sInvestigator: Facilitating Inquiry-based Teaching and Learning of Critical Thinking Skills

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Innovations in Teaching and Learning Conference
George Mason University, September 21-25, 2020

Introduction

Inquiry-based teaching and learning is recognized as being very effective but difficult to use in the classroom.

With support from the NSF's "Improving Undergraduate STEM Education" program, we have developed a cognitive assistant, called sInvestigator (science Investigator) that facilitates the development of a wide variety of inquiry-based teaching and learning experiences for learning critical thinking skills.

We present a few examples of exercises that can be used in class.

Materials on critical thinking with sInvestigator together with these and other exercises are available at:

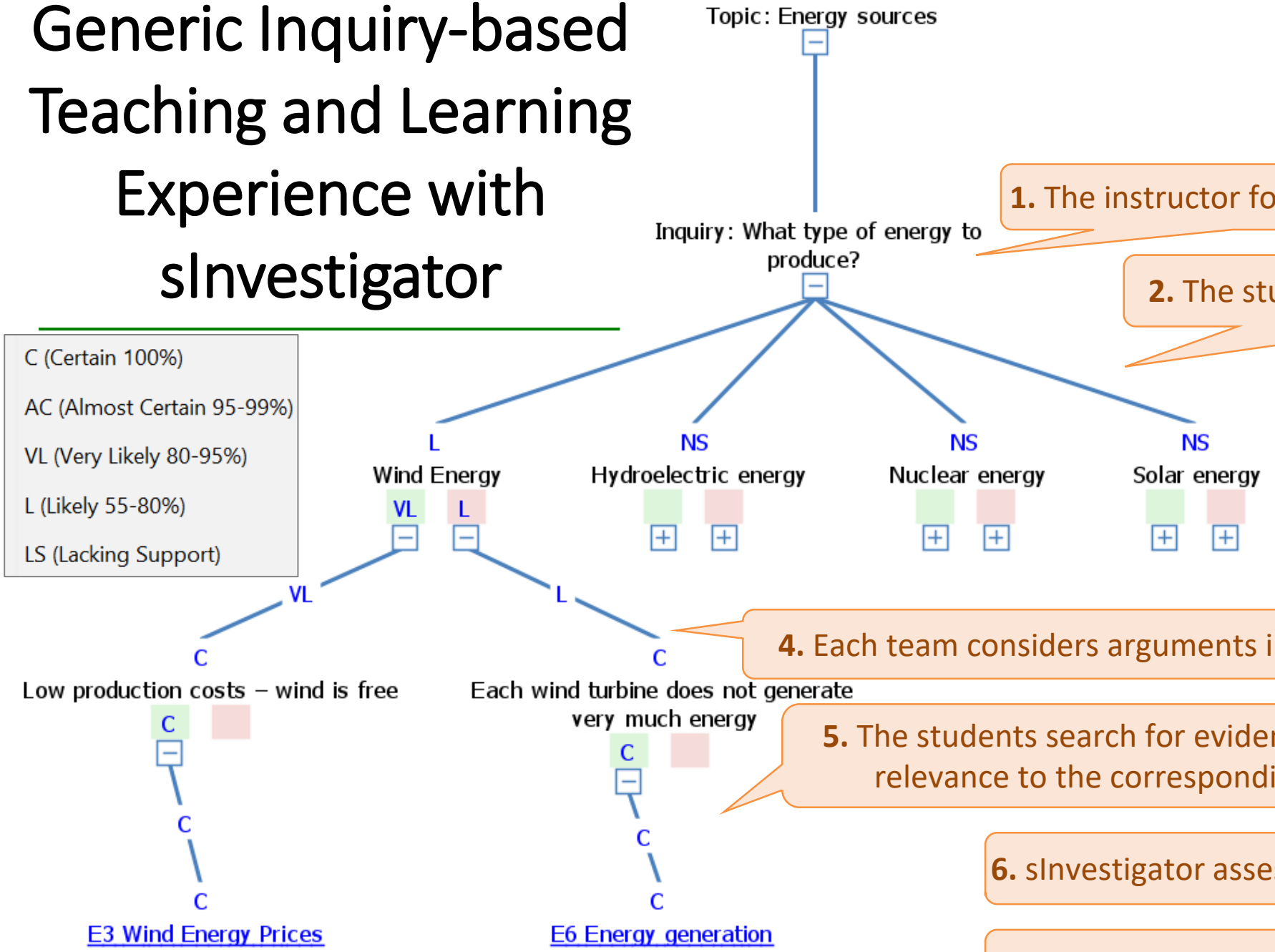
http://lac.gmu.edu/sInvestigator/

sInvestigator for both PC and Mac can de downloaded from:

http://lac.gmu.edu/sInvestigator/Download.html

To obtain assistance with using sInvestigator email Prof. Gheorghe Tecuci (tecuci@gmu.edu).

