CoRe: Content Representation Tool (Loughran, Mulhall, & Berry, 2004)	
Big Ideas/Concept:	Scientific explanations (theories) are tentative and not absolute.
1. What you intend students to learn about this idea	Students will develop an understanding that scientists' explanations of natural world are 1) the best explanation based on the available evidence; 2) that new evidence can alter or modify explanations; 3) that new ways of looking at evidence can lead to new explanations. Kid friendly version Ideas in science are the best that scientists can come up with from the evidence (information from observations, experiments and investigations) they have, but those ideas can change because of new evidence or new ways of thinking about that evidence.
2. Why is it important for students to know this	Students need to understand that scientific explanations (theories) are tentative because students, teachers, scientists and the lay public have misconceptions about the nature of science. In McComas' (1996) *Ten myths of science: Reexamining what we think we know....,* Myth 5: Science and its Methods Provide Absolute Proof directly deals with the common misconception that science can be proved and is absolute. McComas (1996) writes, "a hallmark of scientific knowledge is that it is subject to revision when new information is presented. Tentativeness is one of the points that differentiates science from other forms of knowledge. Accumulated evidence can provide support, validation and substantiation for a law or theory, but will never prove those laws and theories to be true". Yet a common misconception that students hold is that scientific theories and laws are absolute and that science proves these theories and laws through experimentation.
3. What else you know about this idea (that you do not intend students to know yet).	Tentativeness in science is quite complex, with issues regarding the nature of evidence and the subjectivity of theories. While it is clear and obvious that scientific theories will change because of advances in (technology-based) experiments; it is not always obvious that experimental results can be fallible, or that the evidence "can be ignored as irrelevant in the light of some shift in theoretical understanding" (Chalmers, 1999, p31). Chalmers provides an example of difficulty of experimental evidence in the story of Thomson and Hertz and the role technology played in the outcome. Thus, experimental evidence needs to be relevant and significant, but as this evidence is theory-dependant it is also fallible and subject to revision. Chalmers (1999) further makes a solid case that science is not objective, that theories are not derived from the facts. Instead, using the Falsificationists claims that theories can never be proven as true, only falsified. "Although it can never be legitimately said of a theory that it is true, it can hopefully be said that it is the best

	available" (p.60). Using Kuhn's perspective, Chalmers points out that scientists disagree "not only over fundamental theoretical assumptions but also over the kinds of observational phenomena that were relevant to their theories" (p.111). Scientific theories are tentative because they are (socially) constructed explanations that are based not only on theory dependant evidence, but the prior knowledge and biases of the scientists and the scientific community.
4. Difficulties/limitations connected with teaching this idea	The understanding of science as fact, proven, and absolute (rather than tentative) is common in many misconception. Using McComas' (1996) *Ten myths of science: Reexamining what we think we know....*, I will examine several myths as misconceptions relevant to the tentativeness of science. **Myth 1: Hypotheses Become Theories Which Become Laws** "Many believe that scientific ideas pass through the hypothesis and theory stages and finally mature as laws. A former U.S. president showed his misunderstanding of science by saying that he was not troubled by the idea of evolution because it was "just a theory." The president's misstatement is the essence of this myth; that an idea is not worthy of consideration until "lawness" has been bestowed upon it". This viewpoint fails to understand the nature of theory as an explanation of (theory-based) evidence. Laws can be fallible, just like theories. This misconception is based on an inductivist viewpoint that scientists discover the nature of a theory from the facts. This misconception implies that a hierarchal nature of science changes the tentativeness of scientific explanations. **Myth 3: A General and Universal Scientific Method Exists** and **Myth 9: Experiments are the Principle Route to Scientific Knowledge** The belief that a single scientific method is a very common misconception. Many students (as well as scientists and lay persons) believe that if a science does not follow the "scientific method" then it is fallible. If an experiment cannot be done, then the theory is untested, and therefore cannot be proven. This misconception implies that science is a fixed way of looking at nature and if followed, the tentativeness of scientific explanations is resolved. **Myth 4: Evidence Accumulated Carefully Will Result in Sure Knowledge** "All investigators, including scientists, collect and interpret empirical evidence through the process called induction. This is a technique by which individual pieces of evidence are collected and examined until a law is discovered or a theory is invented".

