Inquiry-based Teaching of Critical Thinking Skills in Science with sInvestigator

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Contents

ABSTRACT

Inquiry-based teaching and learning is recognized as being very effective, but very difficult to use in practice. This report presents an inquiry-based approach to the teaching of critical thinking skills in science with an intelligent computer system called sInvestigator (science Investigator). sInvestigator helps students develop critical thinking skills in addressing scientific problems, through a rigorous yet ~~an~~ easy to employ inquiry-based approach. The report first introduces the computational framework of scientific inquiry as discovery of evidence, hypotheses, and arguments, on which sInvestigator is based. Then it introduces the features of sInvestigator with a couple of illustrative examples, a generic inquiry-based teaching and learning exercise and a specific one. Finally it presents a variety of inquiry-based exercises for use in science classes from middle school through university.

1. Introduction

Significant progress has been made in science education with the development of the National Science Education Standards (NRC, 1996). These standards call for inquiry-based teaching and learning which "refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work." Students practice inquiry as they "describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations" (NRC, 1996, p. 2).

Researchers have demonstrated that academic achievement is improved by the use of inquiry instruction in K-12 levels (Bransford and Donovan, 2004; Minner et al., 2010). Inquiry instruction has also been examined at the college level and found to be more effective than traditional science instruction for the development of thinking and problem solving (Oliver-Hoyo et al., 2004). University science faculty value inquiry, but identify time, class size, student motivation, and student ability as obstacles to implementing inquiry-based instruction (Brown et al., 2006). A significant result in the theory of inquiry-based learning is Process-Oriented Guided-Inquiry Learning (POGIL, 2016), a student-centered, group-learning instructional strategy and philosophy. POGIL provides a general framework for developing activities implementing guided inquiry in the classroom, and there are now many POGIL inquiry-based learning activities in a wide variety of disciplines. However, while POGIL and other inquiry approaches offer an alternative to lectures-style instruction, they depend on intensive training of instructors to develop and implement inquiry-based activities in their classrooms.

The NSF's "Improving Undergraduate STEM Education" program (NSF 14-588) provided support for the development of, and experimentation with an intelligent computer system called sInvestigator (science Investigator), that greatly facilitates the development of a wide variety of inquiry-based teaching and learning experiences for learning critical thinking skills. sInvestigator has built-in features to engage the students in understanding, extending, creating, critiquing, and debating evidence-based scientific argumentations in real-life scientific investigations. This involves using science cross-cutting concepts and disciplinary core ideas, giving the students numerous opportunities to exercise imagination and creativity, and develop critical scientific practices, particularly: (1) Asking questions; (2) Constructing explanations; (3) Engaging in argument from evidence; and (4) Obtaining, evaluating, and communicating explanations (NRC, 2012, p.3). Students' progress is assessed based on their ability to deal with new problems on their own, still using sInvestigator, but without any help from the instructor.

This report presents a freely available intelligent computer system, called sInvestigator (science Investigator), that helps students develop critical thinking skills in addressing scientific problems, through a rigorous yet easy to employ inquiry-based approach. sInvestigator was developed as a customized version of Cogent (Tecuci et al., 2015; 2018a), which incorporates the latest version of the Disciple learning agent theory and technology (Tecuci, 1988; Tecuci 1998; Boicu et al., 2000; Tecuci et al., 2000; Boicu et al., 2001; Tecuci et al., 2002a; Tecuci et al. 2016a). Disciple agents have been demonstrated in many domains, including critical thinking education in history (Tecuci and Keeling, 1999), course of action critiquing (Tecuci et al., 2001), center of gravity analysis (Tecuci et al., 2002b; Tecuci et al., 2005; Tecuci et al., 2008a), intelligence analysis (Tecuci et al., 2008b; Tecuci et al., 2011; Tecuci et al., 2016b; Tecuci et al., 2018a), intelligence, surveillance and reconnaissance (Tecuci et al., 2019), and cybersecurity (Tecuci et al., 2018b; Huang et al., 2020).

The next section introduces the computational framework of scientific inquiry as discovery of evidence, hypotheses, and arguments, on which sInvestigator is based (Tecuci et al., 2016). Then Section 3 presents a generic inquiry-based teaching and learning experience. Section 4 illustrates the features of sInvestigator with a detailed case study. The rest of the sections present a variety of inquiry-based exercises, many of them based on those described in (Osbome et al., 2004).

Additional materials on critical thinking with sInvestigator, including instructions to download the system for both PC and Mac are available at: http://lac.gmu.edu/sInvestigator/

2. Scientific Inquiry as Discovery of Evidence, Hypotheses, and Arguments

Figure 1 illustrates the computational model of scientific inquiry which is at the basis of sInvestigator. When the students and sInvestigator address a specific inquiry, for example: *What type of organism is Euglena?*, they first use *abductive (imaginative) reasoning*, which shows that something is *possibly* true, to hypothesize possible answers:

- Euglena is a plant.
- Euglena is an animal.
- Euglena is another type of organism, neither plant nor animal.

Students will need to analyze each of these hypotheses to determine which one is true. For this, they use each hypothesis to discover relevant evidence. One approach is to ask the question, *What evidence would be observable if this hypothesis were true?* The reasoning might go as follows: If H_k were true, then the sub-hypotheses H_{k1} and H_{k2} would also need to be true. But if H_{k1} were true, then one would need to observe evidence E_{k1}, and so on. This process leads to the discovery of new evidence by identifying the necessary conditions for hypothesis H_k.

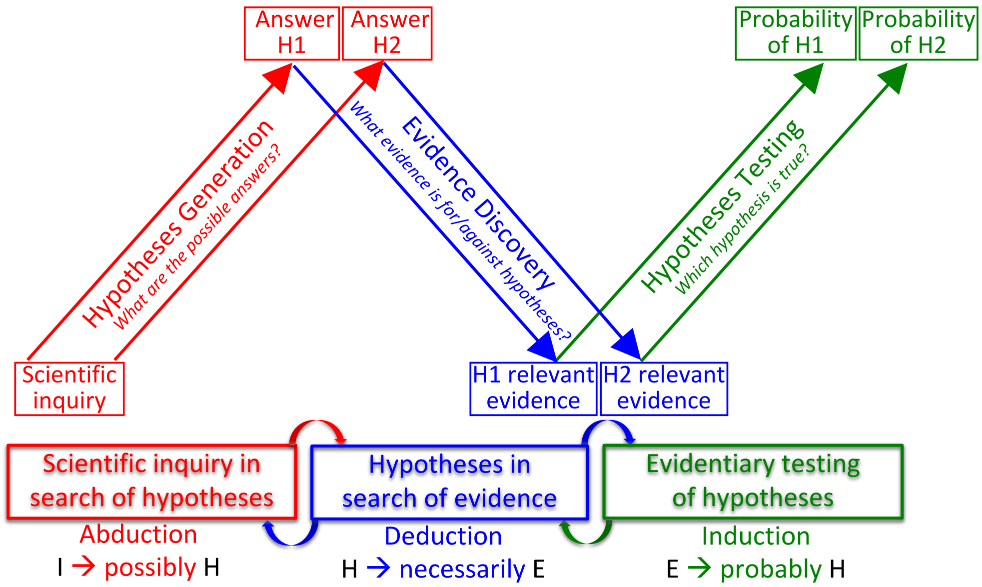


Figure 1. Scientific inquiry as discovery of evidence, hypotheses, and arguments.

A broader question that may guide the discovery of evidence is: *What evidence would be for or against this hypothesis?* In this case one would look for both favoring and disfavoring arguments for the hypothesis H_k to be true. They decompose each hypothesis into simpler and simpler hypotheses by considering favoring arguments (under the left, green square) and disfavoring arguments (under the right, pink square), as illustrated in Figure 2.

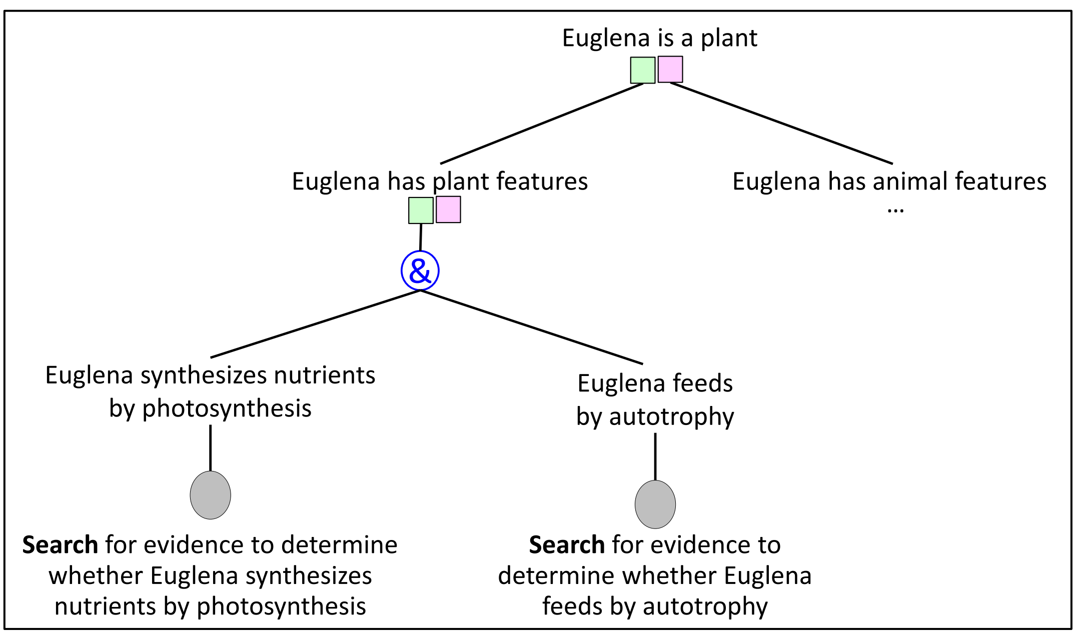


Figure 2. Hypothesis in search of evidence.

Favoring argument: IF "Euglena has plant features" THEN "Euglena is a plant"
Disfavoring argument: IF "Euglena has animal features" THEN "Euglena is not a plant"

The sub-hypotheses are further decomposed until the resulting leaf hypotheses are simple enough to point to what evidence would favor or disfavor each of them:

Favoring argument: IF "Euglena synthesizes nutrients by photosynthesis" and "Euglena feeds by autotrophy"
THEN "Euglena has plant features"

Search for evidence to determine whether Euglena synthesizes nutrients by photosynthesis.
Search for evidence to determine whether Euglena feeds by autotrophy.

Finally the students test the hypotheses based on the credibility and relevance of the discovered evidence, and determine which one is true.

3. Generic Inquiry-based Teaching and Learning Experience

Figure 3 illustrates a generic inquiry-based teaching and learning experience with sInvestigator in the context of the "Energy sources" topic.

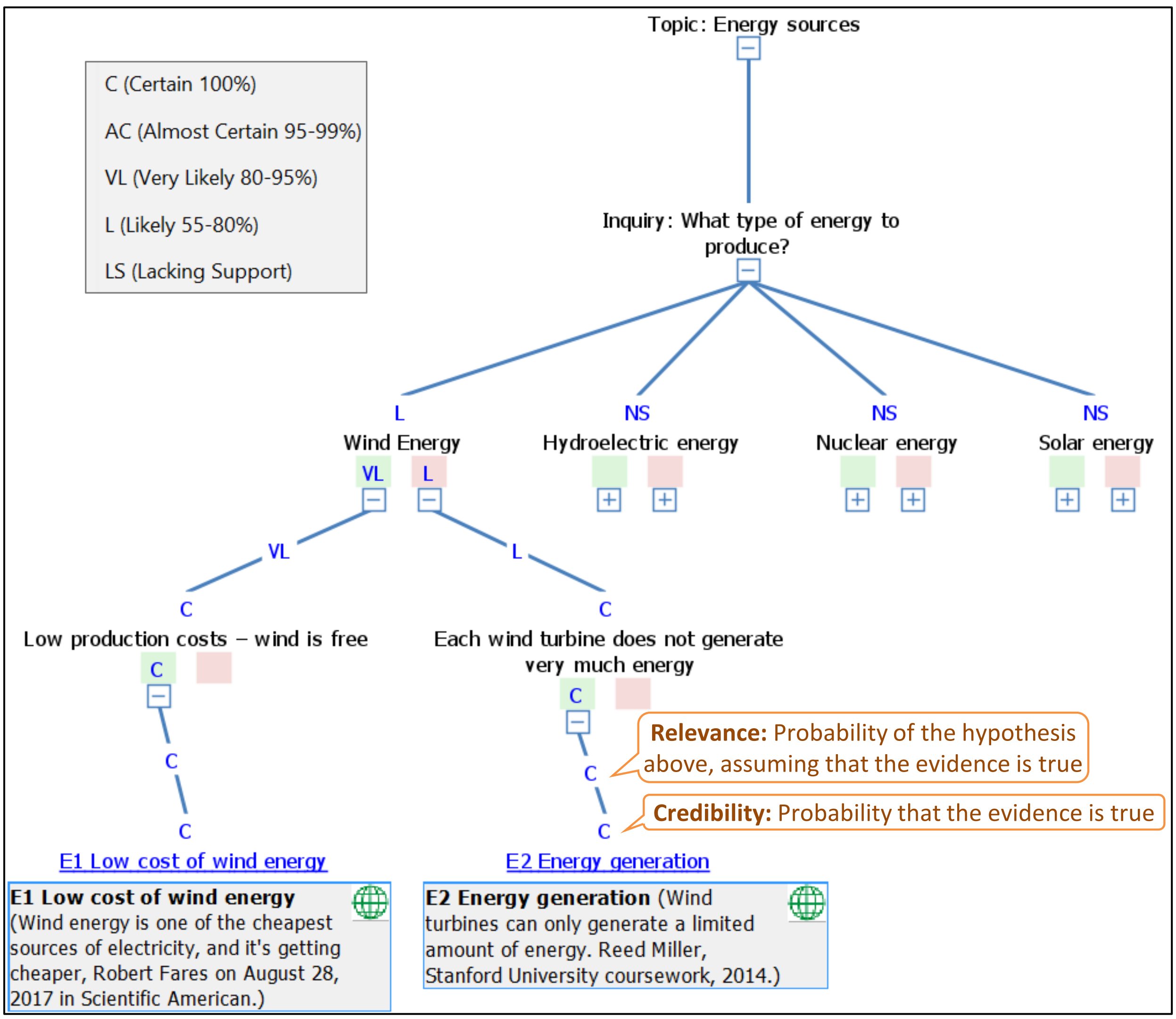


Figure 3. Generic inquiry-based teaching and learning experience.

1. The instructor formulates an inquiry: What type of energy to produce?
2. The students hypothesize possible answers:
   Wind energy, Hydroelectric energy, Nuclear energy, Solar energy.
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 the selected hypothesis:

   Wind energy
   Favoring argument: Low production costs – wind is free
   Disfavoring argument: Each wind turbine does not generate very much energy
5. The students search for evidence on the Internet and evaluate its relevance to the corresponding hypothesis, as well as its credibility:

   E1 Low cost of wind energy

   Wind energy is one of the cheapest sources of electricity, and it's getting cheaper, Robert Fares on August 28, 2017 in Scientific American.
   https://blogs.scientificamerican.com/plugged-in/wind-energy-is-one-of-the-cheapest-sources-of-electricity-and-its-getting-cheaper/

   Relevance: C (Certain 100%)

   Credibility: C (Certain 100%)
6. sInvestigator assesses the probability of the hypotheses.
7. The teams present and debate their argumentations in class.

The next section presents a detailed example of using inquiry in classroom.

4. Sample Inquiry with sInvestigator in a Science Class

A classical textbook example of using inquiry in a classroom is presented in (NRC, 2000, pp.5-11). The following is an adaptation of that example to show how sInvestigator can naturally support inquiry-based teaching and learning.