Generic Inquiry-based Teaching and Learning Experience with sInvestigator



1. The instructor formulates an inquiry

2. The students hypothesize possible answers

3. The students form teams, each team developing an evidence-based argumentation for assessing the probability of their selected hypothesized answer

4. Each team considers arguments in favor and against their hypothesis

5. The students search for evidence on the Internet and evaluate its relevance to the corresponding hypothesis and its credibility

6. sInvestigator assesses the probability of the hypotheses

7. The teams present and debate their argumentations

Analysis of Competing Scientific Theories with sInvestigator

The aim of this exercise, adapted from (Osbome, Erduran, Simon, 2004, pp-31-33)*, is to explore alternative theories for why we see objects, by developing evidence-based argumentations.

Consider the following competing theories on how we see things:

Theory 1: Light rays travel from our eyes onto the objects and enable us to see them.

Theory 2: Light rays are produced by a source of light and reflect off objects into our eyes so we can see them.

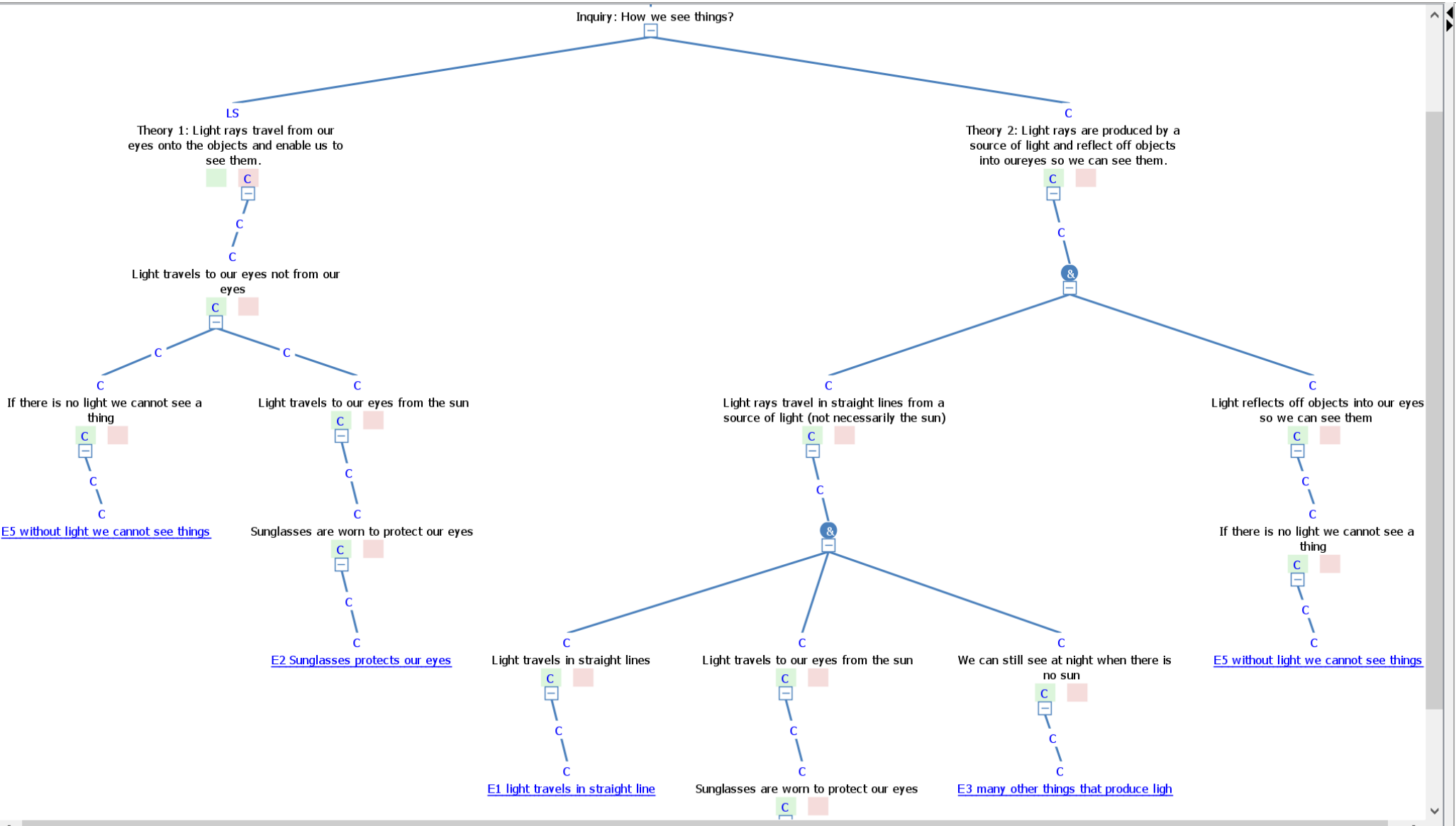
The following statements might be used to support or refute these theories:

- Light travels in straight lines.
- We can still see at night when there is no sun.
- Sunglasses are worn to protect our eyes.
- If there is no light we cannot see a thing.
- We 'stare at' people, 'look daggers' and 'catch people's eye'.

Assess their truthfulness based on evidence and use the relevant ones to determine which theory is correct.

