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

Big Ideas/Concept:	Empirical Consistency is the Basis for Scientific Explanations
1. What you intend students to learn about this idea	• Knowledge in science is constructed from **uniform** explanations about the physical universe. • Explanations rely upon scientific evidence to support explanations. • Claims are only as strong as the evidence that supports them. • These explanations can be subjected to rigorous review and verification through repetitive experimentation and observations to determine their validity.

2. Why is it important for students to know this	• Explanations are composed of three basic parts: a claim (answer to the testable question), evidence (data/observations that support the claim), and reasoning (links evidence to claim, shows why the evidence counts, and includes connections to the underlying scientific principles responsible for the claim)
	• The realization that explanations provide the foundation of scientific knowledge is important for overall scientific literacy.
	• Driver, et al support 5 fundamental reasons why recognizing the importance of empirical consistency is an essential element associated with an overall understanding of the Nature of Science and to promote public understanding of science from different perspectives
	  o Economic: national success relies on education supplying qualified scientists
	  o Utilitarian: day to day events require management and practical skills that science can provide
	  o Democratic: produce educated voters who are literate on issues related to science
	  o Cultural: science is able to achieve dramatic results that all can appreciate
	  o Moral: science practices embody norms and commitments of a wider value
	• Driver, et al (1996): the aim of science is to establish explanations for the behavior of natural objects and phenomena which can command widespread acceptance

3. What else you know about this idea (that you do not intend students to know yet).	• Creativity and imagination play a role in the development of testable questions and experimental procedures as well as the organization and interpretation of empirical data.
	• Scientific knowledge is tentative.
	• How science determines what constitutes evidence
	• Interpretations of evidence
	  o May not simply be based on observations: some claims may result from inferences or models of phenomena rather than the actual phenomena in question
	  o Theory-laden interpretation of the evidence: Relying on the consistency of the evidence may lead to an interpretation of the evidence that is only rooted in the existing theories that currently align with the constructed explanation.

4. Difficulties/limitations connected with teaching this idea	• Misconceptions regarding hypothesis→theory→law
	  o Students often see these as a continuum where one turns into the other over time
	  o Observations can provide hypotheses
	  o Hypotheses are testable explanations
	  o Theories are broader explanations that explain how nature works
	  o Laws describe what nature is doing in certain conditions
	• What constitutes knowledge, observations/facts
	  o Facts are interpreted from observations as evidence that counts towards a claim regarding a testable question
	  o The knowledge is what is interpreted from the facts based on what are currently known, bias, social, and political influences of the time.
	• Inherent views about science
	  o Incorrect assumptions that science is absolute; 100% reliable; answers all questions
	  o Science only provides explanations based upon the available evidence at that time.
	  o As additional evidence is collected, newer technologies are developed, and increasing levels of knowledge are achieved can science allow a better understanding of the underlying principles of the phenomena in question.
	• Continuity from this learning in this course than should be carried and expressed in subsequent science courses.
	  o Some science teachers may not fully implement issues regarding the Nature of Science
	  o Students may eventually disregard important NOS issues stressed during this unit if it isn't continually addressed in other courses.

5. Knowledge about students' thinking which influences your teaching of this idea	• Impact of society and culture determines what "counts" as valid evidence
	• Reliance on induction to provide enough evidence for explanations
	• Driver, et al (1996): connections between evidence and theory
	    o Student ideas about science seem to show that they perceive explanations only emerging from, or closely tied to evidence.
	    o Students must be able to see evidence and the explanations they support as separate entities
	    o As age progresses understanding of the connection between evidence and explanation increases proportionately
	• Driver, et al (1996): Epistemological Representations
	        ▪ Students who demonstrate phenomenon-based reasoning cannot demonstrate a clear separation between description of phenomena and explanations.
	        ▪ Students who demonstrate relation-based reasoning are able to see explanations emerging from the data, and view the relationship between theory and evidence as unproblematic (theories can be "proved")
	        ▪ Students who demonstrate model-based reasoning recognize that explanations cannot be logically deduced from observational data

6. Other factors that influence your teaching of this idea	• Experiments won't always be "perfect" (results aren't always predictable even in cookbook experiments) • Pre-service teachers need to feel comfortable understanding how various pieces of evidence are obtained in experiments, how their students respond to conflicts in the evidence, and why having their students evaluate their own explanations in light of alternatives is important in developing uniform explanations. • Time allotted for activities limits instructional opportunities for other valid curriculum content that needs to be addressed. • Activities need to be targeted for specific learning outcomes.

7. Teaching procedures (and particular reasons for using these to engage with this idea)	• Inquiry cube activities, constructing explanations, and forming Inferences to explicitly demonstrate issues related to the Nature of Science
	    o Number cube: students will observe 5 sides of a cube and individually attempt to infer what the bottom of the cube may look like
	        ▪ Students will then confer within their group to determine which claim they will share with the other groups
	    o Shape cube: student groups will observe 5 sides of a cube with numbers, shapes, and colored backgrounds in an attempt to infer what the bottom of the cube may look like
	    o Student groups will present their claim about what is on the bottom of the Shape Cube and present it to the class.
	        ▪ They will justify their explanation by providing the empirical evidence that supports their conclusions and defend their reasons for why their claim counts as valid knowledge
	    o Students will recognize alternative explanations for the same set of data that are provided by their peers.
	• Old Woman/Young Lady Optical Illusion to explicitly demonstrate how similar evidence may be interpreted differently
	• Bridging Analogies
	• Nature of Science Role Play (from "*An Interactive Beginning of the Semester Activity"* by Cavallo, May/June 2008, <u>Journal of College Science Teaching</u>.)
	    o Chosen "scientists" will have to determine the "rules of the society" from observations made during the activity
	    o Students should recognize that interpretations of the evidence may be validated through repeated observations of the phenomena
	    o "Scientists" may have to work together to develop a shared understanding that characterizes the "rules of the society"

8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses).	• Snowball activity (formative assessment): writing explanations from the same data and sharing that explanation with others • Group explanations of activities with gallery walk evaluations followed by revisions and presentations • Cartoons to demonstrate understanding (www.makebeliefscomix.com) • Myths of Science Quiz (<u>The Science Teacher</u>, November, 2004)