« Several of the students in Mrs. Graham’s fifth grade science class were excited when they returned to their room after the Spring break. They pulled their teacher over to a window, pointed outside, and said, *we noticed something about the trees on the playground. The left one has lost all its leaves, the middle one has multicolored leaves — mostly yellow — while the right one has lush, green leaves. Why are those trees different? They used to look the same, didn’t they?* Mrs. Graham didn’t know the answer. But she knew that her class was scheduled to study plants later in the year, and this was an opportunity for them to investigate questions about plant growth that they had originated and thus were especially motivated to answer. Although she was uncertain about where her students’ questions would lead, Mrs. Graham chose to take the risk of letting her students pursue investigations with the assistance of sInvestigator. *Let’s use sInvestigator to make a list of hypotheses that might explain what’s happening to those trees* *outside.* They used sInvestigator to specify the topic of study, the inquiry, and the following list of competing explanatory hypotheses (see Figure 4):

- It must be too much water that causes a tree to die.
- Insects are eating two of the trees.
- The trees have different ages.

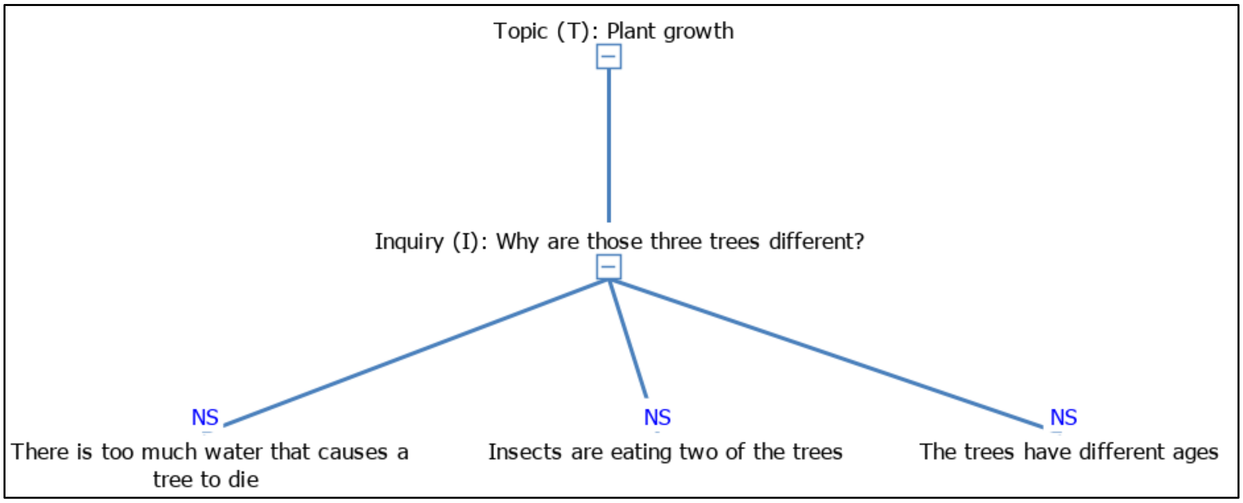


Figure 4. Topic, inquiry, and possible answers.

Mrs. Graham then invited each student to pick one hypothesis which led to several groups, a "water" group, an "illness" group, and an "age" group. She asked each group to use sInvestigator in order to plan and conduct a simple investigation to test their preferred hypothesis.

For the next three weeks, science periods were set aside for each group to carry out its investigation. Each group used sInvestigator to conduct its investigation, discovering a variety of sources with information about characteristics of trees, their life cycles, and their environments.

Let us consider the water group that investigated the hypothesis "There is too much water that causes a tree to die." They decomposed this hypothesis into two simpler hypotheses that showed more clearly what evidence may be used to test it (see Figure 5):

- There is too much water at the root of the dying tree.
- Too much water at the root causes the tree to die.

To discover evidence for the first sub-hypotheses, the water group decided to look at the ground around the trees every hour that they could. They took turns on making individual observations and since some of them lived near the school, their observations continued after school hours and on weekends. Even though they missed some hourly observations, they had sufficient data indicating that there is too much water at the root of the dying tree. They introduced this information into sInvestigator, naming it E1 Water observations, as shown in the right hand side of Figure 5. Then they dragged it on the left (green) square under the "There is too much water at the root of the dying tree" sub-hypothesis, to indicate that this is favoring evidence for it.

Now the water group can assess the probability of the "There is too much water at the root of the dying tree" hypothesis based on E1 Water observations, by using the following symbolic probability scale (shown also in the upper-left of Figure 9):

LS (Lacking Support) < L (Likely 55-80%) < VL (Very Likely 80-95%) <
< AC (Almost Certain 95-99%) < C (Certain 100%)

In this scale, the considered hypothesis may be "Lacking Support" from evidence, or the evidence may indicate some level of support, such as "Very Likely 80-95%." Each symbolic probability value (e.g., "Very Likely") is abbreviated ("VL") in the sInvestigator analysis whiteboard in order to reduce space usage and facilitate the visualization of larger argumentations.

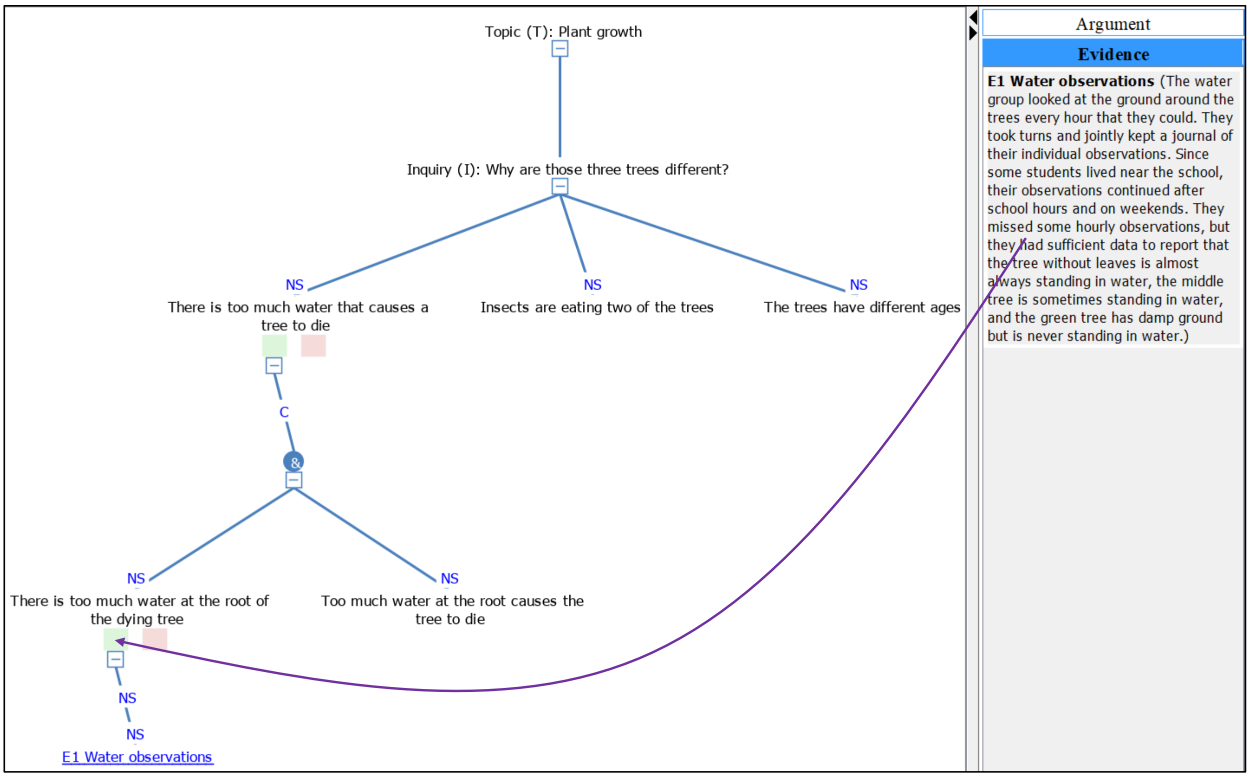


Figure 5. Hypotheses in search of evidence

To assess the probability of a hypothesis based on an item of evidence, the water group has to first assess the *credibility* and the *relevance* of evidence. Then sInvestigator determines the *inferential force* of evidence and *probability* of hypothesis, as illustrated in Figure 6.

The *credibility* of the evidence item E1 Water observations is obtained by answering the question: *What is the probability that the evidence is true?* The students' answer was AC (Almost Certain 95-99%) since a few data points were missing and, on rare occasions, the tree was not standing in the water. This justification was entered into sInvestigator, as shown in the bottom-right of 6.

The *relevance* of the evidence item E1 Water observations is obtained by answering the question: *What would the probability of the hypothesis be if the evidence were true?* The students' answer was certain (C). Indeed, if the evidence item is true then the hypothesis is true.

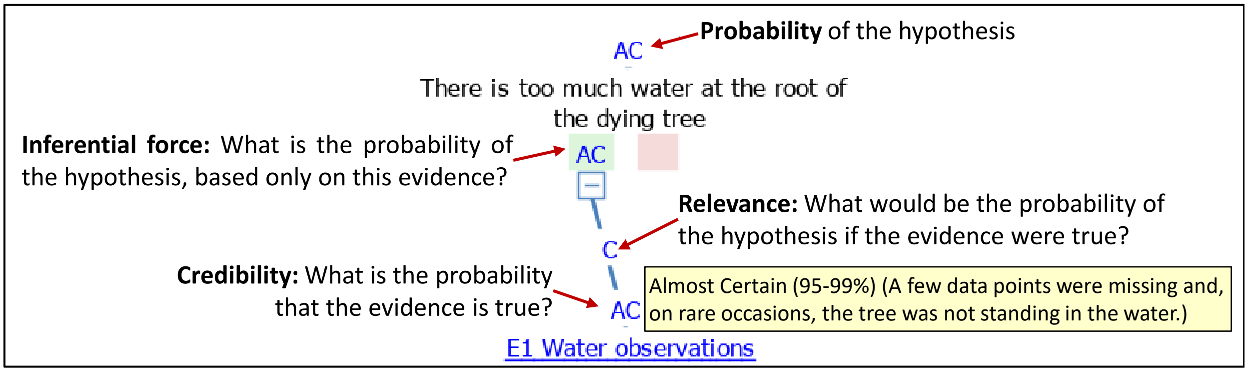


Figure 6. The credentials of evidence.

The *inferential force* of the evidence item on the hypothesis answers the question, *"What is the probability of the hypothesis, based only on this evidence?"* Obviously, an irrelevant item of evidence will have no inferential force, and will not convince us that the hypothesis is true. An item of evidence that is not credible will have no inferential force either. Only an item of evidence that is both very relevant and very credible will convince us that the hypothesis is true. Consistent with both the Baconian and the Fuzzy min/max probability combination rules (Cohen, 1977, pp.167-187; Zadeh, 1965, pp.340-341; Schum, 1979, pp.460-463), the inferential force of an item of evidence on a hypothesis is determined as the minimum between its credibility and its relevance which, in this illustration, is AC (Almost Certain 95-99%).

Because, in this case, we have only one item of evidence, its inferential force on the hypothesis is also the *probability* of the hypothesis.

Concerning the sub-hypothesis "Too much water at the root causes the tree to die," one of the students recalled that several months ago the leaves on one of his mother's geraniums had begun to turn yellow. She told him that the geranium was getting too much water. This item of information was represented in sInvestigator as the item of evidence E2 Geranium case, favoring the hypothesis. The students agreed to assess its credibility as AC (Almost Certain 95-99%) because, although the mother has experience with plants, she is not a professional. They assessed the relevance as VL (Very Likely 80-95%) because geraniums is a different type of plant. As a result, sInvestigator assessed the inferential force of E2 Geranium case as VL (Very Likely 80-95%). Additionally, the students searched the Internet and found the article "We Had Plenty of Rain; Why Are My Trees Dying?" by Sheila Dunning from the University of Florida, stating that a saturated soil may result in the death of the tree. The students conducted a deeper credibility analysis by assessing author's competence (affiliation and history), objectivity (relationship to current knowledge and conflict of interest), and publication's reputation, and sInvestigator computed the credibility as C (Certain 100%). The relevance was also assessed as C (Certain 100%), leading sInvestigator to assess its inferential force as C (Certain 100%). Additionally, sInvestigator assessed the inferential force of all favoring evidence (i.e., both E2 Geranium case and E3 Saturated soil) as C (Certain 100%), by taking the maximum of their inferential forces. This is also the probability of the hypothesis "Too much water at the root causes the tree to die" because no disfavoring evidence was found. However, if any disfavoring evidence would have been found, then sInvestigator would have determined whether, on balance, the totality of evidence favors or disfavors the hypothesis, and to what degree.

Having assessed the probability of “There is too much water at the root” as AC (Almost Certain 95-99%), and that of “Too much water at the root causes the tree to die” as C (Certain 100%), sInvestigator inferred the probability of their top-level hypothesis “There is too much water at the root that causes a tree to die” as AC (Almost Certain 95-99%). This is the minimum between these probabilities and the joint relevance of the two sub-hypotheses, which is C (Certain 100%) (see the left part of Figure 7).

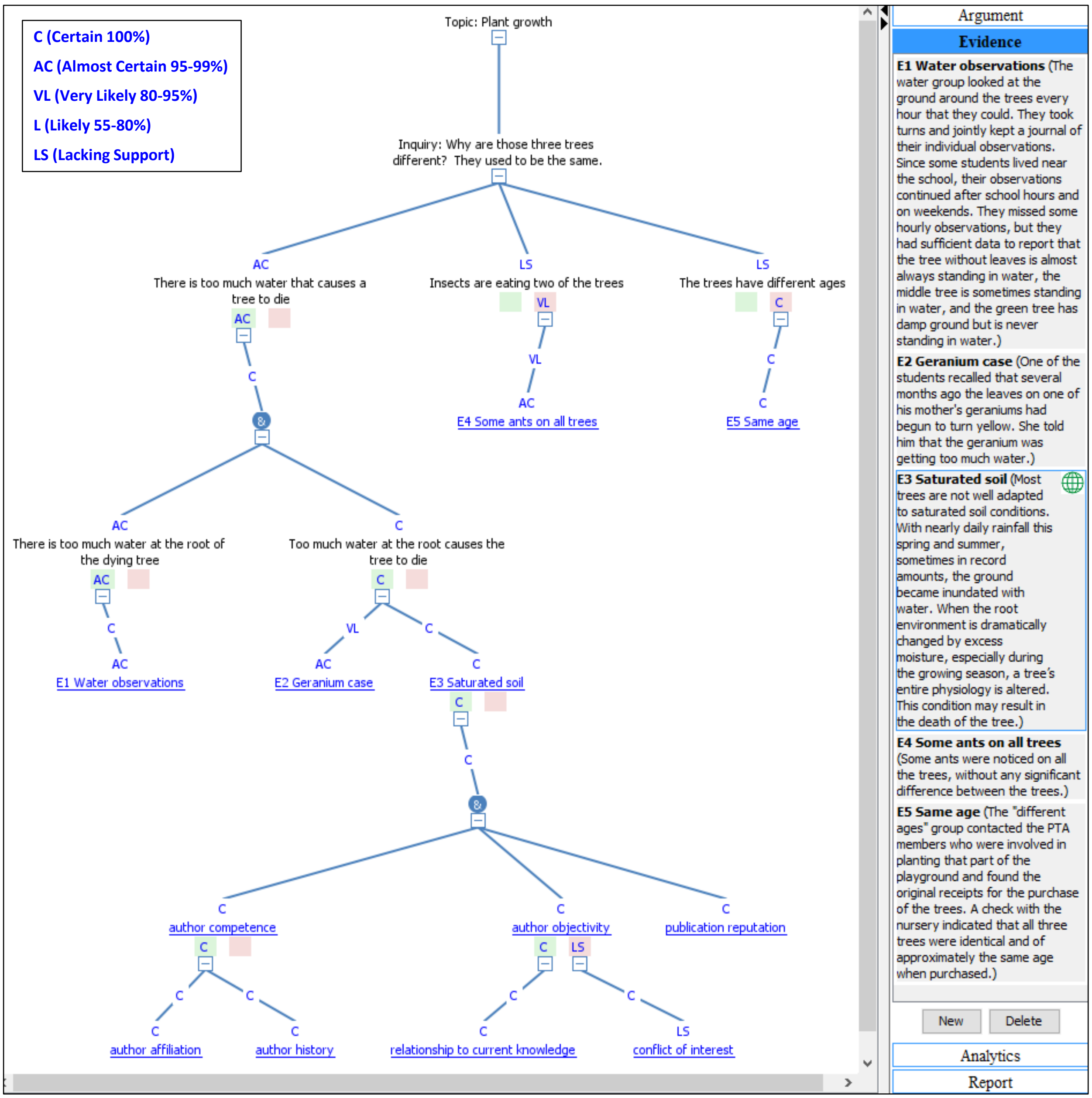


Figure 7. Hypotheses testing.