* Jonathan Osbome, Sibel Erduran, Shirley Simon, *Ideas, Evidence & Argument in Science* (IDEAS), King's College London, 2004, https://www.stem.org.uk/elibrary/collection/3308

Light - paper



Argument

Evidence

E1 light travels in straight line (Once light has been produced, it will keep travelling in a straight line until it hits something else. Shadows are evidence of light travelling in straight lines. An object blocks light so that it can't reach the surface where we see the shadow. Light fills up all of the space before it hits the object, but the whole region between the object and the surface is in shadow.)

E2 Sunglasses protects our eyes (Sunglasses or sun glasses (informally called shades or sunnies; more names below) are a form of protective eyewear designed primarily to prevent bright sunlight and high-energy visible light from damaging or discomforting the eyes. They can sometimes also function as a visual aid, as variously termed spectacles or glasses exist, featuring lenses that are colored, polarized or darkened.)

E3 many other things that produce ligh (When a light globe is turned on it gives out light. There are many other things that produce light. Candles, fluorescent tubes, the Sun, television screens, computer screens and glow-worms are just some of them. After light has been reflected off an object, such as a tree or a book, it still travels in straight lines, but in a new direction. If the light enters our eyes, we see the object (ie our eyes can detect light).)

E4 reflection of light (During the day, the sun generates sufficient light to illuminate objects on Earth. The blue skies, the white clouds, the green grass, the colored leaves of fall, the neighbor's house, and the car approaching the intersection are all seen as a result of light from the sun (the luminous object) reflecting off the illuminated objects and traveling to our eyes.)

E5 without light we cannot see things (During the evening when the Earth has rotated to a position where the light from the sun can no longer reach our part of the Earth (due to its inability to bend around the spherical shape of the Earth), objects on Earth appear black (or at least so dark that we could say they are nearly black). In the absence of a porch light or a street light, the neighbor's house can no longer be seen; the grass is no longer green, but rather black; the leaves on the trees are dark; and were it not for the headlights of the car, it would not be seen approaching the intersection. Without luminous objects generating light that propagates through space to illuminate non-luminous objects, those non-luminous objects cannot bee seen. Without light, there would be no sight.)

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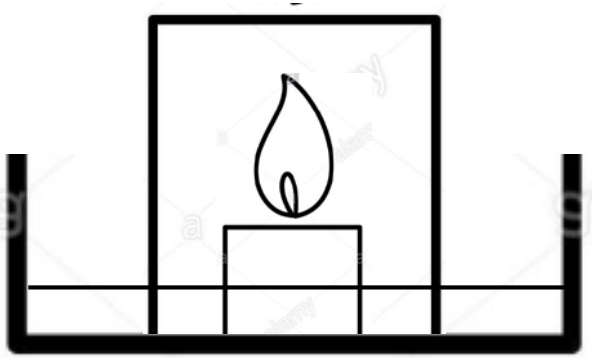
Predicting, Observing and Explaining with sInvestigator

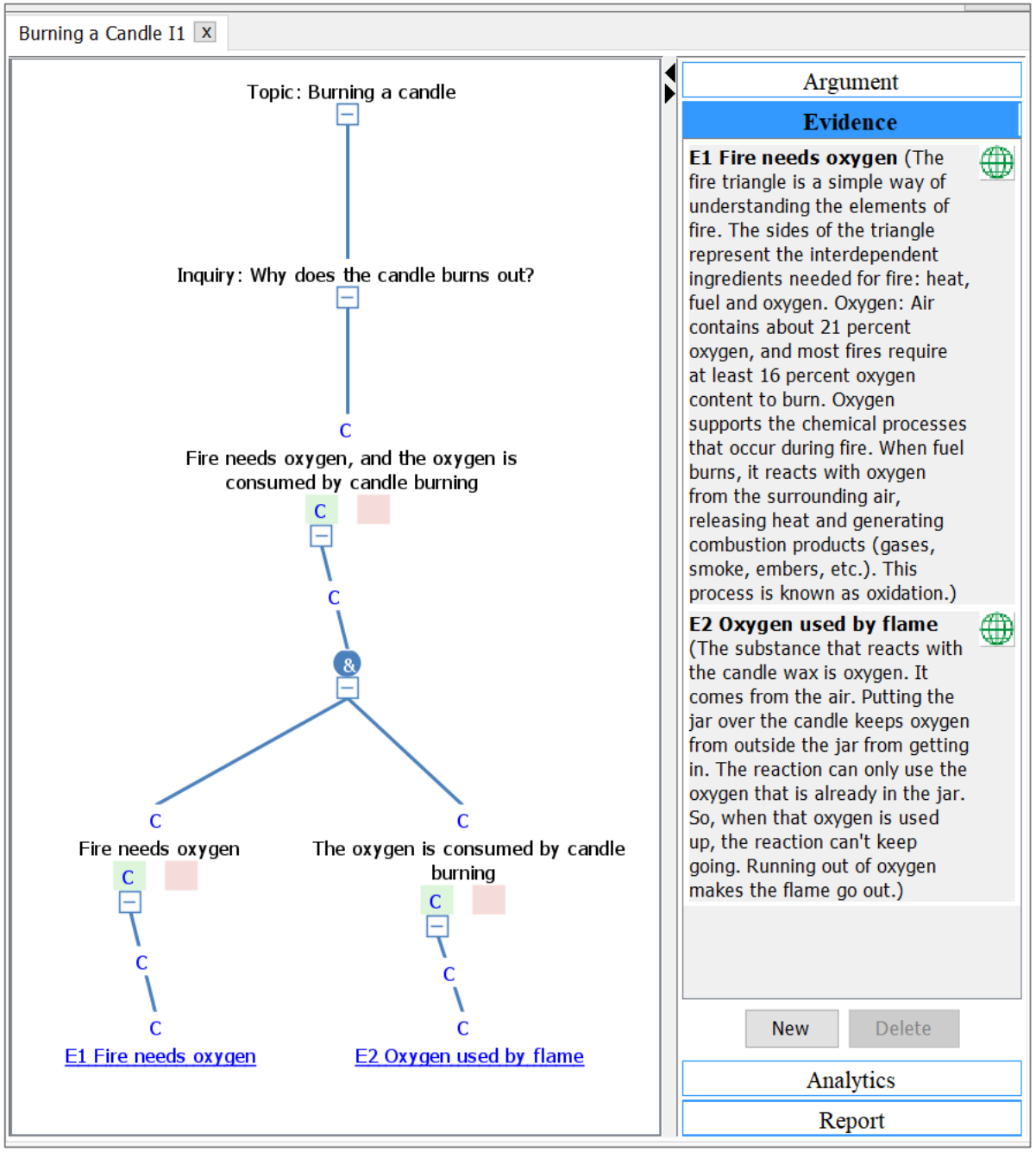
The aim of this exercise, adapted from (Osbome, Erduran, Simon, 2004, pp7-11), is to learn about combustion.



