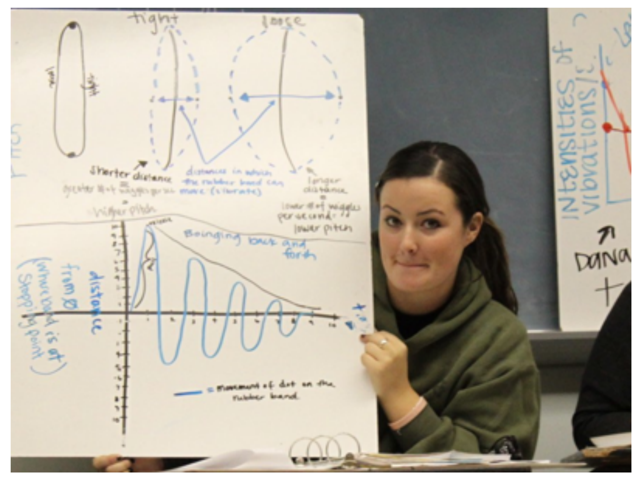

Surveys Fail to Measure Grasp of Scientific Practice

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There is debate in the science education literature about how best to improve students' understanding of the nature of science: Can an "immersion" experience in the process of doing science like scientists outperform explicit instruction on the nature of science? Central in resolving that debate is the development of appropriate measures of students' understanding of the nature of science (NOS). We report on a course in which students engaged in sophisticated scientific practices, and yet student responses to a standard NOS survey showed surprisingly few pre-post changes. We argue that this data suggests that when students do science like scientists do, they gain a grasp of scientific practice that cannot be measured by declarative means such as surveys and interviews

How To Teach The Nature of Science

The best instructional practices for improving NOS have been hotly debated. One approach argues that students who engage in doing science through inquiry will necessarily develop more sophisticated understandings about NOS. Such an "**implicit**" approach is the experience of practicing scientists who, through their immersion in the daily practice of science, come to better understand scientific epistemology. In contrast, an "**explicit**" approach uses hands-on activities that highlight NOS ideas, followed by reflective discussions and writing to draw out the connections to targeted NOS themes. For instance, students might explore an 'Inquiry Cube' as a way to trigger discussions about the distinction between observation and inference. Unfortunately, the scientific inquiry found in classroom settings is so varied and typically so unlike authentic scientific practice, that determining whether an implicit approach leads to improved NOS understandings is difficult.

A Different Kind of Course

Student Generated Scientific Inquiry offers undergraduate elementary education majors the chance to engage in authentic scientific practices. **The course is solidly grounded in the implicit approach to developing NOS understandings** -- students were presented with complex observable phenomena (such as a cow eye, color mixing, rubber band guitars, or a pinhole camera) and challenged to develop scientific explanations and theories in the same ways that practicing scientists might: by asking questions, constructing models, designing tests of those models, engaging in debates, writing up and presenting their findings, and critiquing one another's work. Students eventually think and act like scientists [1].

(See website - google SGSI.)

METHODS: Measuring NOS Understanding

15 students completed a frequently used open-ended NOS survey, the Views about the Nature of Science, Form C (VNOS) [2], before and after the course. Responses were analyzed and coded following the methods of Schwartz and Lederman [3] who analyzed the responses of practicing research scientists on a VNOS survey. Subthemes emerged upon a first reading of students' responses and were refined through further rounds of analysis. Pre- and post-comparisons of each individual's conceptions were conducted and scored by a qualitative measure of the degree of change (none, slight, or large change). The small sample size precluded the use of statistical measures. Subthemes are non-exclusive. For instance, students can simultaneously believe that creativity is required both in the design of new experiments and in coming up with new questions to investigate.

Why is there so little change on a NOS survey?

Large shifts were distributed across individuals. No individual showed large changes in more than two theme areas at the same time. The almost word-for-word similarity between students' responses at the beginning and end of the course was startling. Students appear to be drawing from a definition of the word "experiment" and "science" that was learned previously.

Amy Pre-course: "An experiment is something that tests out an idea that you are trying to prove. An experiment uses different variables and controls to test out an idea or thought."

Amy Post-course: "An experiment is when you test something to prove whether or not your idea is true or false. You have various variables and controls to test an idea that you have."

Jaime Pre-course: "I think that science is just a way of knowing things. It is different from religion or philosophy because they are a different way of knowing things. I believe that religion aims to answer questions about why we are here. Yet, science aims to answer questions like how do things work, and what are things made up."

Jaime Post-course: "I think that science is a way of knowing things. When I want to know how something works, or why something is the color that it is I would turn to science. If I wanted to know where my soul goes when I die, or why I am even here in the first place, I would turn to religion."

Although we were initially surprised, **we came to realize that the use of a survey to measure students' grasp of scientific practice relies on the assumption that NOS understandings are a form of declarative knowledge** (knowledge about science in general that can be expressed as a statement). **Such an assumption overlooks the possibility that "doing science" is a form of procedural knowledge** (knowledge of how to conduct scientific inquiry within a community of practice). Thus, it may not be surprising that our students failed to show changes on a declarative survey. Analysis of students' investigations, notebooks and conversations indicate that they develop a far more sophisticated NOS understanding than these survey measures show [1]. Knowing how to do science -- what to do when confronted with a puzzling phenomena, when analyzing data that conflicts with ones theory, or when one's explanation is challenged by a fellow scientist -- requires a set of procedural knowledge that does not necessarily carry over to the ability to declaratively express the correct "expert" NOS view.

What the education research community needs are assessment tools that monitor the development of procedural knowledge, an implicit "grasp of practice" [4], that students call upon when they wonder how the world works or consider another person's scientific claim even if this does not extend to students knowing what to say in response to a survey or interview question.