The “illness” group searched for insects on the trees. Some ants were noticed on all the trees, but without any significant difference between the trees to justify why one of the trees was dying because of them. This information was entered as evidence item E4 Some ants on all trees, disfavoring the hypothesis that “Insects are eating one of the trees.” Therefore sInvestigator concluded that there is no support for this hypothesis (see Figure 7).

Similarly, the “age” group answered their question fairly quickly. They contacted the PTA members who were involved in planting that part of the playground and found the original receipts for the purchase of the trees. A check with the nursery indicated that all three trees were identical and of approximately the same age when purchased.

Finally, sInvestigator automatically generated a report for each group, describing the analysis logic, citing sources of data used, and the manner in which the analysis was performed. These reports were further edited by the groups before being presented to the class.

As different groups presented and compared their analyses, the class learned that some evidence — such as that from the group investigating whether the trees have different ages — did not explain the observations. But the explanation that seemed most reasonable to the students, that fit all the observations and conformed with what they had learned from other sources, was “too much water.” After their three weeks of work, the class was satisfied that together they have found a reasonable answer to their question. **»** (adapted from NRC, 2000, pp.5-11).

The next sections present various types of inquiry-based exercises.

5. Analysis of Competing Scientific Theories

5.1. Competing Theories of Light

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

5.1.1. Inquiry: How do we see things?

Consider the following competing theories on how we see things:

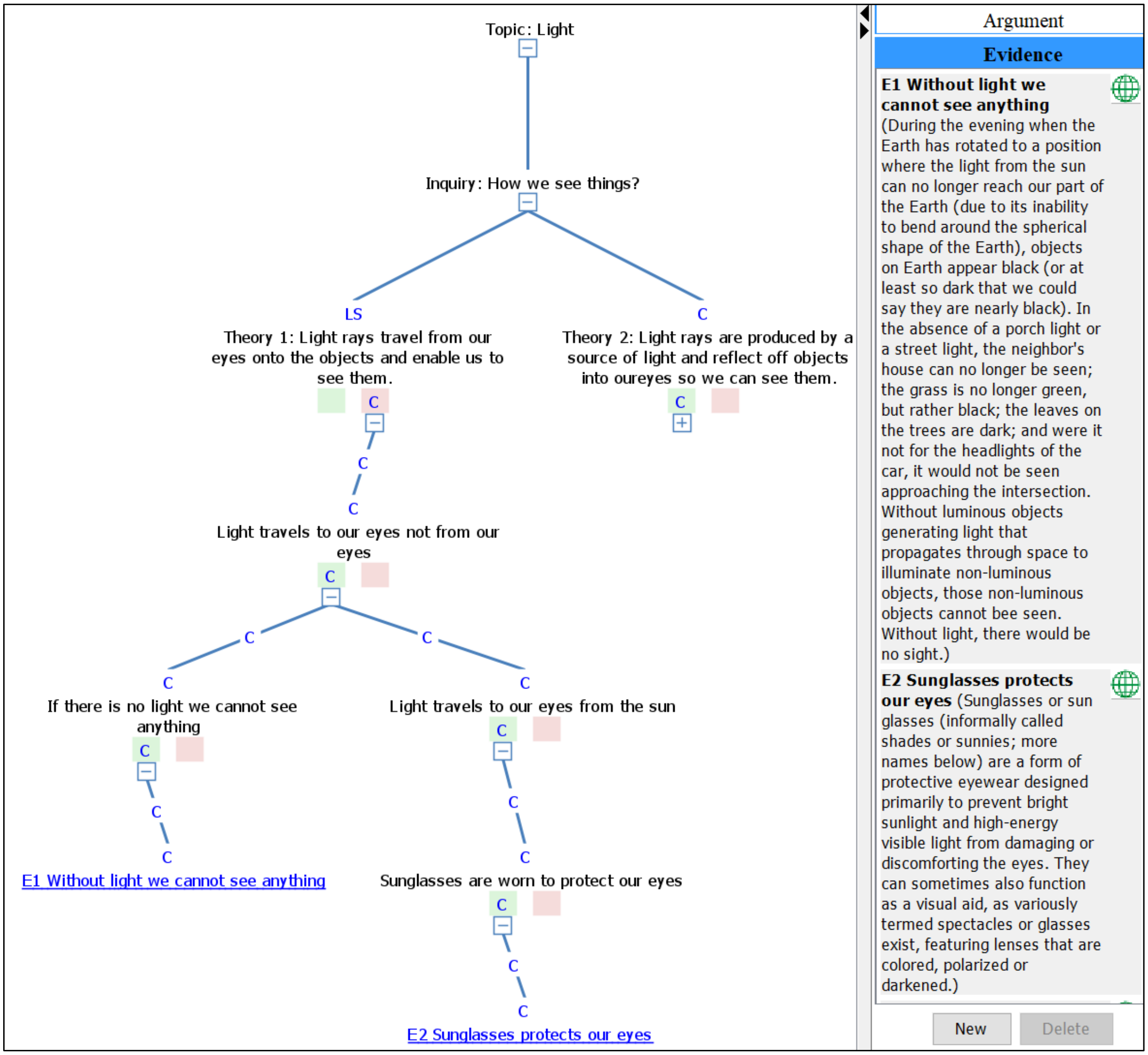
Theory 1: Light rays travel from our eyes onto the objects and enable us to see them.

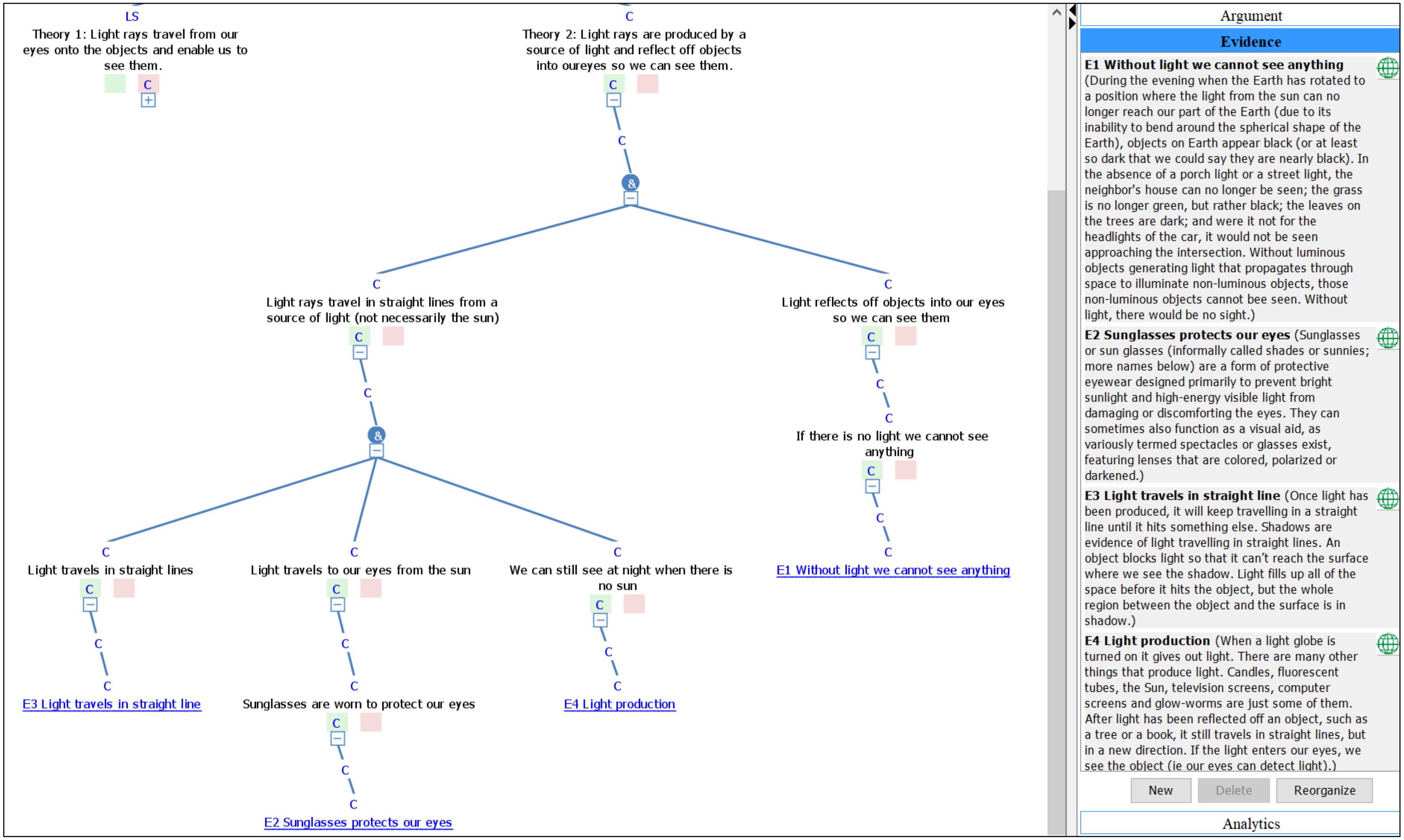
Theory 2: Light rays are produced by a source of light and reflect off objects into our eyes so we can see them.

The students will have to search for evidence on the Internet to determine which one is true. To facilitate their task, they are provided with the following statements that may be used to develop favoring and disfavoring arguments for the two hypothesized 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 anything.

5.1.2. Argumentations




LS
Theory 1: Light rays travel from our eyes onto the objects and enable us to see them.
C
C
Theory 2: Light rays are produced by a source of light and reflect off objects into oureyes so we can see them.
C
C
&
C
Light rays travel in straight lines from a source of light (not necessarily the sun)
C
Light reflects off objects into our eyes so we can see them
C
C
&
C
C
If there is no light we cannot see anything
C
C
Light travels in straight lines
C
Light travels to our eyes from the sun
C
We can still see at night when there is no sun
E1 Without light we cannot see anything
E3 Light travels in straight line
Sunglasses are worn to protect our eyes
E4 Light production
E2 Sunglasses protects our eyes
Argument
Evidence
E1 Without light we cannot see anything (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.)
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 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.)
E4 Light production (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).)
New
Delete
Reorganize
Analytics

5.2. Competing Theories of Ice Melting and Water Boiling

In this exercise, adapted from (Osbome et al., 2004, pp.59-62), the students are presented with the contrasting graphs from Figure 8 of temperature against time as ice is heated to water vapor.

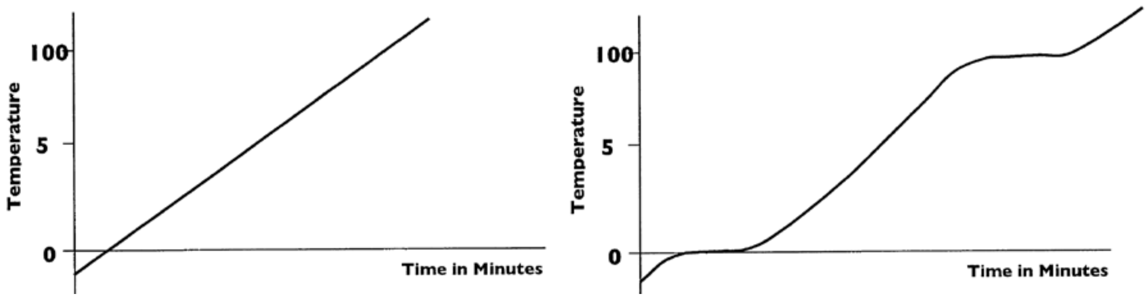


Figure 8. Contrasting graphs of temperature against time as ice is heated to water vapor, reproduced from (Osbome et al., 2004, p. 61).

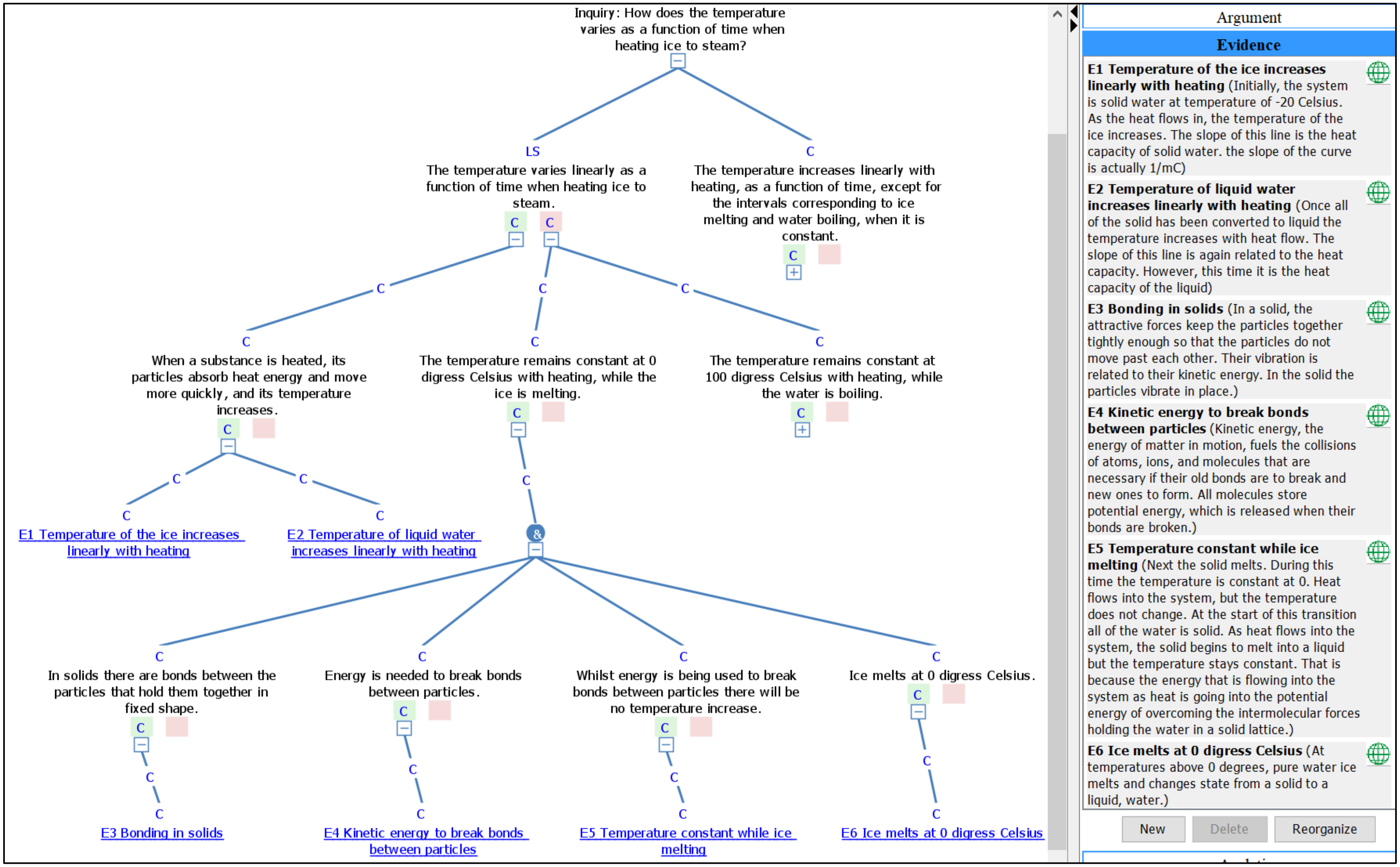
They have to determine which graph is correct (if any) by developing evidence-based argumentations. Their task is facilitated by presenting them with statements that may support one graph or the other.