The students are explained the experiment to be performed which is illustrated in this figure: A burning candle inside a container with water is covered with a glass.

They are asked to predict what will happen with the candle and the water level inside the glass, perform the experiment, and observe the actual results.

Finally they are asked to develop two evidence-based argumentations, one that explains why the candle burns out when it is covered with the glass, and the other that explains why the water level inside the glass raises.


Burning a Candle I1
Topic: Burning a candle
Inquiry: Why does the candle burns out?
C
Fire needs oxygen, and the oxygen is consumed by candle burning
C
C
&
C
Fire needs oxygen
C
C
C
E1 Fire needs oxygen
C
The oxygen is consumed by candle burning
C
C
C
E2 Oxygen used by flame
Argument
Evidence
E1 Fire needs oxygen (The fire triangle is a simple way of understanding the elements of fire. The sides of the triangle represent the interdependent ingredients needed for fire: heat, fuel and oxygen. Oxygen: Air contains about 21 percent oxygen, and most fires require at least 16 percent oxygen content to burn. Oxygen supports the chemical processes that occur during fire. When fuel burns, it reacts with oxygen from the surrounding air, releasing heat and generating combustion products (gases, smoke, embers, etc.). This process is known as oxidation.)
E2 Oxygen used by flame (The substance that reacts with the candle wax is oxygen. It comes from the air. Putting the jar over the candle keeps oxygen from outside the jar from getting in. The reaction can only use the oxygen that is already in the jar. So, when that oxygen is used up, the reaction can't keep going. Running out of oxygen makes the flame go out.)
