

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

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Big Ideas/Concept:	“Science is NOT objective!”
1. What you intend students to learn about this idea	<p>That science is ultimately a human endeavor and therefore cannot be objective. I think it is important for students to recognize that scientists as a whole strive for objectivity, but can also see for themselves instances where science simply cannot be objective.</p> <ul style="list-style-type: none"> • Driver et al. (1996, p. 14) stated that it was important for students to have an “awareness of the possible influence of social commitments and values on the choices and interpretations that scientists make, and of the influence on the wider culture of scientific ideas and artifacts.” • The College Pathways to Science Education Standards (Siebert and McIntosh, 2001) emphasizes that science is a human endeavor. The Standard Level G includes this concept at all grade levels. It is important that students understand that for science to be a human endeavor, it cannot be completely objective. • The National Science Teachers Association (NSTA) Standards for Science Teacher Preparation state that science teachers must “engage students successfully in studies of the nature of science including, when possible, the critical analysis of false or doubtful assertions made in the name of science.
2. Why is it important for students to know this	<p>There is a built in sociocultural bias towards taking everything that science provides us as absolute, objective fact. I think this leads to a lack of critical thinking about a lot of scientific issues. If students are made explicitly aware of the humanistic traits of science, I think it will tend to crack the illusion and make it easier for students to question and try to more deeply understand scientific phenomena. I have started paying closer attention to many commercials on TV that use the terms “scientifically proven” and “doctors recommend” and am concerned about how casually these terms are thrown around. I think it is critically important to educate students to be savvy consumers so that they are not taken in by misleading advertisements, etc.</p> <p><u>I connect this general idea to two arguments by Driver et al. (1996):</u></p> <ul style="list-style-type: none"> • The “Democratic” argument would support the idea of an educated, scientifically literate society that is capable of making informed decisions. This argument states that “everyone should understand science in order to be able to participate in discussion, debate, and decision-making about these (Driver et al., 1996, p.11).” If students do not have an understanding of the nature of science, then “facts” that are presented to them will not be questioned and decisions will be made with potentially faulty information. • The “Moral” argument reinforces the idea of questioning the bias of “facts” and “scientific proof.” The moral argument states that the practice of science embodies norms and commitments, which are of wider value (Driver et al., 1996, p.11).” It is impossible to ignore the effect of social and cultural norms that value science as an idealistic endeavor as many students will come from backgrounds where physicians and scientists are to be respected and are not to be questioned.
3. What else you know about this idea (that you do not intend students to know yet).	<ul style="list-style-type: none"> • That this subjectivity is sometimes purposeful on the scientist’s part. Reasons may include getting published, getting funding, not being ridiculed scientifically, or simply the built in bias of the scientist themselves. I think it helps to put things into perspective and to understand the motivation of all people, including scientists, when evaluating their body of work. • I would also like to use this idea as an opportunity to expose students to the idea of scientific philosophy. I think, without becoming too detailed, the ideas of the Inductionists, Popper, and Kuhn could be introduced as discussion points (Chalmers,

	<p>1999). I think by describing the ideals of each philosophy and asking the students to reflect on relative strengths and weaknesses of each in describing how science is done or should be done. In particular, discussions on how scientific knowledge is progressed could be a useful tool to get students to reflect on whether or not science can be objective.</p>
<p>4. Difficulties/limitations connected with teaching this idea</p>	<ul style="list-style-type: none"> • How do you balance getting students to understand the fallibility of science without disregarding all the wonderful advances that have come as a result of work of scientists? It is difficult to overcome prior conceptions, especially those that are rooted in cultural or home situations. Many students will have been raised to respect scientists and doctors and will encounter opposition if they challenge current thinking. • From a pedagogical standpoint, this could be a very time consuming idea to instill and reinforce in the classroom. Teachers just may not have time. I also feel that it is an idea that requires a lot of explicit instruction to make ties concrete enough for students to relate to it in any meaningful way.
<p>5. Knowledge about students' thinking which influences your teaching of this idea</p>	<ul style="list-style-type: none"> • That an important purpose of pre-college science education is to educate individuals who can make valid judgments on the value of knowledge created by science and other ways of knowing, and to understand why the literature regards scientific knowledge not as absolute, but as tentative, empirically based, culturally embedded, and the product of some degree of assumption, subjectivity, creativity, and inference (Lederman & Niess, 1997). • McComas put forth the myth (#8) that "scientists are particularly objective" (1996). This puts an obvious red flag about a misconception in student knowledge that needs to be addressed. • Students also hold the misconception that scientific progress can only be achieved through experimentation (McComas, 1996) and that the data itself gives the answer. There is a lack of understanding that observations do not have to be in conjunction with experiments or that interpretation of data is done by the scientist. • Driver et al. (1996) discussed a Canadian study that found that the majority of students thought that scientists were no more honest as individuals than non-scientists, but that honesty might be more important in their professional activities than for non-scientists. • Students tend to think of scientists as people in lab coats who live in the lab and have a very dry, boring life. The idea of objectivity to me seems to reinforce this sterile, lackluster ideal. I think it will humanize scientists in many ways to increase student understanding of the subjectivity of science. • On a personal level, I think students LIKE to think in terms of black and white and it is comforting to be told facts that you do not have to understand or question and are able to take as absolute truths. There are very few, if any, absolute truths in life, but I don't think many students are ready to accept this idea at the high school or college level.
<p>6. Other factors that influence your teaching of this idea</p>	<ul style="list-style-type: none"> • Unfortunately, not all teachers have a good understanding of the nature of science or are unable to translate that knowledge effectively in the classroom. The example given by Jennifer regarding the undoing of a lot of her attempts to instill a good understanding in her students was largely undone by a teacher in the subsequent science class. • A desire for students to have a better understanding of the nature of science and of the subjective nature of science, in particular, to encourage them to question/challenge ideas for themselves and to learn to evaluate evidence on its merits before making their own decisions. • Explicit instruction is needed both to prepare teachers (Abd-El-Khalick & Lederman, 2000) and to lead students to understand the nature of science (Khishfe & Abd-El-Khalick, 2002). If students are not made explicitly aware of the relationship between science and the nature of science, they may not be able to make those bridges.
<p>7. Teaching procedures (and</p>	<p>I think the tie between the nature of science and content must become second-hand to teachers during training so that it is not a conscious decision about the teaching of the nature of science,</p>