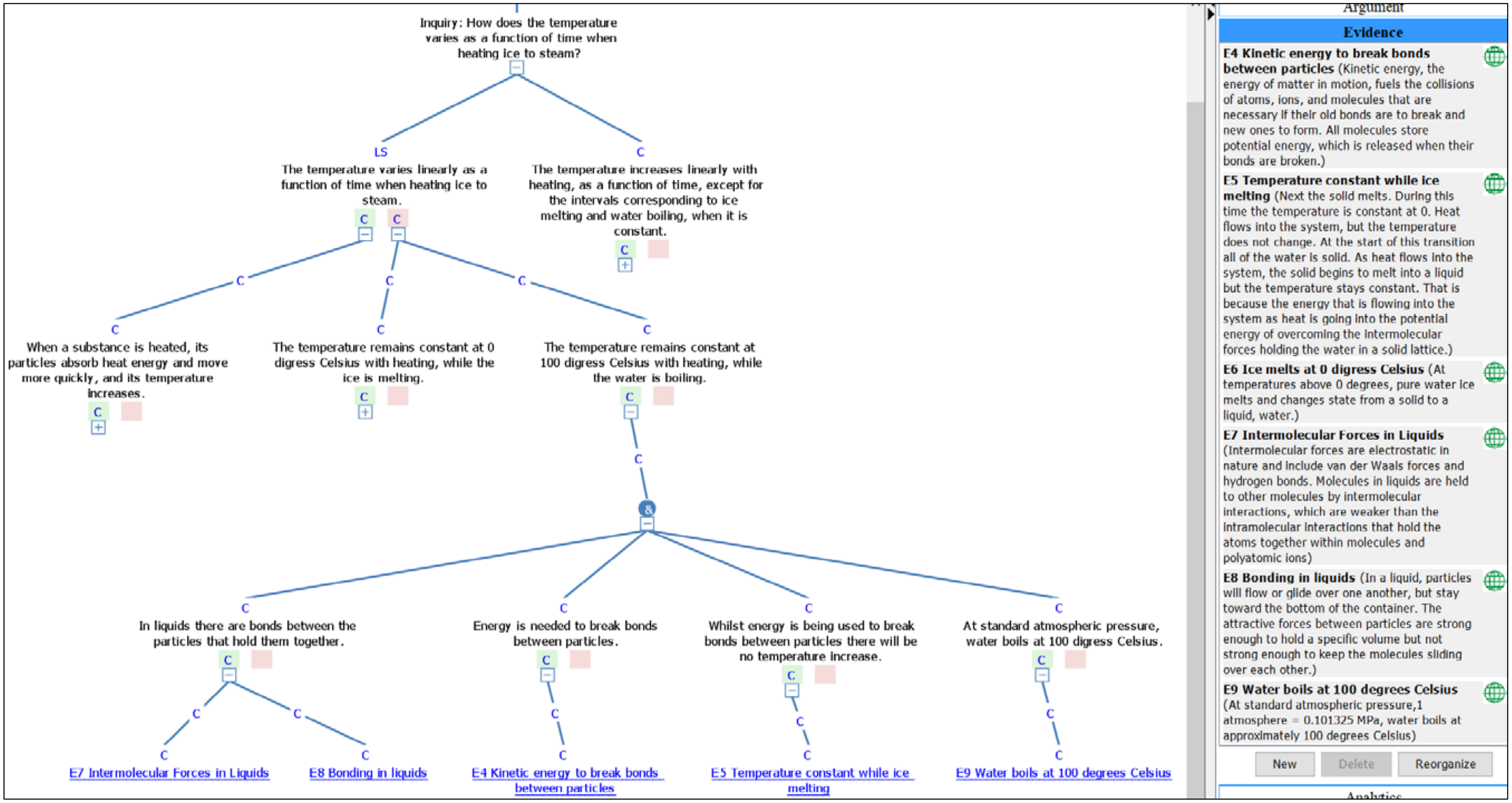
5.2.1. Inquiry: How does the temperature vary as a function of time when heating ice to steam?

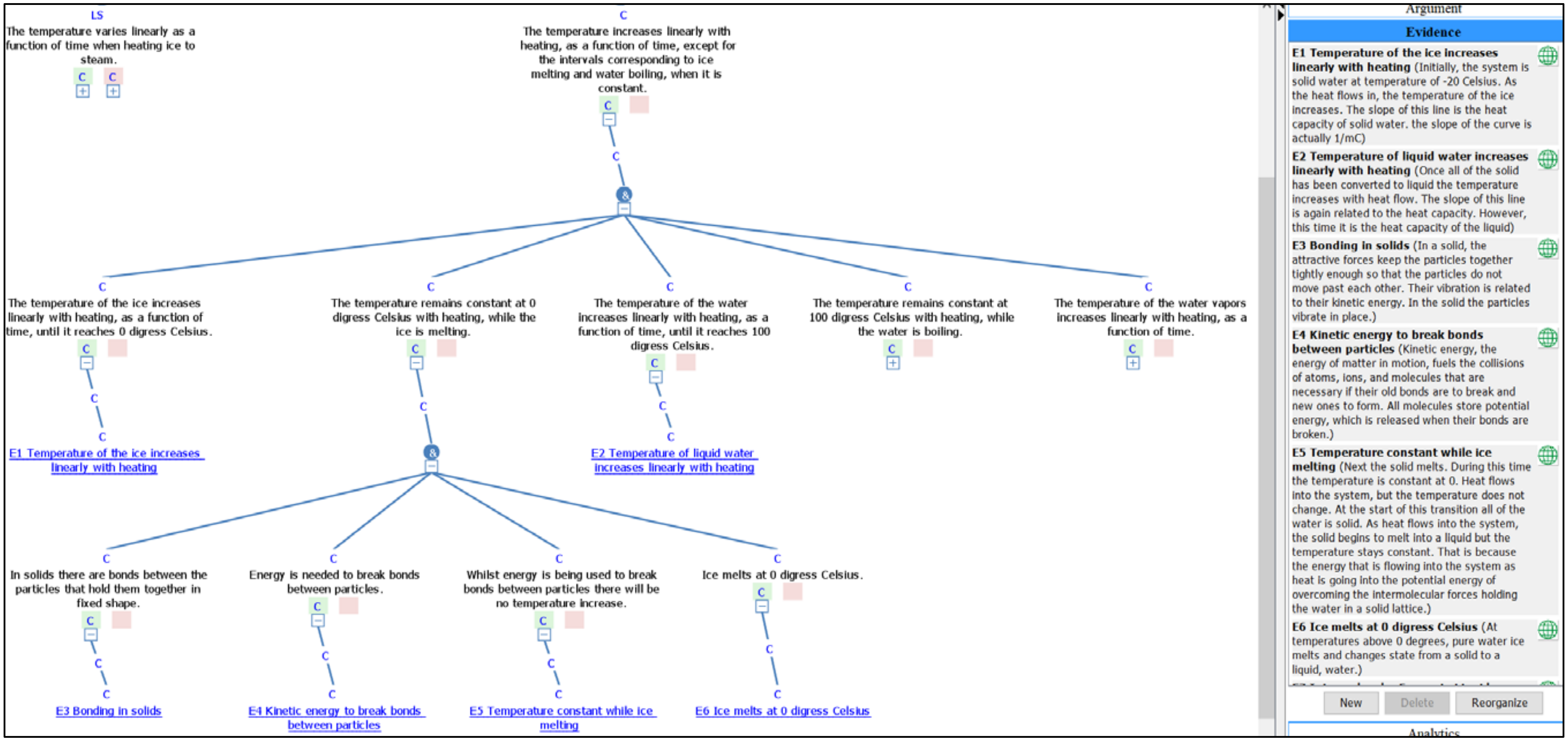
Potentially useful statements:

- Ice will melt when it is heated and turns into water.
- In solids there are bonds between the particles that hold them together in fixed shape.
- When you heat a substance the supply of heat energy is usually constant.
- Energy is needed to break bonds between particles.
- Ice melts at 0 degrees Celsius and boils at 100 degrees Celsius.
- Whilst energy is being used to break bonds between particles there will be no temperature increase.
- When a substance is heated the particles in it absorb heat energy and move about more quickly, and its temperature increases.

5.2.2. Argumentations




Inquiry: How does the temperature varies as a function of time when heating ice to steam?
The temperature varies linearly as a function of time when heating ice to steam.
The temperature increases linearly with heating, as a function of time, except for the intervals corresponding to ice melting and water boiling, when it is constant.
When a substance is heated, its particles absorb heat energy and move more quickly, and its temperature increases.
The temperature remains constant at 0 digress Celsius with heating, while the ice is melting.
The temperature remains constant at 100 digress Celsius with heating, while the water is boiling.
In liquids there are bonds between the particles that hold them together.
Energy is needed to break bonds between particles.
Whilst energy is being used to break bonds between particles there will be no temperature increase.
At standard atmospheric pressure, water boils at 100 digress Celsius.
E7 Intermolecular Forces in Liquids
E8 Bonding in liquids
E4 Kinetic energy to break bonds between particles
E5 Temperature constant while ice melting
E9 Water boils at 100 degrees Celsius
Argument
Evidence
E4 Kinetic energy to break bonds between particles (Kinetic energy, the energy of matter in motion, fuels the collisions of atoms, ions, and molecules that are necessary if their old bonds are to break and new ones to form. All molecules store potential energy, which is released when their bonds are broken.)
E5 Temperature constant while ice melting (Next the solid melts. During this time the temperature is constant at 0. Heat flows into the system, but the temperature does not change. At the start of this transition all of the water is solid. As heat flows into the system, the solid begins to melt into a liquid but the temperature stays constant. That is because the energy that is flowing into the system as heat is going into the potential energy of overcoming the intermolecular forces holding the water in a solid lattice.)
E6 Ice melts at 0 digress Celsius (At temperatures above 0 degrees, pure water ice melts and changes state from a solid to a liquid, water.)
E7 Intermolecular Forces in Liquids (Intermolecular forces are electrostatic in nature and include van der Waals forces and hydrogen bonds. Molecules in liquids are held to other molecules by intermolecular interactions, which are weaker than the intramolecular interactions that hold the atoms together within molecules and polyatomic ions)
E8 Bonding in liquids (In a liquid, particles will flow or glide over one another, but stay toward the bottom of the container. The attractive forces between particles are strong enough to hold a specific volume but not strong enough to keep the molecules sliding over each other.)
E9 Water boils at 100 degrees Celsius (At standard atmospheric pressure,1 atmosphere = 0.101325 MPa, water boils at approximately 100 degrees Celsius)
New
Delete
Reorganize
Analytics


LS
The temperature varies linearly as a function of time when heating ice to steam.
C
The temperature increases linearly with heating, as a function of time, except for the intervals corresponding to ice melting and water boiling, when it is constant.
The temperature of the ice increases linearly with heating, as a function of time, until it reaches 0 digress Celsius.
The temperature remains constant at 0 digress Celsius with heating, while the ice is melting.
The temperature of the water increases linearly with heating, as a function of time, until it reaches 100 digress Celsius.
The temperature remains constant at 100 digress Celsius with heating, while the water is boiling.
The temperature of the water vapors increases linearly with heating, as a function of time.
E1 Temperature of the ice increases linearly with heating
E2 Temperature of liquid water increases linearly with heating
In solids there are bonds between the particles that hold them together in fixed shape.
Energy is needed to break bonds between particles.
Whilst energy is being used to break bonds between particles there will be no temperature increase.
Ice melts at 0 digress Celsius.
E3 Bonding in solids
E4 Kinetic energy to break bonds between particles
E5 Temperature constant while ice melting
E6 Ice melts at 0 digress Celsius
Argument
Evidence
E1 Temperature of the ice increases linearly with heating (Initially, the system is solid water at temperature of -20 Celsius. As the heat flows in, the temperature of the ice increases. The slope of this line is the heat capacity of solid water. the slope of the curve is actually 1/mC)
E2 Temperature of liquid water increases linearly with heating (Once all of the solid has been converted to liquid the temperature increases with heat flow. The slope of this line is again related to the heat capacity. However, this time it is the heat capacity of the liquid)
E3 Bonding in solids (In a solid, the attractive forces keep the particles together tightly enough so that the particles do not move past each other. Their vibration is related to their kinetic energy. In the solid the particles vibrate in place.)
E4 Kinetic energy to break bonds between particles (Kinetic energy, the energy of matter in motion, fuels the collisions of atoms, ions, and molecules that are necessary if their old bonds are to break and new ones to form. All molecules store potential energy, which is released when their bonds are broken.)
E5 Temperature constant while ice melting (Next the solid melts. During this time the temperature is constant at 0. Heat flows into the system, but the temperature does not change. At the start of this transition all of the water is solid. As heat flows into the system, the solid begins to melt into a liquid but the temperature stays constant. That is because the energy that is flowing into the system as heat is going into the potential energy of overcoming the intermolecular forces holding the water in a solid lattice.)
E6 Ice melts at 0 digress Celsius (At temperatures above 0 degrees, pure water ice melts and changes state from a solid to a liquid, water.)
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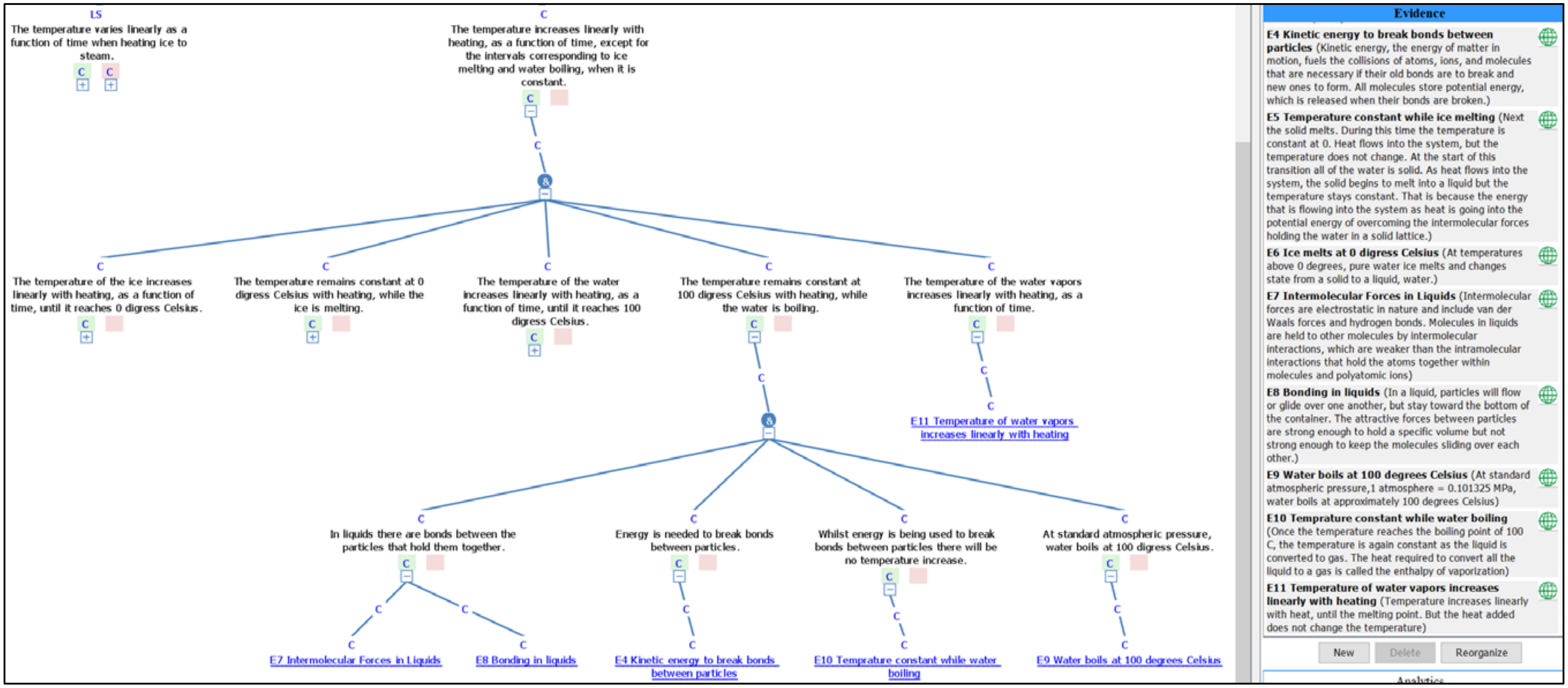