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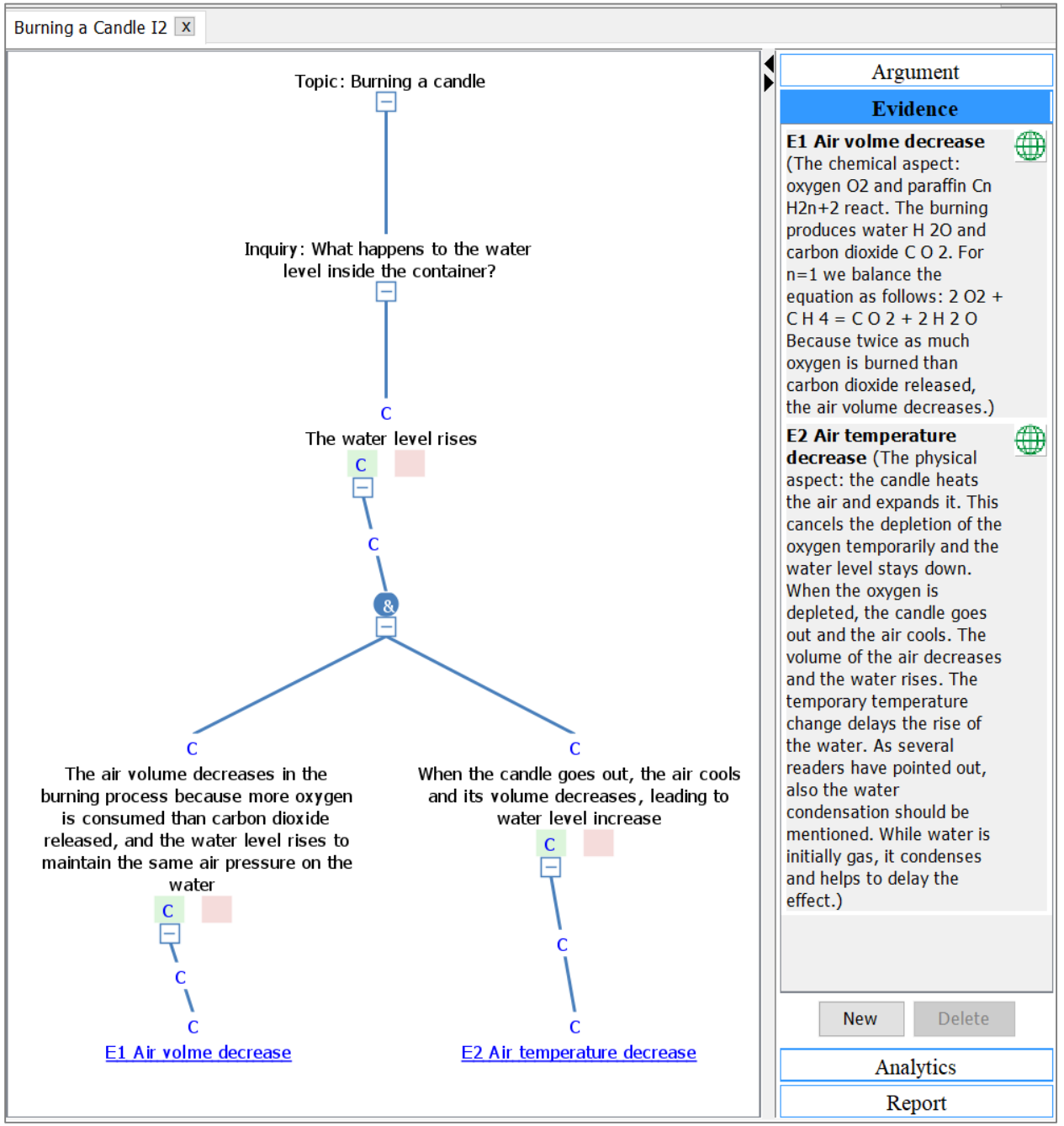
Burning a Candle I2
Topic: Burning a candle
Inquiry: What happens to the water level inside the container?
C
The water level rises
C
C
&
C
The air volume decreases in the burning process because more oxygen is consumed than carbon dioxide released, and the water level rises to maintain the same air pressure on the water
C
C
C
E1 Air volme decrease
C
When the candle goes out, the air cools and its volume decreases, leading to water level increase
C
C
C
E2 Air temperature decrease
Argument
Evidence
E1 Air volme decrease (The chemical aspect: oxygen O2 and paraffin Cn H2n+2 react. The burning produces water H 2O and carbon dioxide C O 2. For n=1 we balance the equation as follows: 2 O2 + C H 4 = C O 2 + 2 H 2 O Because twice as much oxygen is burned than carbon dioxide released, the air volume decreases.)
E2 Air temperature decrease (The physical aspect: the candle heats the air and expands it. This cancels the depletion of the oxygen temporarily and the water level stays down. When the oxygen is depleted, the candle goes out and the air cools. The volume of the air decreases and the water rises. The temporary temperature change delays the rise of the water. As several readers have pointed out, also the water condensation should be mentioned. While water is initially gas, it condenses and helps to delay the effect.)
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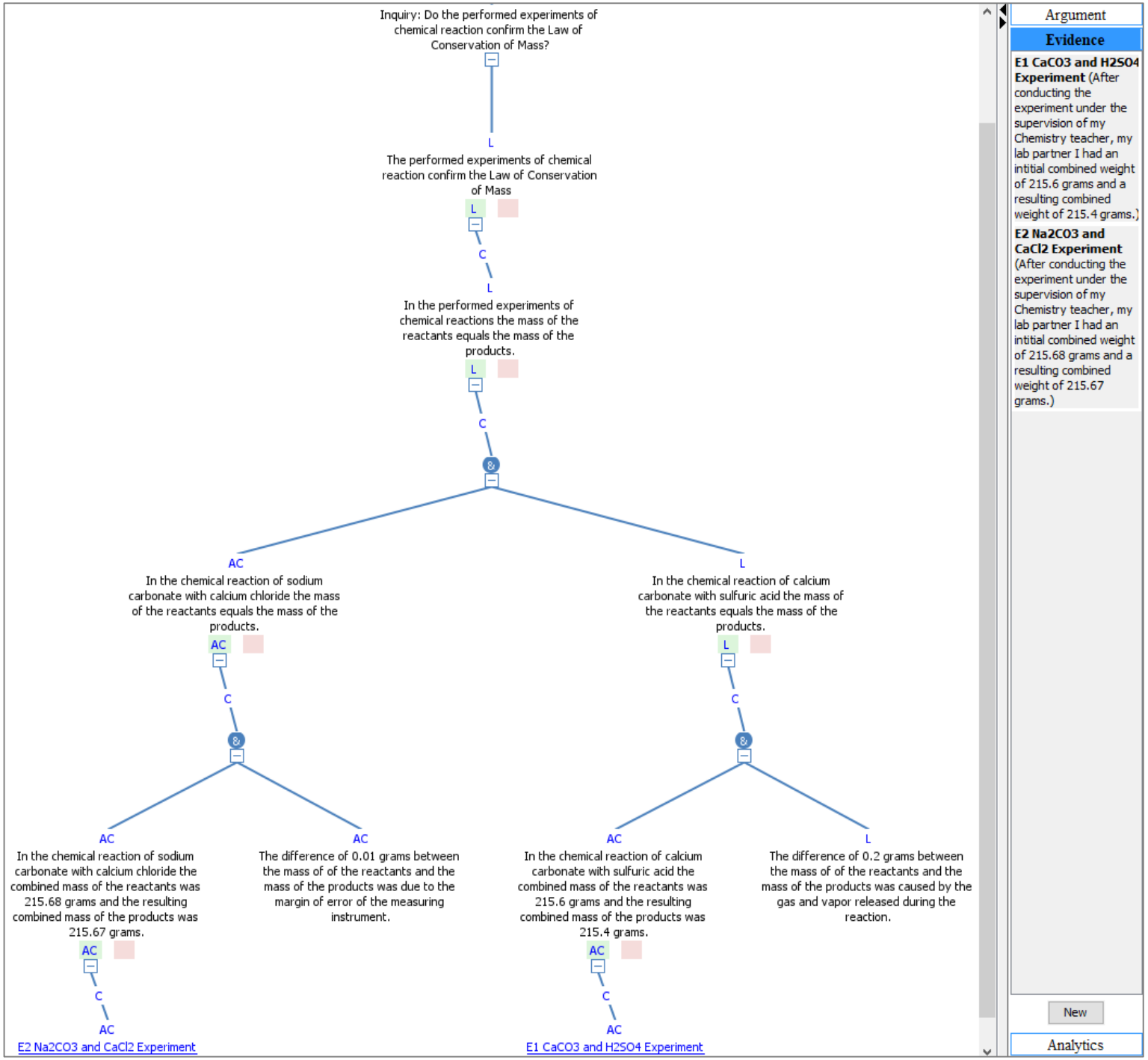
Explaining the Results of a Chemical Experiment