particular reasons for using these to engage with this idea)

but rather something so ingrained that you cannot teach without it. As a teacher, I would look at specific methodologies that might be well paired with scientific content that I am teaching (like a fine wine) and try to impart an understanding of the nature of science in an implicit way, while occasionally pointing out what I am doing and why in an explicit way.

- I think the use of multi-media teaching tools is especially useful for teaching this subject. I think teachers may not be given sufficient credibility to overcome prior conceptions, but when students here Bill Nye (or Dr. Science, etc) talk about things, I think it may become more relevant to them. Unfortunately, this also perpetuates the problem, because again someone is being deemed “objective” and an “authority figure.”
- Visual tasks that can help students to understand that observations are not uniform, that there can be no truly objective observation as there is always interpretation. This would be a good launching point for a class discussion. I would have students write down their observation of what the visual cue was (see below) and then have them wad up their answer and toss it across the room. I might consider having students defend the observation they catch and then refute it. I tend to think that discourse is a good way for students to gain a deeper understanding of a process.



- Interactive tasks that encourage students to either evaluate text within a framework or to develop a framework from given text. I would distribute the text to small groups with specific directions about which task they were to do. The specific use for understanding the subjectivity of science would be to use this as a bridging analogy for how scientists can also receive the same data (of any sort) and can interpret it differently. This would lead to a possible “think, pair, share” activity about reasons for differing interpretations, etc. See example below.

The procedure is actually quite simple. First, arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities, that is the next step, otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity of this task in the immediate future, but then one can never tell. After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life.

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

The use of a card sort activity is another effective way to evaluate student learning of the nature of science in general and the subjectivity of science in particular.

Card Sort Activity: What is Science?

1. Cut the cards apart
2. Sort the cards into two piles: agree and disagree
3. Identify the cards in your agree pile by card number, then do the same for the cards in your disagree pile.
4. Compare your cards with a friend and discuss the choices you made.
5. Select 4 cards that you believe represent your thoughts about science.
6. Pick 4 cards that are not representative of science.
7. Pick cards from both piles to help you write a paragraph about the nature of science.

1. Science gets closer and closer to the truth.	8. Scientific observations of the same object or process leads to identical interpretations.	15. Science and its methods provide absolute proof.
2. Science and its methods can answer all questions.	9. Facts do not speak for themselves, they must be interpreted by theory.	16. Scientific concepts are discovered.
3. A scientist should not allow preconceived theoretical ideas to guide observation and experimentation.	10. Experiments are the principle route to scientific knowledge.	17. Scientists are particularly objective.
4. Careful observation gives us the truth about the world around us.	11. Science is one of several ways of knowing.	18. Historically, Science has been dominated by white Europeans and North American males.
5. Evidence accumulated carefully will result in knowledge.	12. All work in science is reviewed to keep the process honest.	19. Theories change when new conceptualizations account for anomalous data.
6. Hypothesis become theories, which become laws.	13. Theories serve to give direction to observations -- they tell one where to look.	20. Science deals with testable questions.
7. A general and universal scientific method is used by all scientists.	14. Scientific concepts are invented	21. What scientists choose to study reflect the social values and views of the time.

The use of concept cartoons (see below) is a non-threatening and effective assessment for teasing out student understanding of the nature of science. This assessment would be used to elicit a short answer/essay from the student about possible sources of bias on the part of a scientist.



VNOS – C questions could be used to generally assess student misconceptions and understandings about nature of science and subjectivity in particular. Even though the questions do not directly ask for their understanding of this particular topic, the answers would provide information that was valuable in determining their level of understanding.

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
8. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
 - If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
 - If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples.
 - If you believe that science is universal, explain why and how. Defend your answer with examples.

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