RESULTS: In All Theme Areas, the Vast Majority of Students Showed No Change in Their Views.

NOS Theme	Subtheme	Representative quotes	# Pre	# Post	# no change	# slight change	# large change
Empiricism	Yes - experiments/observations lead directly to facts, certainty and proven truths	Scientific knowledge needs to have proof. Experiments help solidify scientific ideas, but they also help alter or disprove ideas.	11	7	**10**	4	1
	Yes - experiments/observations allow us to figure out how/why things work (and can prove to others)	You can't explain and convince someone how something works if you haven't personally worked with something of relevance. You need to work with the product or idea you are trying to explain.	5	6			
	Yes - experiments/observations help individuals to learn better and prove to self	Sometimes [experiments] can help you learn better. I'm more of a hands on person. I feel that personally for myself it helps me understand a concept better.	2	3			
	No - science is everything (incl. religion, philosophy)	I think science is basically everything... Science has little difference compared to religion or philosophy, those too are a science but less experimental and more thought-process based.	1	1			
Process	Scientific method - sequential steps to follow	An experiment is part of the scientific method that was created by scientist to regulate what is and is not a proven theory of the universe. The scientific method has 4-5 steps that break down whether something is going to be a law of how things work on the planet.	4	1	**9**	3	3
	Science fair - answer a question; variables to control; test a idea/theory to prove if right or wrong	An experiment is anything that involves variables that are being tested, altered, observed or changed. [An experiment is] a highly specific test to see if an idea about something is true or not.	8	9			
	Give support or evidence to a theory or idea; come up with a new idea; make discoveries	An [experiment is an] attempt at discovering a new idea. They are used to support theories. Experiments are the only way to keep science uncovering new ideas and perceptions about the world we live in.	4	5			
Tentativeness	Yes - (no durability) theories change all the time	Yes; theories can change all the time. A theory is just that, a theory- not a fact. theories, generally speaking are always subject to change.	3	2	**12**	2	1
	Yes - (durability) theories change with new evidence	Some theories can change, but it takes a lot of observing, researching, and experimenting... Theories only change when someone comes up with enough evidence to disprove the current theory.	11	10			
	No - theories proven to be true	Once a theory is developed, like evolution, the theory is never changed. A theory isn't changed because communities of scientists have been gathering research and data to come out with conclusions that they have agreed on and disagreed on until everyone came out with similar results.	1	3			
Subjectivity	Yes - will believe whatever want to	[What you think] depends on how you interpret the information... For example when we look at clouds. Someone might say it looks like a rabbit one person may say it looks like a car. It all depends on the individual.	2	2	**11**	4	0
	Yes - diff underlying theories lead to bias/ diff ways to interpret same data	There are two possible conclusions because they are two separate theories... If different people think differently than it is possible to come to separate conclusions, especially if we have no way in knowing for sure.	7	4			
	No - ultimately data will tell you (data not good enough or both ideas must be right)	The two groups of scientists could have come up with different conclusions for the explanation of the dinosaur extinction because they would be studying the same rock samples. Neither of them was there for the event, so it would be easy to have different views. Maybe a meteor rock is similar to a volcanic rock. From the rock sample, the scientists could have made different conclusions.	9	10			
Context	Yes - affects process (funding, who can do science, what experiments to do)	Although science is meant to be as objective as possible, I believe that social, political, and philosophical values contribute to science. One example that I can think of is the funding of scientific research... Funding of certain "valued" projects leads to more research in those areas as opposed to less valued areas.	4	5	**8**	3	3
	Yes - affects interpretations (reasoning, assumptions, what conclusions open to)	In Galileo's time it was heresy to say that the sun was the center of the universe, and that the earth revolves around the sun.	2	3			
	Depends - not supposed to be but sometimes is	Because science is conducted by humans, there is always the potential for hypotheses to reflect the cultural setting... But scientists do their best to think of these considerations and account for them. This is also why peer review and repeatability of the experiment is so important. When conducted with a minimum of subjectivity, repeated, and confirmed, science can clearly produce facts that are true in any place or time regardless of culture.	2	1			
	No - science is universal (gravity is gravity)	I believe that science is universal and transcends culture/nation boundaries... The way that electricity works is accepted on all of the inhabited continents.	10	10			
Creativity	Yes - in designing experiment	The design of the experiment definitely has to be out of the ordinary and creative to test its ability in the world. If you aren't creative during planning, no new interesting theories could ever be created.	13	11	**8**	5	2
	Yes - in coming up with new questions/ideas	Coming up with something that no one else has thought of yet, or trying to disprove an idea because you think you have the right explanation, that takes creativity.	7	7			
	Yes - in interpreting results/ generating explanations	Scientists must look at reality in a unique way in order to derive new hypotheses or fit existing scientific knowledge into theories. An example of creativity in science is Darwin's observation of finches in his derivation of the theory of evolution. Darwin used his imagination to tie together similar looking birds with specific differences. Imagining that slight differences in beaks, behaviors and colors may be adaptations within one species contributed to Darwin's recognition of evolution of subspecies.	5	7			
	Yes - in collecting/presenting data	Scientist use creativity… in writing, bullets, charts, graphs, drawings and when they present their investigation.	3	2			

References

1. I. Y. Salter and L. J. Atkins, *Journal of Science Teacher Education*, Online First (Sept. 7, 2011), 1-21. (2011).
2. N. G. Lederman, F. Abd-El-Khalick, R. L. Bell, and R. Schwartz, *Journal of Research in Science Teaching, 3, 497-521. (2002).*
3. R. Schwartz and N. Lederman, *International Journal of Science Education*, 30, 727–771. (2008).
4. M. Ford, *Science & Education*. 17, 147-177. (2008).

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