The aim of this exercise is to develop an evidence-based argumentation that explains the results obtained by individual students in a Chemistry experiment designed to verify the Law of Conservation of Mass.

This is an actual experiment conducted in the course taught by prof. Robin Taylor at the Thomas Jefferson High School for Science and Technology, in Fairfax, Virginia.

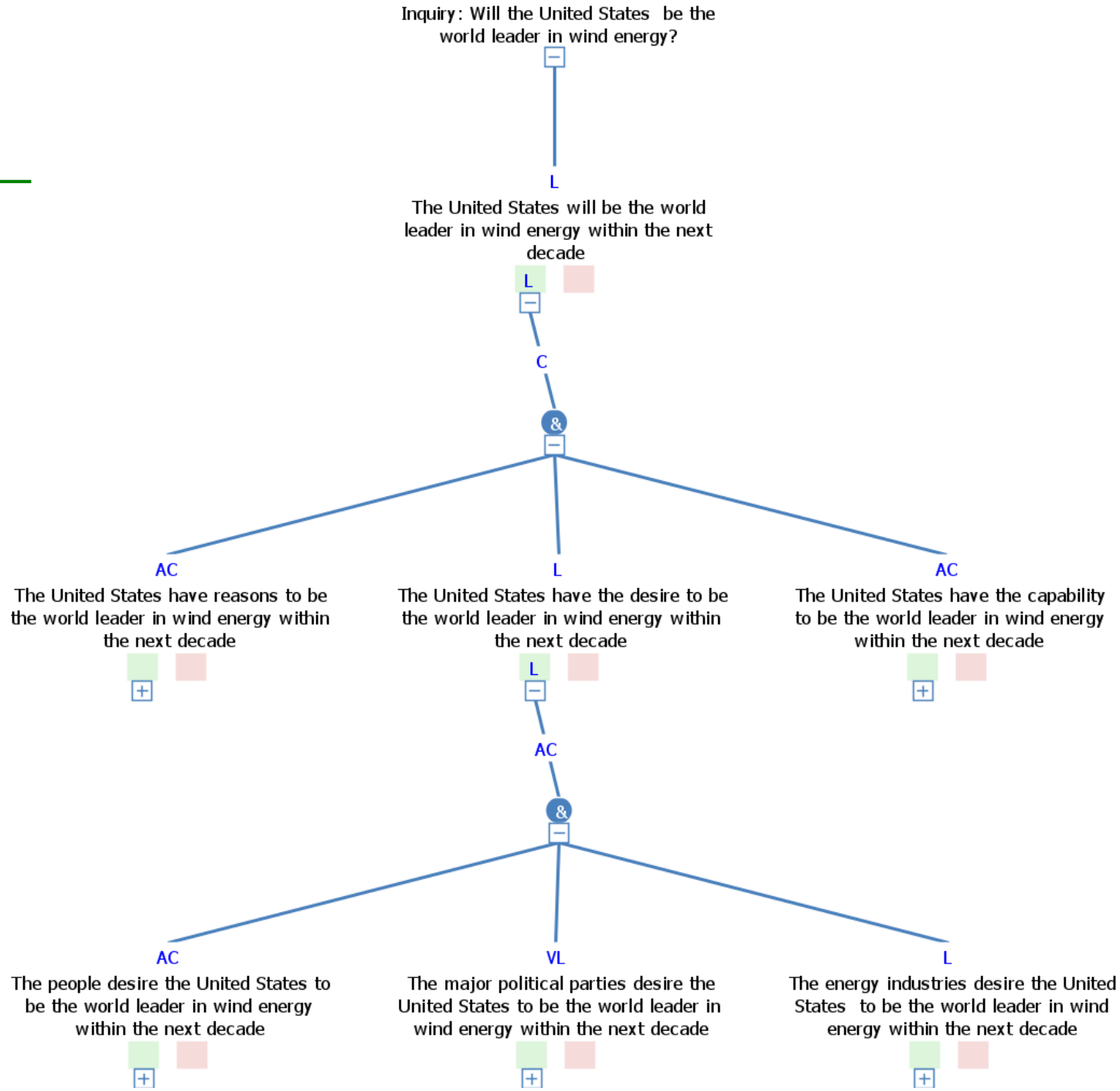
Do the performed experiments of chemical reaction confirm the Law of Conservation of Mass?