LS
The temperature varies linearly as a function of time when heating ice to steam.
C
The temperature increases linearly with heating, as a function of time, except for the intervals corresponding to ice melting and water boiling, when it is constant.
The temperature of the ice increases linearly with heating, as a function of time, until it reaches 0 digress Celsius.
The temperature remains constant at 0 digress Celsius with heating, while the ice is melting.
The temperature of the water increases linearly with heating, as a function of time, until it reaches 100 digress Celsius.
The temperature remains constant at 100 digress Celsius with heating, while the water is boiling.
The temperature of the water vapors increases linearly with heating, as a function of time.
E11 Temperature of water vapors increases linearly with heating
In liquids there are bonds between the particles that hold them together.
Energy is needed to break bonds between particles.
Whilst energy is being used to break bonds between particles there will be no temperature increase.
At standard atmospheric pressure, water boils at 100 digress Celsius.
E7 Intermolecular Forces in Liquids
E8 Bonding in liquids
E4 Kinetic energy to break bonds between particles
E10 Temprature constant while water boiling
E9 Water boils at 100 degrees Celsius
Evidence
E4 Kinetic energy to break bonds between particles (Kinetic energy, the energy of matter in motion, fuels the collisions of atoms, ions, and molecules that are necessary if their old bonds are to break and new ones to form. All molecules store potential energy, which is released when their bonds are broken.)
E5 Temperature constant while ice melting (Next the solid melts. During this time the temperature is constant at 0. Heat flows into the system, but the temperature does not change. At the start of this transition all of the water is solid. As heat flows into the system, the solid begins to melt into a liquid but the temperature stays constant. That is because the energy that is flowing into the system as heat is going into the potential energy of overcoming the intermolecular forces holding the water in a solid lattice.)
E6 Ice melts at 0 digress Celsius (At temperatures above 0 degrees, pure water ice melts and changes state from a solid to a liquid, water.)
E7 Intermolecular Forces in Liquids (Intermolecular forces are electrostatic in nature and include van der Waals forces and hydrogen bonds. Molecules in liquids are held to other molecules by intermolecular interactions, which are weaker than the intramolecular interactions that hold the atoms together within molecules and polyatomic ions)
E8 Bonding in liquids (In a liquid, particles will flow or glide over one another, but stay toward the bottom of the container. The attractive forces between particles are strong enough to hold a specific volume but not strong enough to keep the molecules sliding over each other.)
E9 Water boils at 100 degrees Celsius (At standard atmospheric pressure,1 atmosphere = 0.101325 MPa, water boils at approximately 100 degrees Celsius)
E10 Temprature constant while water boiling (Once the temperature reaches the boiling point of 100 C, the temperature is again constant as the liquid is converted to gas. The heat required to convert all the liquid to a gas is called the enthalpy of vaporization)
E11 Temperature of water vapors increases linearly with heating (Temperature increases linearly with heat, until the melting point. But the heat added does not change the temperature)
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Reorganize
Analytics

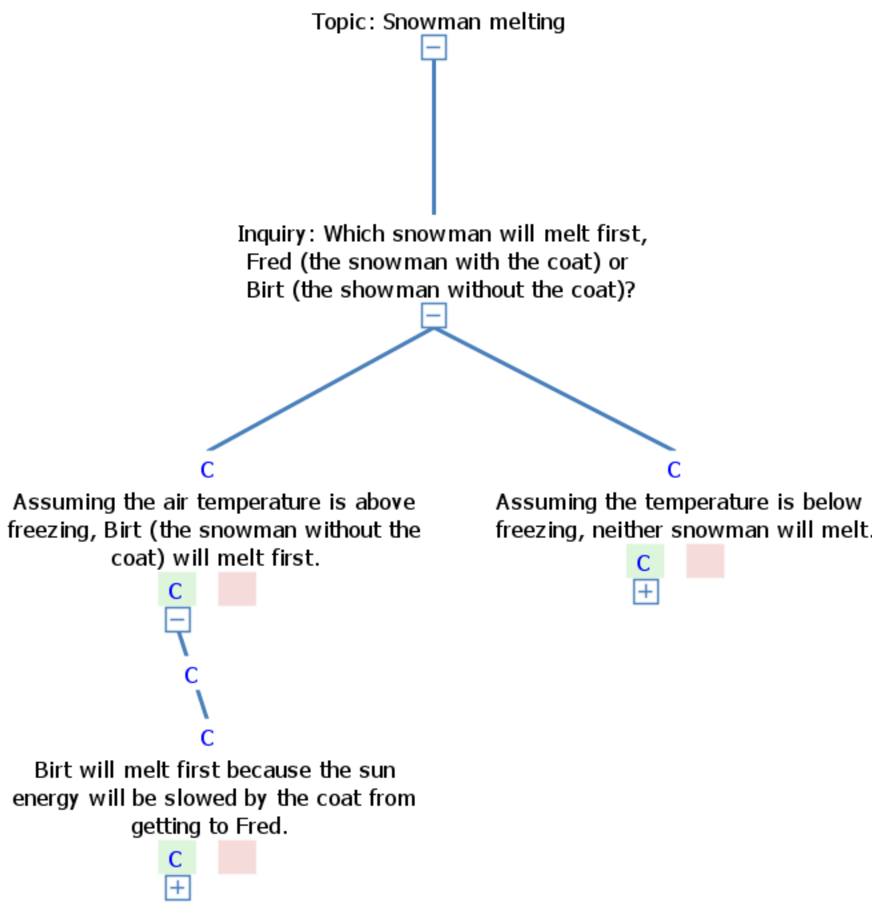
5.3. Competing Theories of Snowman Melting

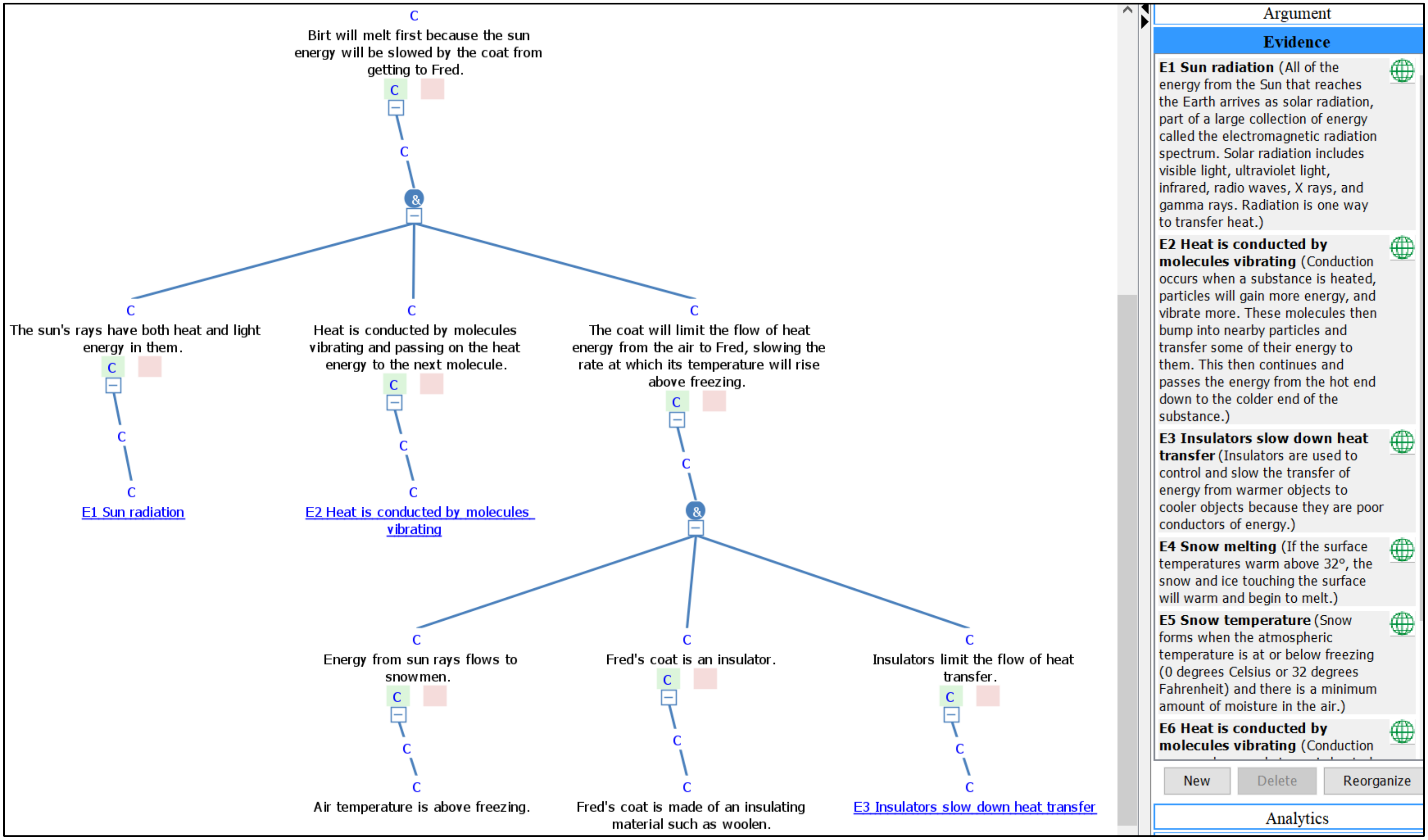
The aim of this exercise, adapted from (Osbome et al., 2004, pp.50-55), is to determine which snowman - one wearing a coat or the other one not wearing a coat - will melt first, by building evidence-based argumentations.

5.3.1. Inquiry: Which showman will melt first?

Which snowman will melt first, Fred (the snowman with the coat) or Birt (the showman without the coat)?

5.3.2. Argumentations





C
Birt will melt first because the sun energy will be slowed by the coat from getting to Fred.
The sun's rays have both heat and light energy in them.
E1 Sun radiation
Heat is conducted by molecules vibrating and passing on the heat energy to the next molecule.
E2 Heat is conducted by molecules vibrating
The coat will limit the flow of heat energy from the air to Fred, slowing the rate at which its temperature will rise above freezing.
Energy from sun rays flows to snowmen.
Air temperature is above freezing.
Fred's coat is an insulator.
Fred's coat is made of an insulating material such as woolen.
Insulators limit the flow of heat transfer.
E3 Insulators slow down heat transfer
Argument
Evidence
E1 Sun radiation (All of the energy from the Sun that reaches the Earth arrives as solar radiation, part of a large collection of energy called the electromagnetic radiation spectrum. Solar radiation includes visible light, ultraviolet light, infrared, radio waves, X rays, and gamma rays. Radiation is one way to transfer heat.)
E2 Heat is conducted by molecules vibrating (Conduction occurs when a substance is heated, particles will gain more energy, and vibrate more. These molecules then bump into nearby particles and transfer some of their energy to them. This then continues and passes the energy from the hot end down to the colder end of the substance.)
E3 Insulators slow down heat transfer (Insulators are used to control and slow the transfer of energy from warmer objects to cooler objects because they are poor conductors of energy.)
E4 Snow melting (If the surface temperatures warm above 32°, the snow and ice touching the surface will warm and begin to melt.)
E5 Snow temperature (Snow forms when the atmospheric temperature is at or below freezing (0 degrees Celsius or 32 degrees Fahrenheit) and there is a minimum amount of moisture in the air.)
E6 Heat is conducted by molecules vibrating (Conduction
New
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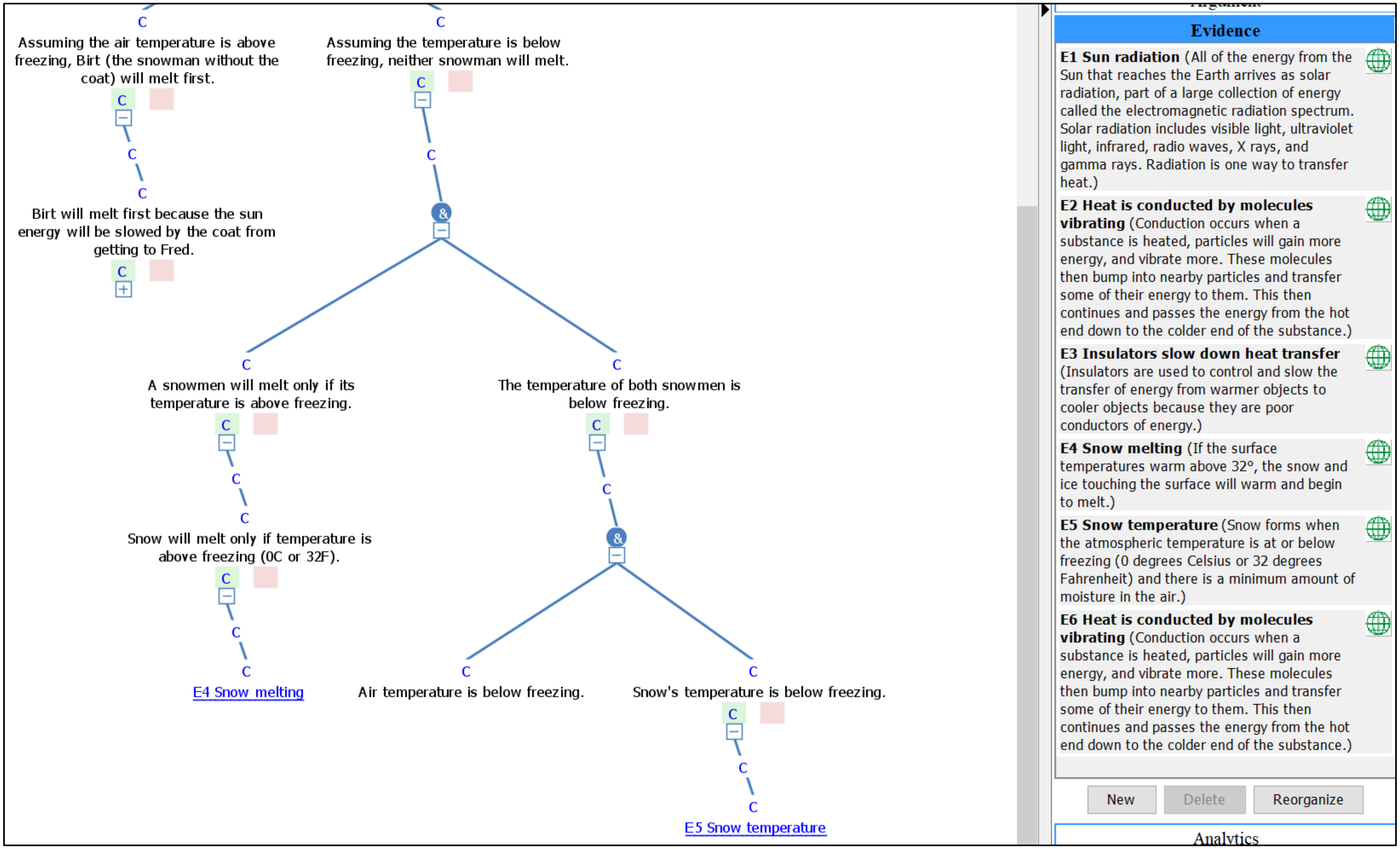

Assuming the air temperature is above freezing, Birt (the snowman without the coat) will melt first.
Assuming the temperature is below freezing, neither snowman will melt.
Birt will melt first because the sun energy will be slowed by the coat from getting to Fred.
A snowmen will melt only if its temperature is above freezing.
The temperature of both snowmen is below freezing.
Snow will melt only if temperature is above freezing (0C or 32F).
E4 Snow melting
Air temperature is below freezing.
Snow's temperature is below freezing.
E5 Snow temperature
Evidence
E1 Sun radiation (All of the energy from the Sun that reaches the Earth arrives as solar radiation, part of a large collection of energy called the electromagnetic radiation spectrum. Solar radiation includes visible light, ultraviolet light, infrared, radio waves, X rays, and gamma rays. Radiation is one way to transfer heat.)
E2 Heat is conducted by molecules vibrating (Conduction occurs when a substance is heated, particles will gain more energy, and vibrate more. These molecules then bump into nearby particles and transfer some of their energy to them. This then continues and passes the energy from the hot end down to the colder end of the substance.)
E3 Insulators slow down heat transfer (Insulators are used to control and slow the transfer of energy from warmer objects to cooler objects because they are poor conductors of energy.)
E4 Snow melting (If the surface temperatures warm above 32°, the snow and ice touching the surface will warm and begin to melt.)
E5 Snow temperature (Snow forms when the atmospheric temperature is at or below freezing (0 degrees Celsius or 32 degrees Fahrenheit) and there is a minimum amount of moisture in the air.)
E6 Heat is conducted by molecules vibrating (Conduction occurs when a substance is heated, particles will gain more energy, and vibrate more. These molecules then bump into nearby particles and transfer some of their energy to them. This then continues and passes the energy from the hot end down to the colder end of the substance.)
New
Delete
Reorganize
Analytics

6. Predicting, Observing and Explaining the Result of an Experiment

This is an example, adapted from (Osbome et al., 2004, pp.7-11), of a "predict, observe, and explain" experiment to learn about combustion: A burning candle inside a container with water is covered with a glass (see Figure 9). Students 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 that explain the results of the experiment.