	This misconception is at the root of the belief that evidence is not theory-ladden. That evidence will tell scientists the nature of a theory from the facts, rather than scientist inventing a theory and using the evidence to support that invented construct. This misconception implies that if evidence is carefully examined then theories are correctly constucted, and the tentativeness of scientific explanations is resolved.
5. Knowledge about students' thinking which influences your teaching of this idea	There are no direct studies on elementary student understandings of the tentativeness of science, however information can be inferred from studies looking at students abilities to understand the meaning of the word "theory", and the coordination of evidence and explanations. Driver, et al (1996) found that students aged 9 years old understanding of the word "theory" had a vague idea of its meaning, "A theory is … an idea" (p.93). Yet there were some students who had an "awareness" of a deeper understanding, theory as a contextual or general explanation. Driver, and colleagues (1996) found that elementary students can use direct perceptual evidence as a warrant for belief, but had difficulty with inferences from evidence. They also found that most students accepted theories based on "blind" authority. When Driver and colleagues (1996) examined students ability to coordinate evidence and explanations, they found that elementary students were inconsistent, but were able in certain instances to consistently use evidence and explanation, and phenomenon-based reasoning. From this study elementary students have an ability to understand the tentativeness of science. From this information elementary students need direct instruction on theory-based explanations, which is a basic to understanding the tentativeness of science.
6. Other factors that influence your teaching of this idea	Children at early ages are able to make evidence-based explanations and are able to choose the best explanation based on evidence (Gagnon and Abell, 2008); therefore it makes sense that students should also be able to understand that scientists make evidence-based explanations, or theories, and like themselves, scientists are able to evaluate theories when new evidence is presented. "Samarapungavan (1992) interviewed first, third, and fifth graders to find out what criteria they used for choosing among alternate explanations about the relative shapes, positions, and movements of heavenly bodies. She found that even the youngest children could use logic to choose the best explanation based on evidence" (Gagnon and Abell, 2008, p.60). However, from research on classroom-based studies, Gagnon and Abell (2008) concluded that specific scaffolding is necessary for students to use and generate evidence-based scientific explanations.
7. Teaching procedures (and particular reasons for	In order for students to understand that ideas (theories) in science are tentative and not absolute. Using a learning cycle format students will develop an understanding of the tentativeness of science through an exploration of a unit on the history of plate tectonics. This unit would be designed for upper elementary (or

using these to engage with this idea)	middle grade) students. The 4th Grade Missouri Grade Level Expectations state in Strand 5 Earth Systems that students learn about the changes in the Earth's surface, although the concepts of plate tectonics are not accessed at this grade level, students can be exposed to the big picture to help them understand geologic changes. The Nature of Science standards are incorporated into the Inquiry Strand (Strand 7) and this unit addresses Concept C *Evidence is used to formulate explanations: (b) - Use data as support for observed patterns and relationships, and to make predictions to be tested* and Concept D *Use data as support for observed patterns and relationships, and to make predictions to be tested: (a) Evaluate the reasonableness of an explanation (b) Analyze whether evidence supports proposed explanations.* In the NRC (1996) National Science Education Standards the Nature of Science Standard states that students develop an understanding that science is a human endeavor: "Although men and women using scientific inquiry have learned much about the objects, events, and phenomena in nature, much more remains to be understood. Science will never be finished" (p. 141). These standards give inference to the tentativeness of science. Explore: Students will be asked, "Do you think the continents have always been in the same spot?" and "What reasons can you give for thinking that the continents have always been in the same spot?" or "What reasons can you give for thinking that the continents have moved?" Following discussion of student ideas, students will then be asked to cut out and arrange the continents on a blank map of Earth. Students will be encouraged to try a variety of arrangements, using observation and prediction, and to give reasons why they might arrange the continents the way they did. Students will share their arrangements in whole class discussion, during this discussion students will be asked, "Do you think scientists have had different ideas about where the continents have been? Explain your thinking". Concept Formation: Students will read an account of the contribution of Alfred Wegener, the ideas that were accepted at the time and why Wegener's ideas were not accepted, and the evidence that changed scientists' viewpoints to accept the explanation of continental drift/plate tectonics. Students will be asked, "Do you think scientists were unfair to reject Wegener's ideas at the time?" and "Is it reasonable that scientists can change their minds?" Students will discuss their ideas about science and scientists. Students will then read several comic strips that lead them to think about and discuss the tentativeness of theories. For example:

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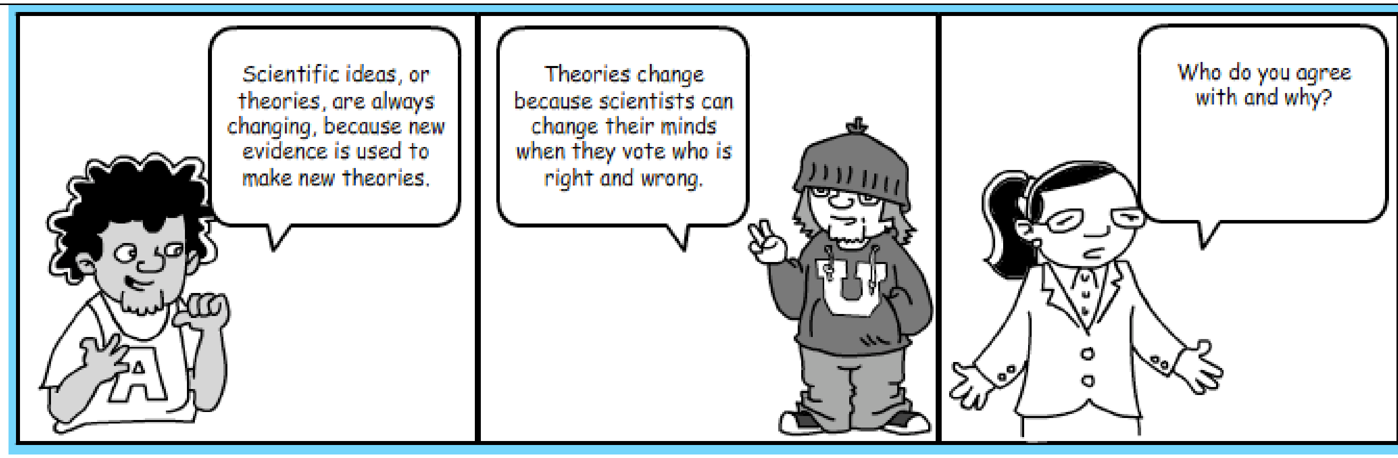

Application:
Students will be asked, “Do you think the case of Alfred Wegener is unique in science?” and “Can you think of other examples in which ideas in science have changed?” Students who cannot come up with examples can google “theories that have changed in science” to read about and gather information. Students will then write a letter to their parents, or someone they know and explain how and why ideas in science change, using Wegener and other examples.
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<td>8. Specific ways of ascertaining students’ understanding or confusion around this idea (including likely range of responses).</td>
<td>As students are discussing their ideas during concept formation using the comic strips, the teacher can guide discussion by changing the statements of the comic strip characters, adding to or eliminating parts of their statements to challenge and deepen the discussions.
Using the application of the learning cycle presented above, students will state their ideas about the tentativeness of science and present evidence for their ideas. From the letter students write, indications of their understanding and at what level can be determined. Students might understand that science changes because new evidence supports some ideas (theories) better than other ideas, that scientists come up with new ideas because evidence no longer supports the currently accepted idea, and that ideas are the best that scientists can come up with based on the evidence. Some students might have partial understandings, that new evidence can change ideas, but still think that scientists discover ideas from the evidence, rather than the explanations are the best based on the evidence. Some students might conclude that Wegener’s ideas were not accepted because other scientists were unfair, lacking an understanding that supporting evidence is crucial to scientific ideas.</td>
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References:

Chalmers, A. F. (1999). What is this thing called science? (3rd ed.). Indianapolis, IN: Hackett Publishing.

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McComas (1996). Ten myths of science: Reexamining what we think we know about the nature of science. School Science and Mathematics, 96, 10-16.

(NRC) National Research Council. (1996). National Science Education Standards. Washinton, DC: National Academic Press.