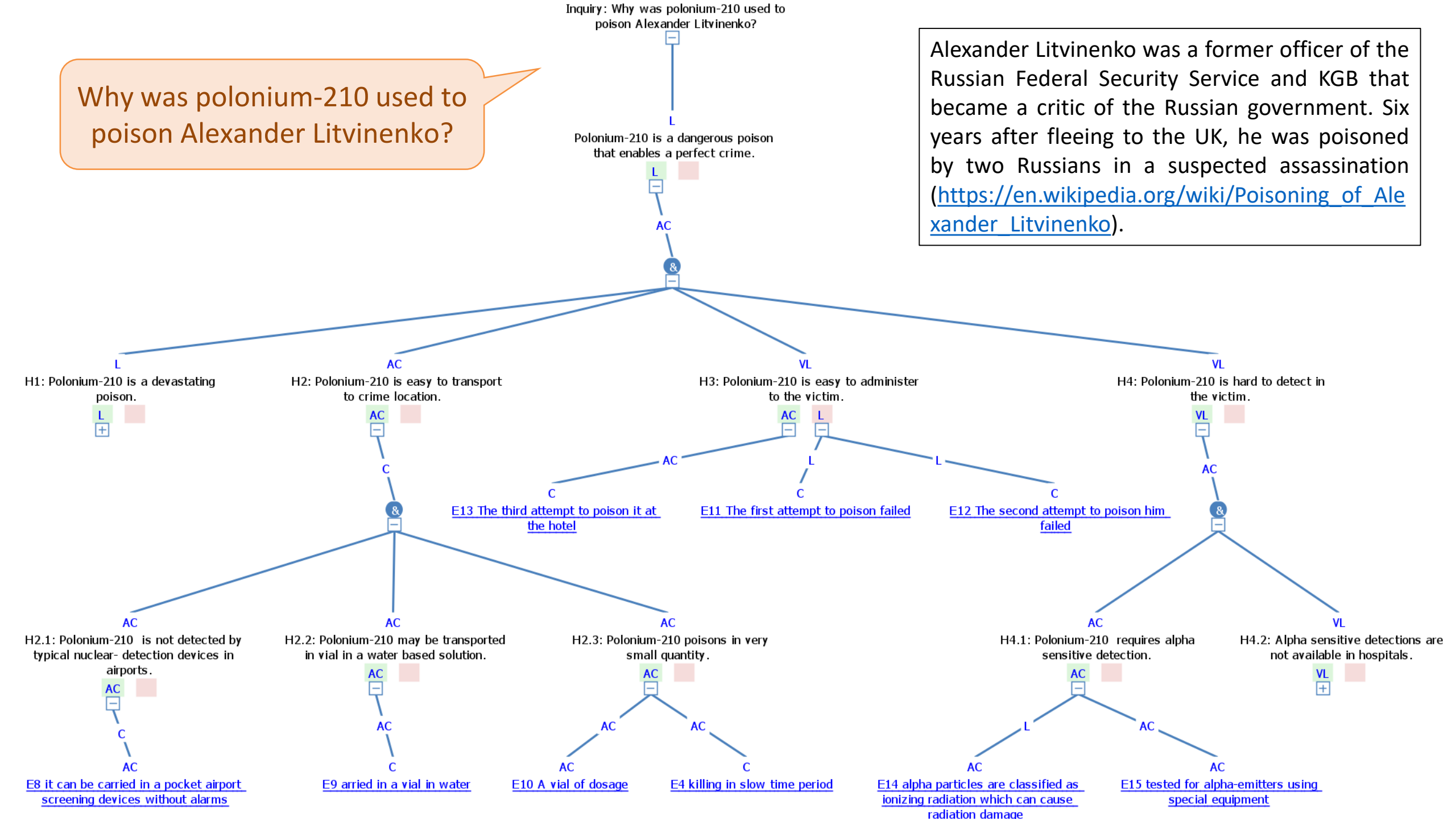


Argumentations for a Wide Variety of Inquiries

sInvestigator can be used in any science class to develop evidence-based argumentations for a wide variety of inquiries.