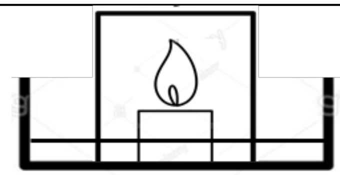
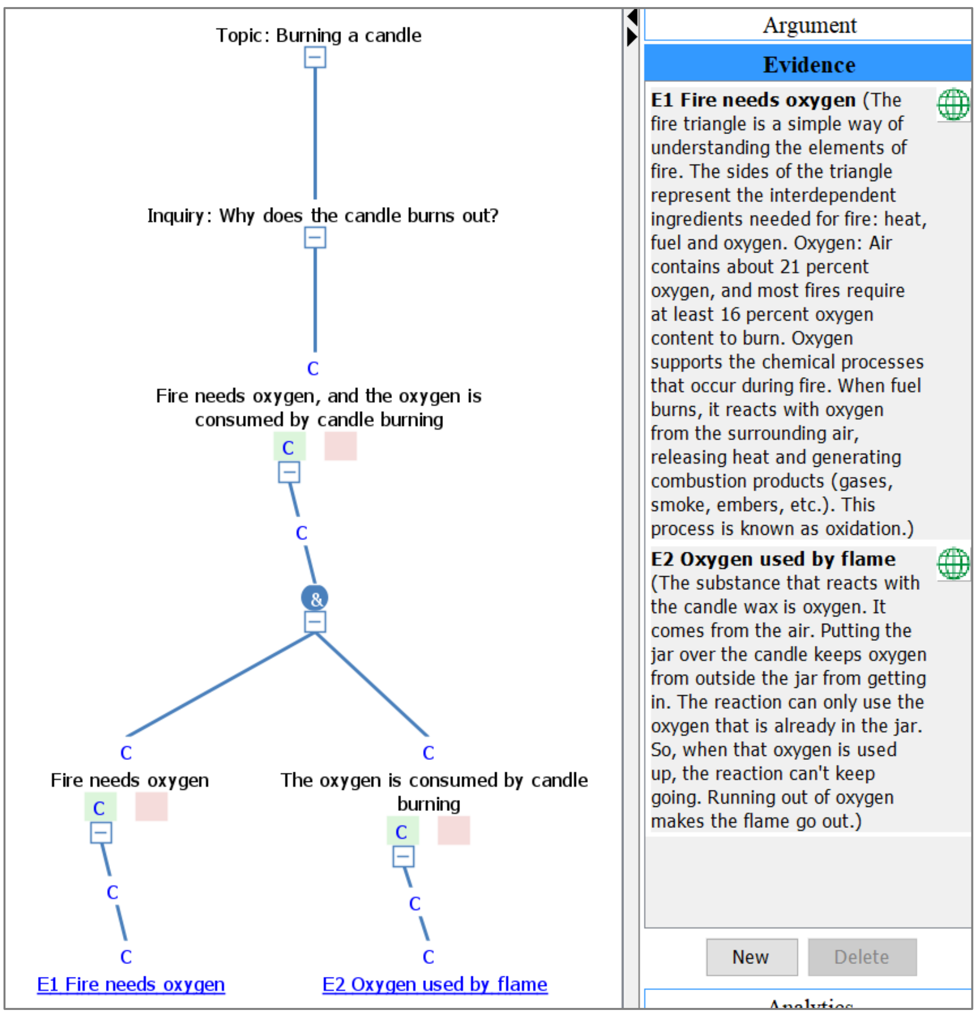


Figure 9. Burning candle covered by a glass.

6.1. Inquiry: Why does the candle burn out?

The students are asked to explain why the candle burns out when it is covered with the glass.

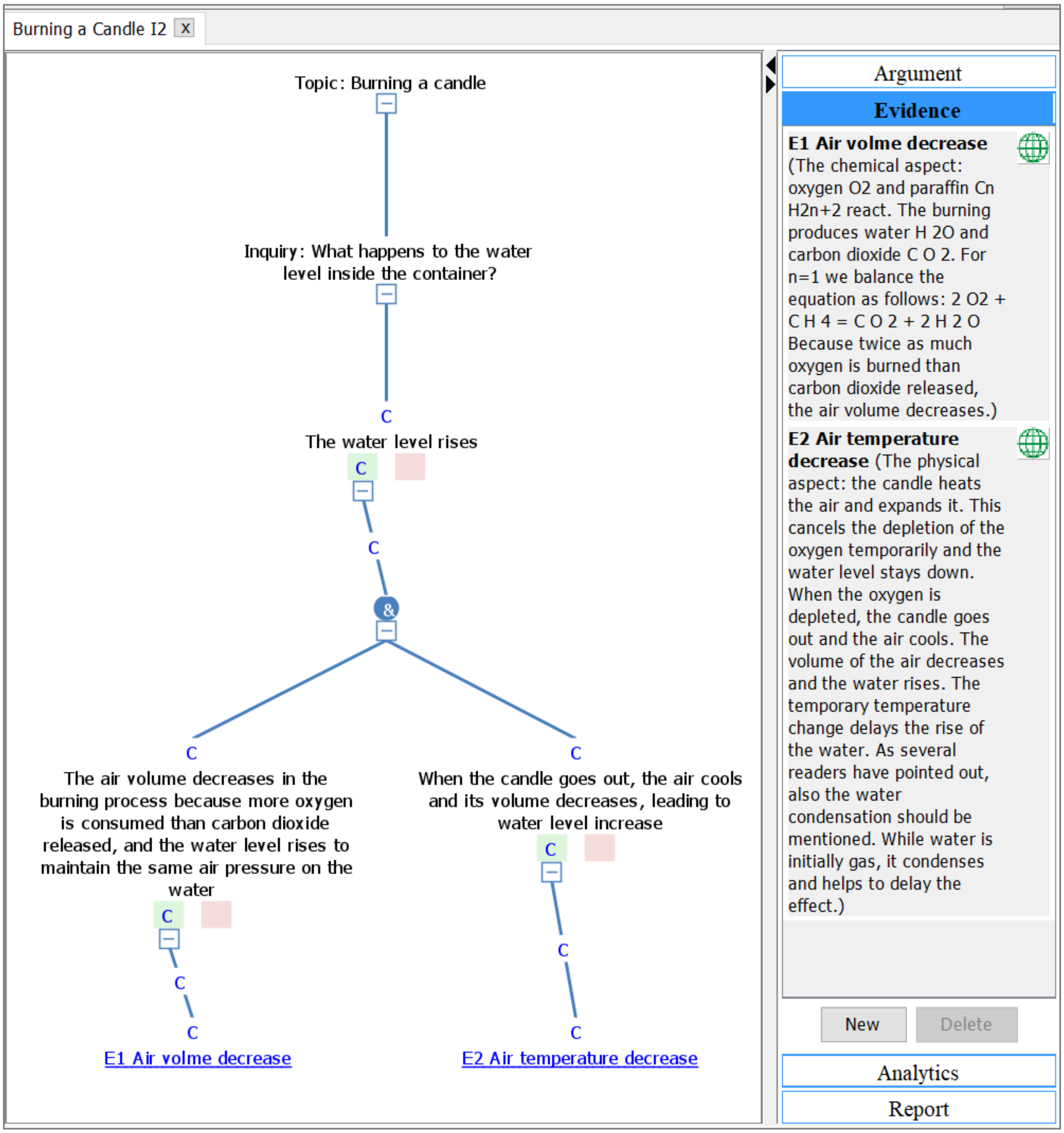
6.2. Argumentation: Candle burns out



6.3. Inquiry: Why does the water level inside the glass raise?

The students are asked to explain why the water level inside the glass raises.

6.4. Argumentation: Water level rises



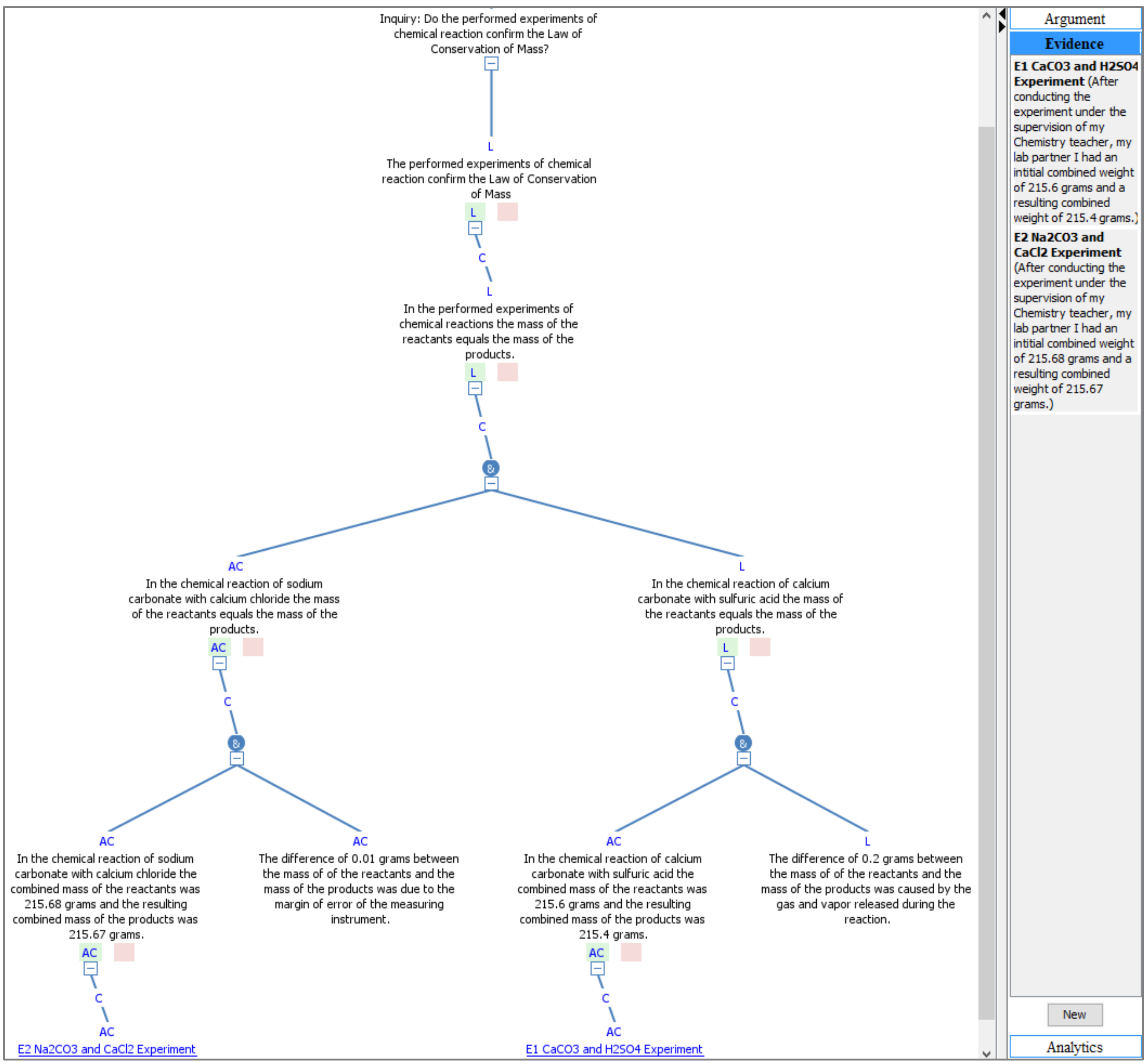
7. Explaining the Result of a Chemical Experiment

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.

7.1. Inquiry: Do the experiments confirm the law of conservation of mass?

The aim of this exercise, created primarily by Anya Parekh, 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.

7.2. Argumentation



8. Explaining a Physical Phenomenon

8.1. Dropping a Box

The aim of this exercise, adapted from (Osbome et al., 2004, pp.47-49), is to explore forces that act upon a dropping box and to develop evidence-based argumentations on how an object falls.

8.1.1. Inquiry: How does a box fall?

A box is dropped from an airplane and falls to the ground. The sequence of statements in the boxes below explain how the box falls.

For each box that contains a single statement develop an evidence-based argumentation to show that the statement is true.

For each box that contains multiple statements, develop an evidence-based argumentation to determine which statement is true.

Then compose an argumentation to answer the question: How does a box fall?

1 There is a force of gravity on the box.

2 This acts downwards.

How does the force change throughout the fall?

3a It is roughly the same size throughout the fall.
3b It gets a lot bigger as the box gets closer to the Earth.
3c It is biggest when the box is high up and gets a lot smaller as it falls.

What is the effect of the force on the box?

4a This force makes the box begin to accelerate downwards.
4b This force makes the box begin to move downwards at a steady speed.

5 Once the box begins to move, there is also an air resistance force on it.

In what direction does the air resistance force act?

6a This acts downwards, in the direction the box is going. 6b This acts upwards, in the opposite direction to the box's motion.

Does the air resistance force change?

7a The size of the air resistance force on the box is constant throughout the fall. 7b The air resistance force gets bigger as the box gets faster.

Should the air resistance force be taken into account?

8a The air resistance force on the box is much smaller than the force of gravity, and so it can be ignored. 8b The air resistance force on the box becomes quite large, and has to be taken into account.

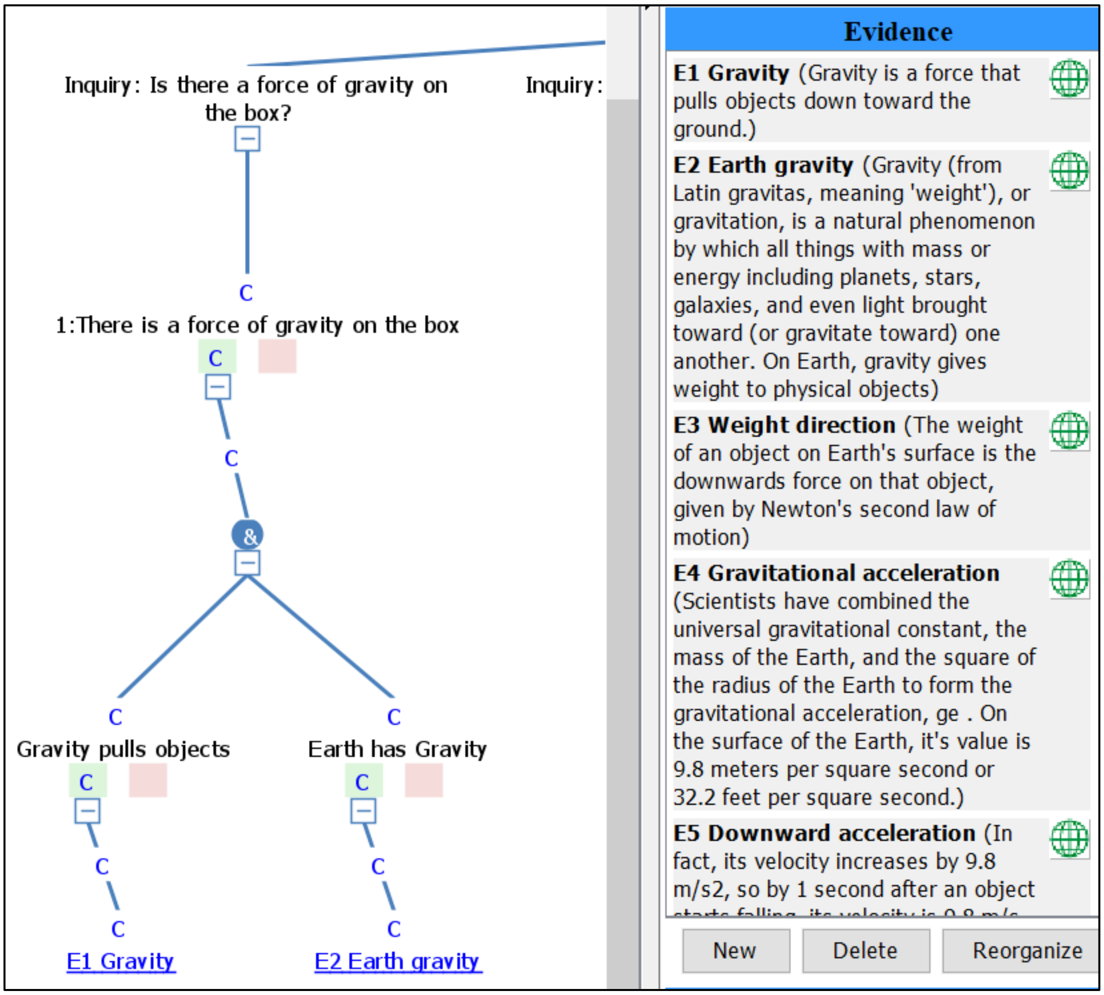
What is the total force on the box?

