most of their time doing "normal science", in which the scientific community assumes what the world is like which gives a foundation for further work. The paradigm provides direction to the research, but may also limit research as well. Scientists have commitments towards a paradigm. This can cause scientists to have a narrower viewpoint of nature and why it acts as it does. These commitments can cause scientists to be subjective and unable to accept another paradigm that differs from their own (Chalmers, 1999).

4. **Difficulties/limitations connected with teaching this idea**

One difficulty may include how students define the words "objective" and "subjective". These are often used incorrectly in everyday language. Science is often portrayed as "objective" by science teachers and the media. Students who learn that science is "subjective" may interpret this as science should be mistrusted.

Another difficulty may include identifying the many preconceptions about this idea. Unless a teacher understands his or her students' preconceptions, he or she will not be able to guide the students through appropriate experiences that will allow students to become dissatisfied with their prior knowledge. Teachers often anticipate that the activities planned, will lead students to the same conclusion.

Teaching this aspect of the nature of science could be limited by later science teachers who may continue to reinforce misconceptions about the subjectivity found in science. Later science teachers may continue to confuse students if they choose to use phrases like, "What does the data tell us?" meaning that the data speaks for itself.

Lastly, this aspect of the nature of science may be limited by the about of time I will have to devote to the nature of science. I believe the nature of science should be embedded in the curriculum, but pressures from the state to meet standards and do well on state testing may limit my time and focus for guiding students to an understanding of the nature of science.

5. **Knowledge about students' thinking which influences your teaching of this idea**

Students often believe a scientist's work is value free and objective. Students often believe that scientific data stands by itself. Students need to learn that data must be interpreted and when it is, scientists may come to different interpretations. Students can also hold the belief that scientists only work in laboratories and their work it not affected by the scientist's personality and background. It is important to understand students' preconceptions about this idea before attempting to teach this idea to them.

6. Other factors that influence your teaching of this idea

I want students to be able to see themselves as an individual (personality and background) in the science process. I want students to experience the freedom to be themselves when participating in scientific activities, but also teach them the importance of objectivity even if it can never be fully achieved.

7. Teaching procedures (and particular reasons for using these to engage with this idea)

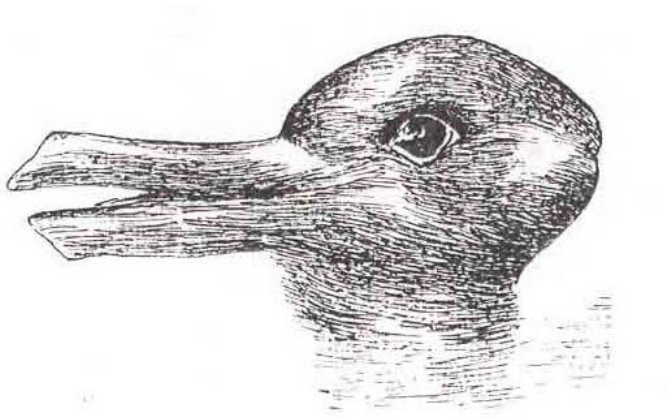
I want my teaching of this idea to be explicit, in which the understanding of subjectivity in science is a direct outcome of learning. Students will be able to directly discuss scientists' biases in observations and research. This idea will be specifically assessed throughout the learning experience with the use of the terms "subjective" and "objective". Research has shown that student understanding of the nature of science improves when the nature of science is taught explicitly (Khishfe and Lederman, 2006). By teaching this aspect of the nature of science explicitly, the teacher will be able to monitor whether or not the students are using the terms "objective" and "subjective" appropriately. This will also allow students to give examples of subjectivity in the history of science and in their own scientific work.

I would also like this idea to be integrated within the science content. I believe using the history of science will be helpful in teaching this idea. In the Khishfe and Lederman study there was a slight increase in understanding when this aspect of the nature of science was integrated in the curriculum instead of being taught by itself (2006).

I would like students to keep a journal which would allow them to write down how their thinking has changed throughout the class. I will also encourage class discussion, so students can reflect on their ideas and other students'.

Formative assessment:
A comic will be used to reveal students' preconceptions about subjectivity in science. Students will write their thoughts down under the comic, wad up the piece of paper and toss it to another student. The write and toss method will allow students to open up about their preconceptions. This method will also create good discussion. The students' ideas will be written on the board, so the students can see all the different perspectives.

Old Woman/Young Lady?
Students will work in groups of four and will be asked to observe some pictures that can be interpreted differently based on students' prior knowledge. These pictures can be used to show students how the same data can be interpreted several different ways. Students will be asked to discuss the following questions with their group and record their answers in their journals.



1. Did everyone observe the same things?
2. If members of your group observed different things, what do these different observations say about how people observe things?
3. Can you think of any reasons why people might observe objects differently?
4. How might these differences in perspective affect the research of scientists if a group of scientists were observing things in nature?
5. How might this activity apply to the objectivity or subjectivity of science?

History of Science:
Students will read an account of history in science that displays subjectivity in scientific work. After reading the story, students will use journals to make connections between what they read in the text and what they have been discussing in class concerning objectivity and subjectivity. After students make these connections, they will answer the following questions. These journal entries will be used to further discuss this aspect of the nature of science.

1. Give an example(s) of how subjectivity played a role in this account of science.
2. Why is it so difficult for scientists to consider alternative ways of interpreting data?
3. How does this story illustrate the idea that "data does not speak for itself?"
4. What are some characteristics scientists should display in order to become less biased and more objective? How might these characteristics benefit the field of science?

Some accounts of the history of science can be found in the following books,

A Short History of Nearly Everything by Bill Bryson
Great Feuds in Science: Ten of the Liveliest Disputes Ever by Hal Hellman
The Best American Science and Nature Writing (The Best American Series)

8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses).

The journals and student responses during discussion will be used to assess student understanding of this aspect of the nature of science. The journal will be especially useful when a

student does not feel as comfortable speaking in front of the class. The journals will be checked daily for understanding and confusion, and any points of confusion will be addressed in later activities or discussion.

Some likely responses of confusion,

Students may believe that objectivity and subjectivity are polar opposites; a person is either objective or subjective in their observations. Students might not realize that the two are often intertwined.

Since science is often portrayed as "objective" by science teachers and the media. Students who learn that science is "subjective" may interpret this as science should be mistrusted.

Also, students often believe that data speaks for itself, instead of understanding that all data must be interpreted.

References

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