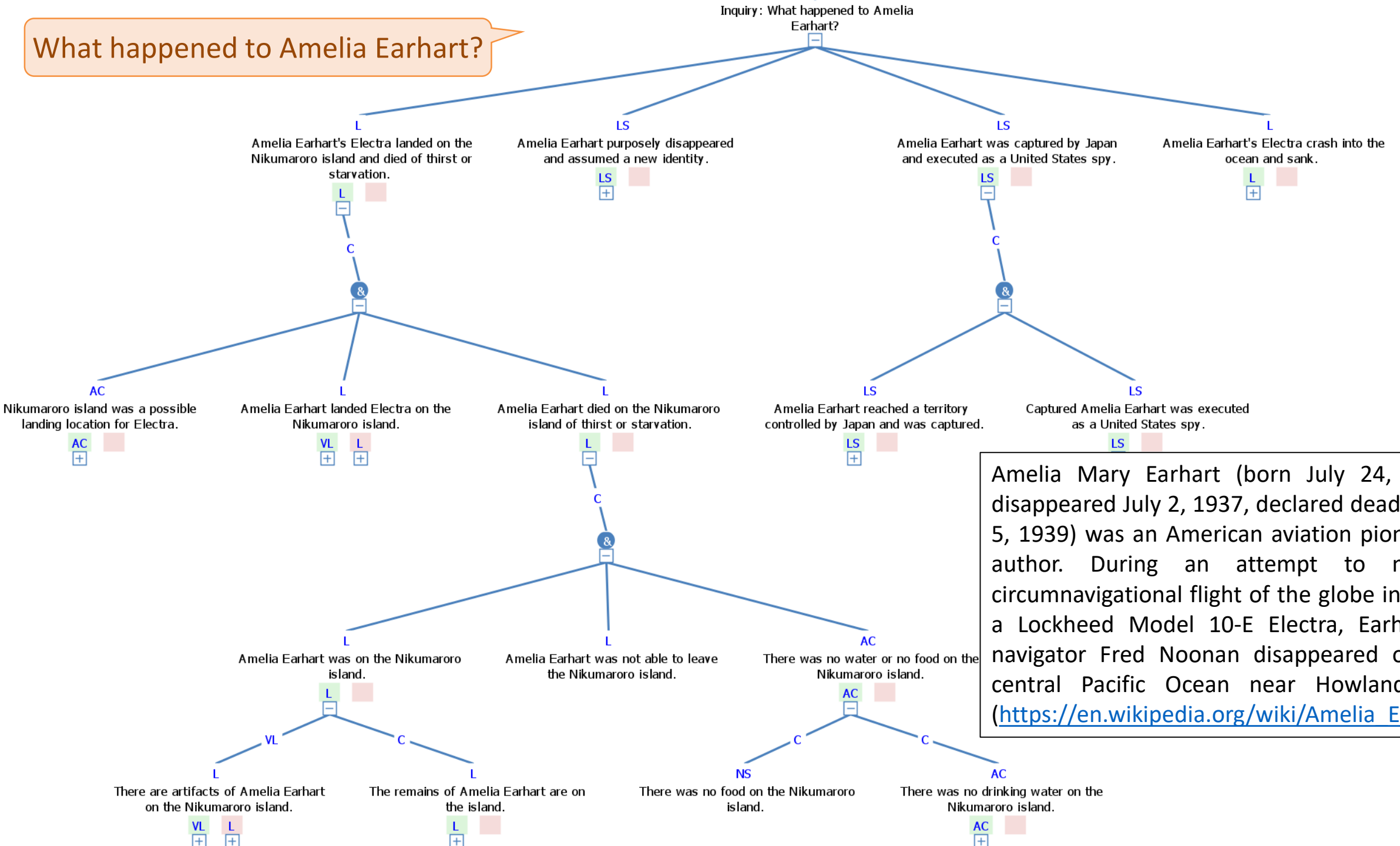
Will the United States be the world leader in wind energy?





Alexander Litvinenko was a former officer of the Russian Federal Security Service and KGB that became a critic of the Russian government. Six years after fleeing to the UK, he was poisoned by two Russians in a suspected assassination (https://en.wikipedia.org/wiki/Poisoning_of_Alexander_Litvinenko).

What happened to Amelia Earhart?



Amelia Mary Earhart (born July 24, 1897 – disappeared July 2, 1937, declared dead January 5, 1939) was an American aviation pioneer and author. During an attempt to make a circumnavigational flight of the globe in 1937 in a Lockheed Model 10-E Electra, Earhart and navigator Fred Noonan disappeared over the central Pacific Ocean near Howland Island (https://en.wikipedia.org/wiki/Amelia_Earhart).

Acknowledgements

This research was performed in the Learning Agents Center and was supported in part by the National Science Foundation under grant number 1611742 (as part of the "Improving Undergraduate STEM Education" program) and by George Mason University.

Mihai Boicu, Nancy Holincheck, James Trefil and Terri Galanti contributed to the "Teaching Critical Thinking Skills in Science with sInvestigator" project and to the use of sInvestigator in several undergraduate science classes at George Mason University.

Several exercises on the sInvestigator website are adaptations of those defined by Jonathan Osbome, Sibel Erduran and Shirley Simon (2004).

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