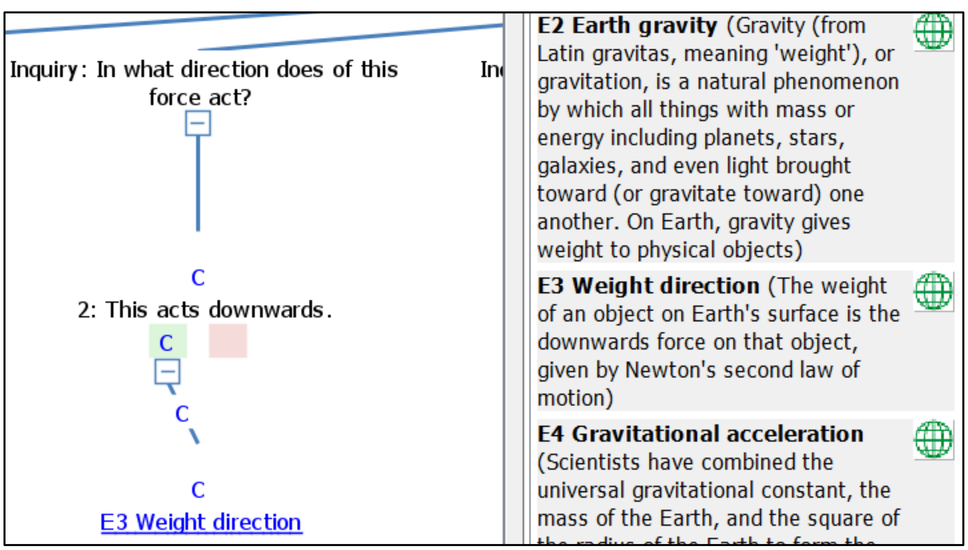
9a The total force on the box is equal to the force of gravity, and is constant. 9b The total force on the box is the sum of the gravity force and air resistance, and this gets gradually less as it falls, because the air resistance increases.

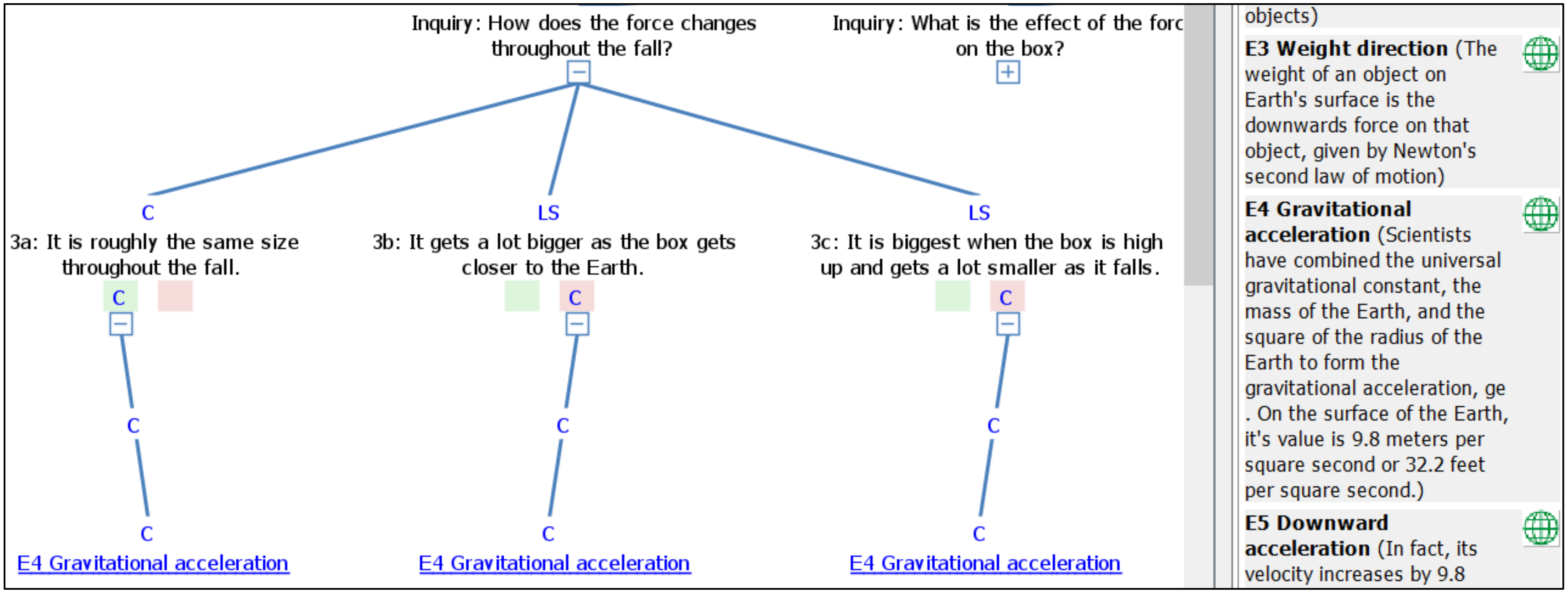
What is the acceleration throughout the fall?

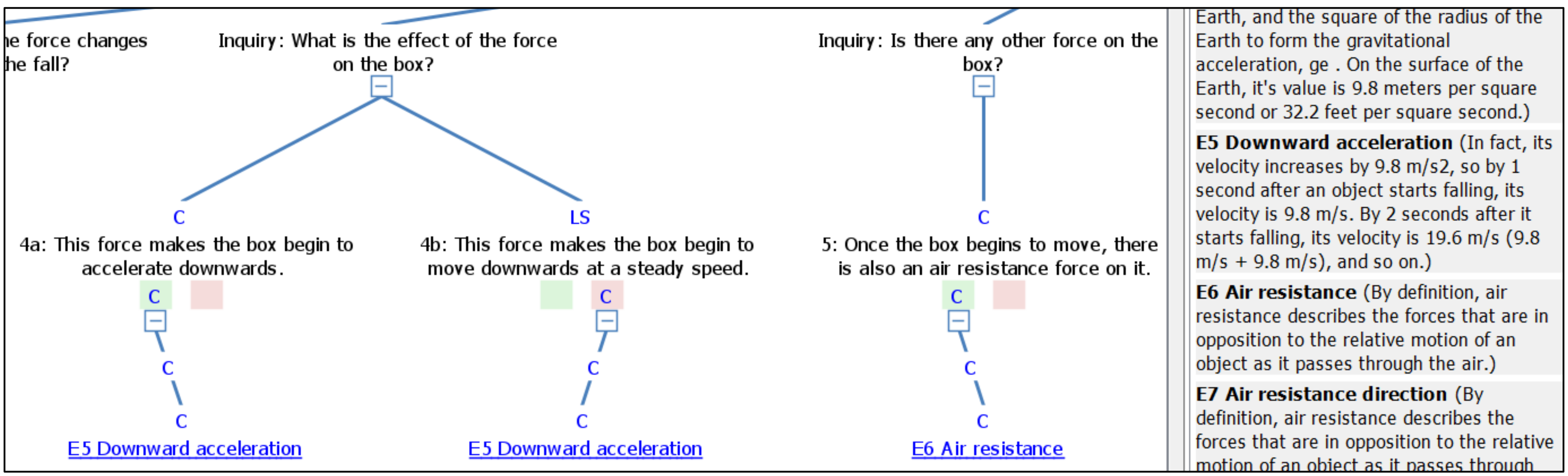
10a The box has a uniform acceleration throughout its fall. 10b The acceleration of the box is biggest to begin with, and gets gradually less. Once the air resistance force becomes equal to the gravity force, the acceleration is zero and the box then falls at a steady speed. 10c The box falls at a steady speed throughout it fall.

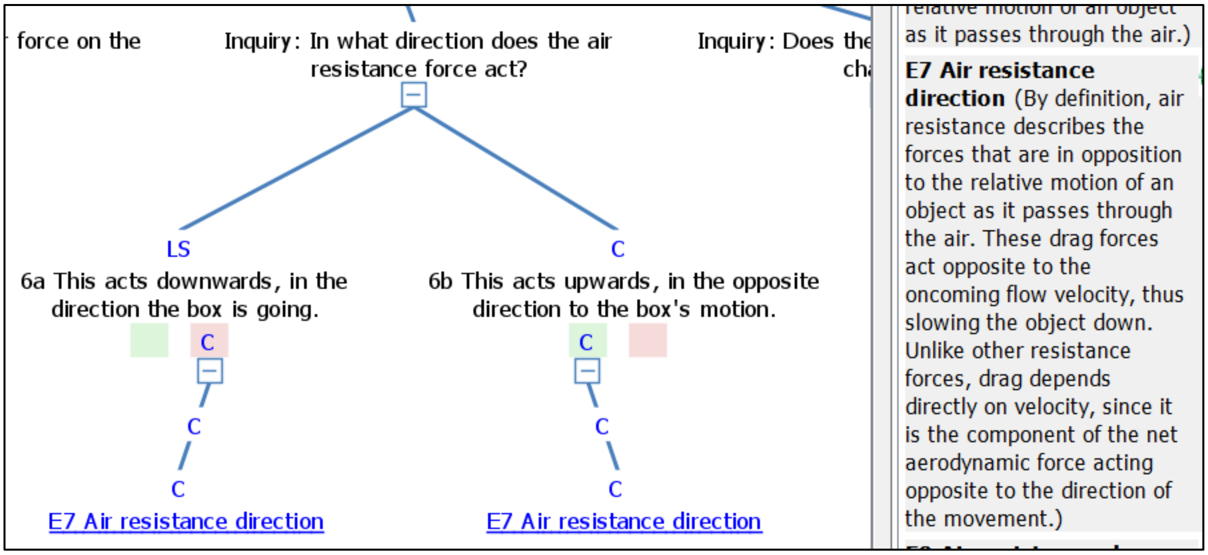
8.1.2. Argumentations

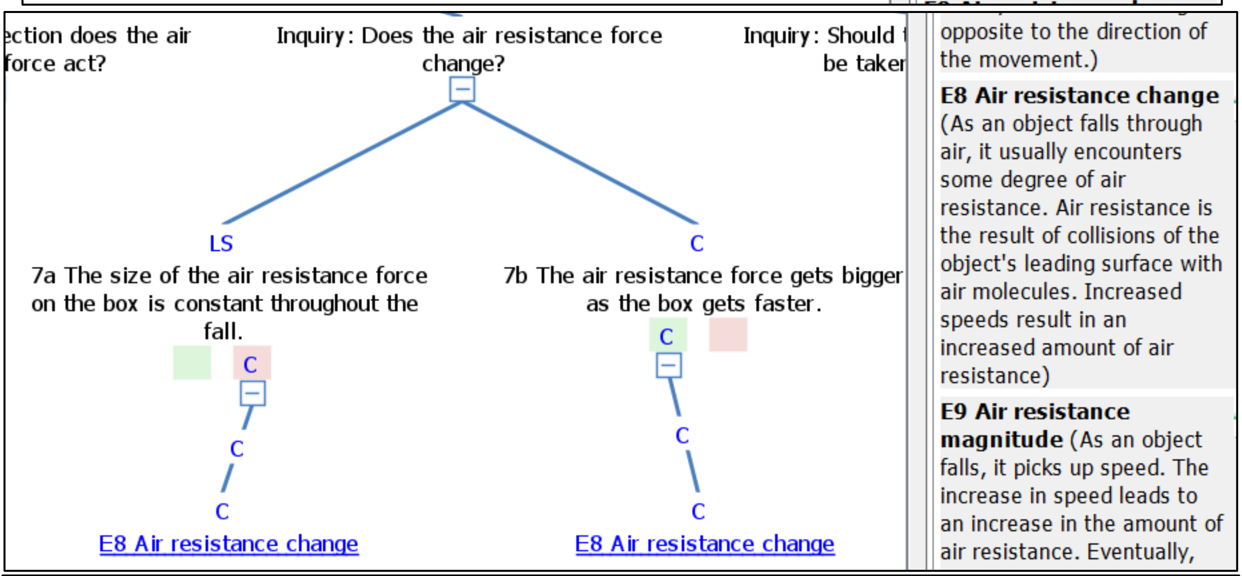


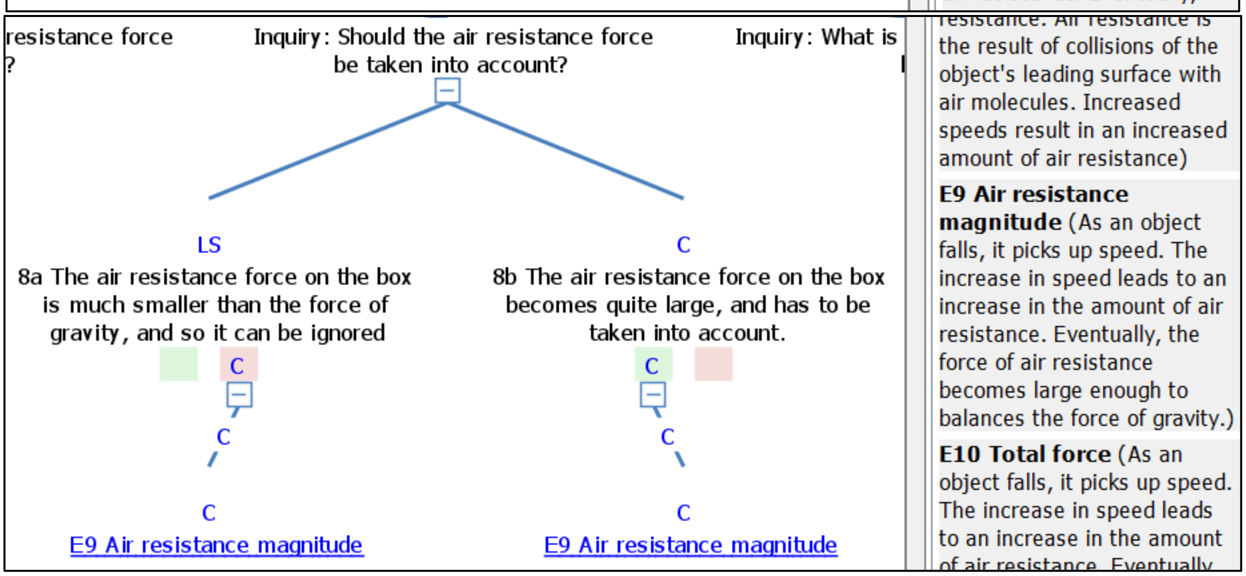


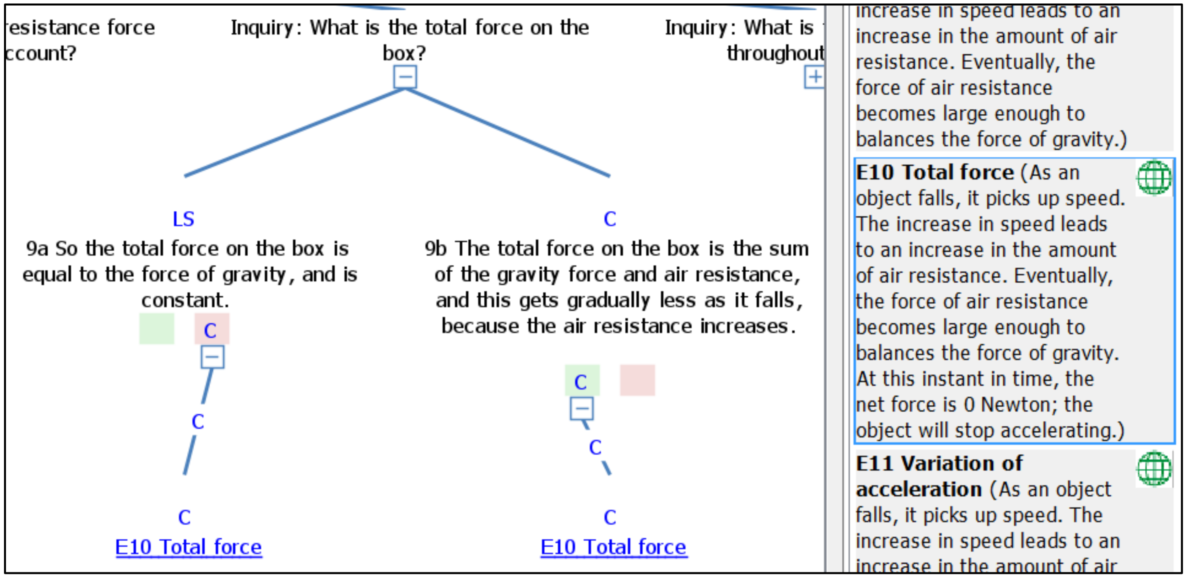

Inquiry: How does the force changes throughout the fall?
Inquiry: What is the effect of the forc on the box?
C
LS
LS
3a: It is roughly the same size throughout the fall.
3b: It gets a lot bigger as the box gets closer to the Earth.
3c: It is biggest when the box is high up and gets a lot smaller as it falls.
C
C
C
C
C
C
C
C
C
E4 Gravitational acceleration
E4 Gravitational acceleration
E4 Gravitational acceleration
objects)
E3 Weight direction (The weight of an object on Earth's surface is the downwards force on that object, given by Newton's second law of motion)
E4 Gravitational acceleration (Scientists have combined the universal gravitational constant, the mass of the Earth, and the square of the radius of the Earth to form the gravitational acceleration, ge . On the surface of the Earth, it's value is 9.8 meters per square second or 32.2 feet per square second.)
E5 Downward acceleration (In fact, its velocity increases by 9.8

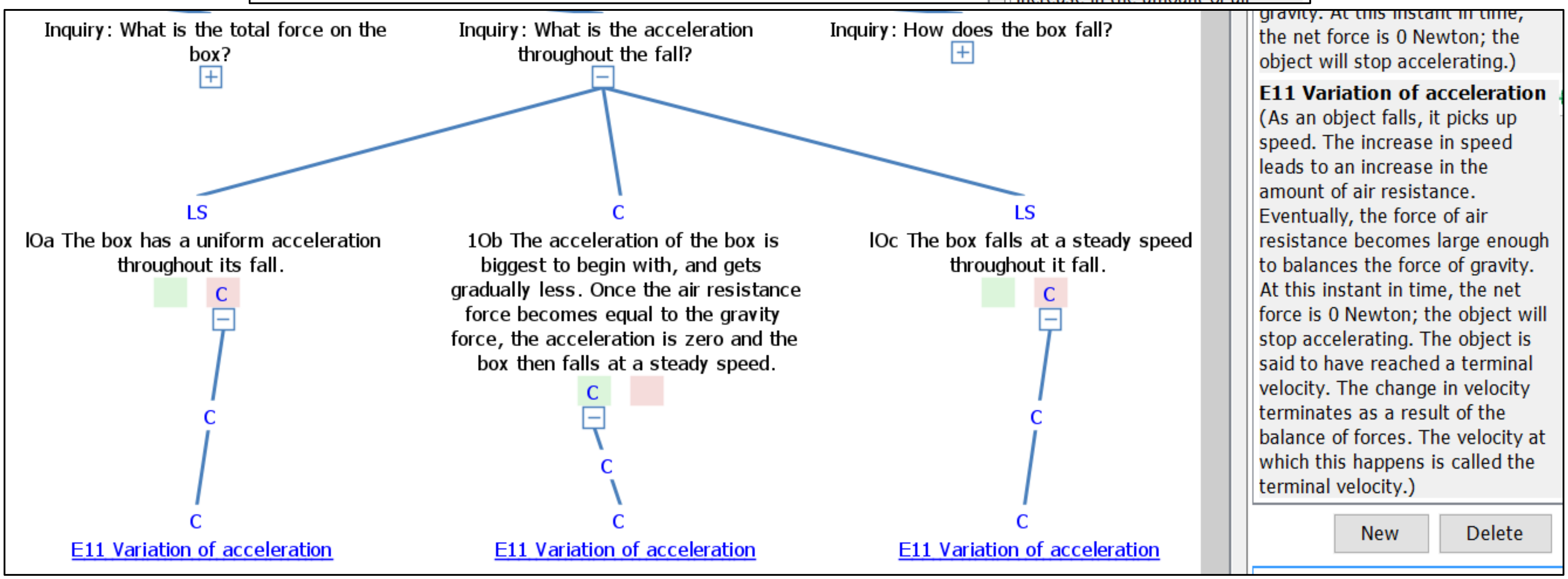

he force changes he fall?
Inquiry: What is the effect of the force on the box?
Inquiry: Is there any other force on the box?
C
LS
C
4a: This force makes the box begin to accelerate downwards.
4b: This force makes the box begin to move downwards at a steady speed.
5: Once the box begins to move, there is also an air resistance force on it.
C
C
C
C
C
C
C
C
C
E5 Downward acceleration
E5 Downward acceleration
E6 Air resistance
Earth, and the square of the radius of the Earth to form the gravitational acceleration, ge . On the surface of the Earth, it's value is 9.8 meters per square second or 32.2 feet per square second.)
E5 Downward acceleration (In fact, its velocity increases by 9.8 m/s2, so by 1 second after an object starts falling, its velocity is 9.8 m/s. By 2 seconds after it starts falling, its velocity is 19.6 m/s (9.8 m/s + 9.8 m/s), and so on.)
E6 Air resistance (By definition, air resistance describes the forces that are in opposition to the relative motion of an object as it passes through the air.)
E7 Air resistance direction (By definition, air resistance describes the forces that are in opposition to the relative motion of an object as it passes through


force on the
Inquiry: In what direction does the air resistance force act?
Inquiry: Does the
LS
6a This acts downwards, in the direction the box is going.
C
C
C
E7 Air resistance direction
C
6b This acts upwards, in the opposite direction to the box's motion.
C
C
C
E7 Air resistance direction
as it passes through the air.)
E7 Air resistance direction (By definition, air resistance describes the forces that are in opposition to the relative motion of an object as it passes through the air. These drag forces act opposite to the oncoming flow velocity, thus slowing the object down. Unlike other resistance forces, drag depends directly on velocity, since it is the component of the net aerodynamic force acting opposite to the direction of the movement.)


force act?
Inquiry: Does the air resistance force change?
Inquiry: Should
be taken
LS
7a The size of the air resistance force on the box is constant throughout the fall.
C
C
C
E8 Air resistance change
C
7b The air resistance force gets bigger as the box gets faster.
C
C
C
E8 Air resistance change
opposite to the direction of the movement.)
E8 Air resistance change (As an object falls through air, it usually encounters some degree of air resistance. Air resistance is the result of collisions of the object's leading surface with air molecules. Increased speeds result in an increased amount of air resistance)
E9 Air resistance magnitude (As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually,


resistance force
Inquiry: Should the air resistance force be taken into account?
Inquiry: What is
LS
8a The air resistance force on the box is much smaller than the force of gravity, and so it can be ignored
C
C
C
E9 Air resistance magnitude
C
8b The air resistance force on the box becomes quite large, and has to be taken into account.
C
C
C
E9 Air resistance magnitude
the result of collisions of the object's leading surface with air molecules. Increased speeds result in an increased amount of air resistance)
E9 Air resistance magnitude (As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity.)
E10 Total force (As an object falls, it picks up speed. The increase in speed leads to an increase in the amount


esistance force
ccount?
Inquiry: What is the total force on the box?
Inquiry: What is
throughout
LS
9a So the total force on the box is equal to the force of gravity, and is constant.
C
C
C
E10 Total force
C
9b The total force on the box is the sum of the gravity force and air resistance, and this gets gradually less as it falls, because the air resistance increases.
C
C
C
E10 Total force
increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity.)
E10 Total force (As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity. At this instant in time, the net force is 0 Newton; the object will stop accelerating.)
E11 Variation of acceleration (As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air


Inquiry: What is the total force on the box?
Inquiry: What is the acceleration throughout the fall?
Inquiry: How does the box fall?
LS
lOa The box has a uniform acceleration throughout its fall.
C
C
C
E11 Variation of acceleration
C
1Ob The acceleration of the box is biggest to begin with, and gets gradually less. Once the air resistance force becomes equal to the gravity force, the acceleration is zero and the box then falls at a steady speed.
C
C
C
E11 Variation of acceleration
LS
lOc The box falls at a steady speed throughout it fall.
C
C
C
E11 Variation of acceleration
gravity. At this instant in time, the net force is 0 Newton; the object will stop accelerating.)
E11 Variation of acceleration (As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity. At this instant in time, the net force is 0 Newton; the object will stop accelerating. The object is said to have reached a terminal velocity. The change in velocity terminates as a result of the balance of forces. The velocity at which this happens is called the terminal velocity.)
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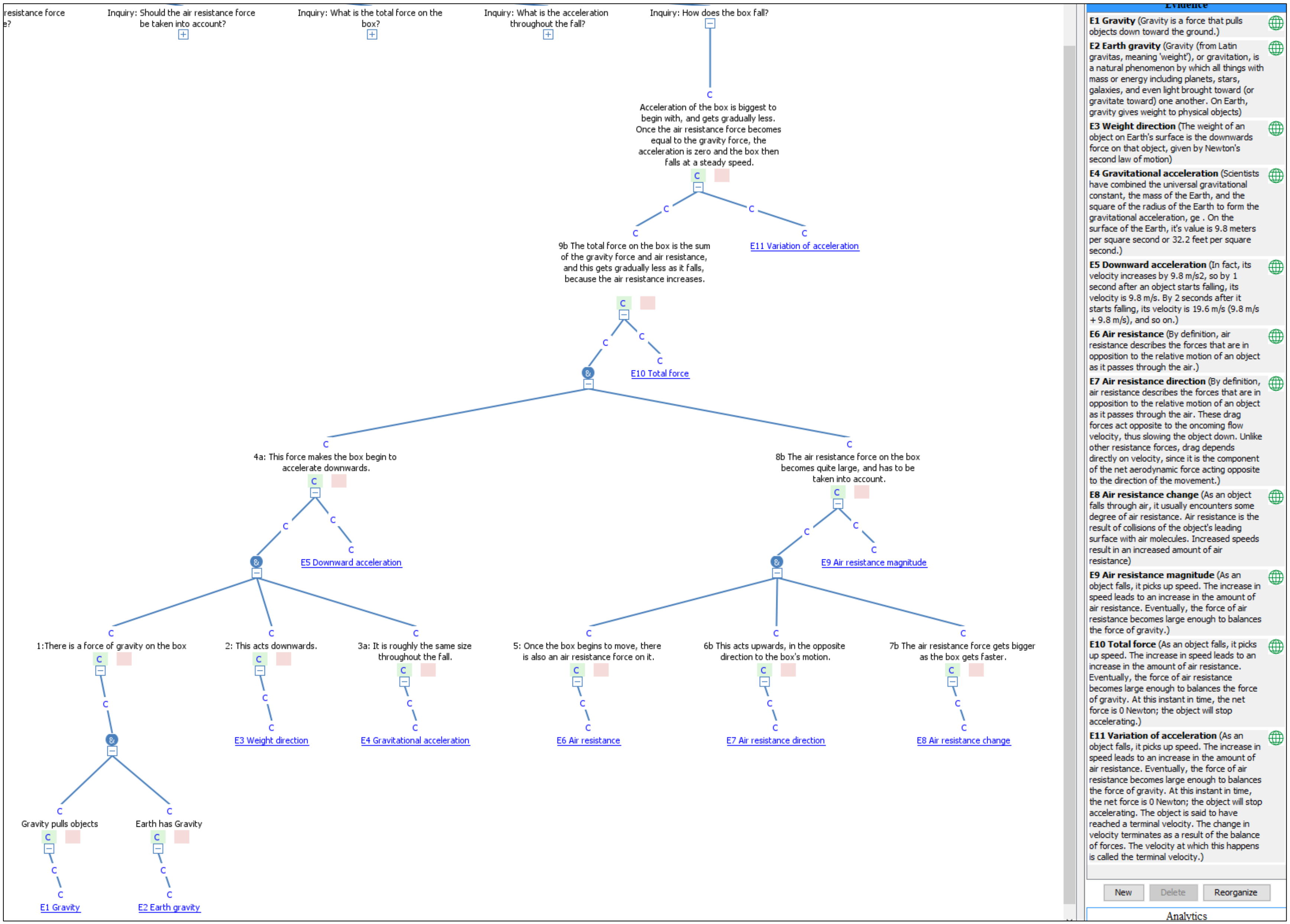

resistance force
e?
Inquiry: Should the air resistance force be taken into account?
Inquiry: What is the total force on the box?
Inquiry: What is the acceleration throughout the fall?
Inquiry: How does the box fall?
Acceleration of the box is biggest to begin with, and gets gradually less. Once the air resistance force becomes equal to the gravity force, the acceleration is zero and the box then falls at a steady speed.
9b The total force on the box is the sum of the gravity force and air resistance, and this gets gradually less as it falls, because the air resistance increases.
E11 Variation of acceleration
E10 Total force
4a: This force makes the box begin to accelerate downwards.
8b The air resistance force on the box becomes quite large, and has to be taken into account.
E5 Downward acceleration
E9 Air resistance magnitude
1:There is a force of gravity on the box
2: This acts downwards.
3a: It is roughly the same size throughout the fall.
5: Once the box begins to move, there is also an air resistance force on it.
6b This acts upwards, in the opposite direction to the box's motion.
7b The air resistance force gets bigger as the box gets faster.
E3 Weight direction
E4 Gravitational acceleration
E6 Air resistance
E7 Air resistance direction
E8 Air resistance change
Gravity pulls objects
Earth has Gravity
E1 Gravity
E2 Earth gravity
Evidence
E1 Gravity (Gravity is a force that pulls objects down toward the ground.)
E2 Earth gravity (Gravity (from Latin gravitas, meaning 'weight'), or gravitation, is a natural phenomenon by which all things with mass or energy including planets, stars, galaxies, and even light brought toward (or gravitate toward) one another. On Earth, gravity gives weight to physical objects)
E3 Weight direction (The weight of an object on Earth's surface is the downwards force on that object, given by Newton's second law of motion)
E4 Gravitational acceleration (Scientists have combined the universal gravitational constant, the mass of the Earth, and the square of the radius of the Earth to form the gravitational acceleration, ge . On the surface of the Earth, it's value is 9.8 meters per square second or 32.2 feet per square second.)
E5 Downward acceleration (In fact, its velocity increases by 9.8 m/s2, so by 1 second after an object starts falling, its velocity is 9.8 m/s. By 2 seconds after it starts falling, its velocity is 19.6 m/s (9.8 m/s + 9.8 m/s), and so on.)
E6 Air resistance (By definition, air resistance describes the forces that are in opposition to the relative motion of an object as it passes through the air.)
E7 Air resistance direction (By definition, air resistance describes the forces that are in opposition to the relative motion of an object as it passes through the air. These drag forces act opposite to the oncoming flow velocity, thus slowing the object down. Unlike other resistance forces, drag depends directly on velocity, since it is the component of the net aerodynamic force acting opposite to the direction of the movement.)
E8 Air resistance change (As an object falls through air, it usually encounters some degree of air resistance. Air resistance is the result of collisions of the object's leading surface with air molecules. Increased speeds result in an increased amount of air resistance)
E9 Air resistance magnitude (As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity.)
E10 Total force (As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity. At this instant in time, the net force is 0 Newton; the object will stop accelerating.)
E11 Variation of acceleration (As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity. At this instant in time, the net force is 0 Newton; the object will stop accelerating. The object is said to have reached a terminal velocity. The change in velocity terminates as a result of the balance of forces. The velocity at which this happens is called the terminal velocity.)
New
Delete
Reorganize
Analytics

8.2. Playing Golf

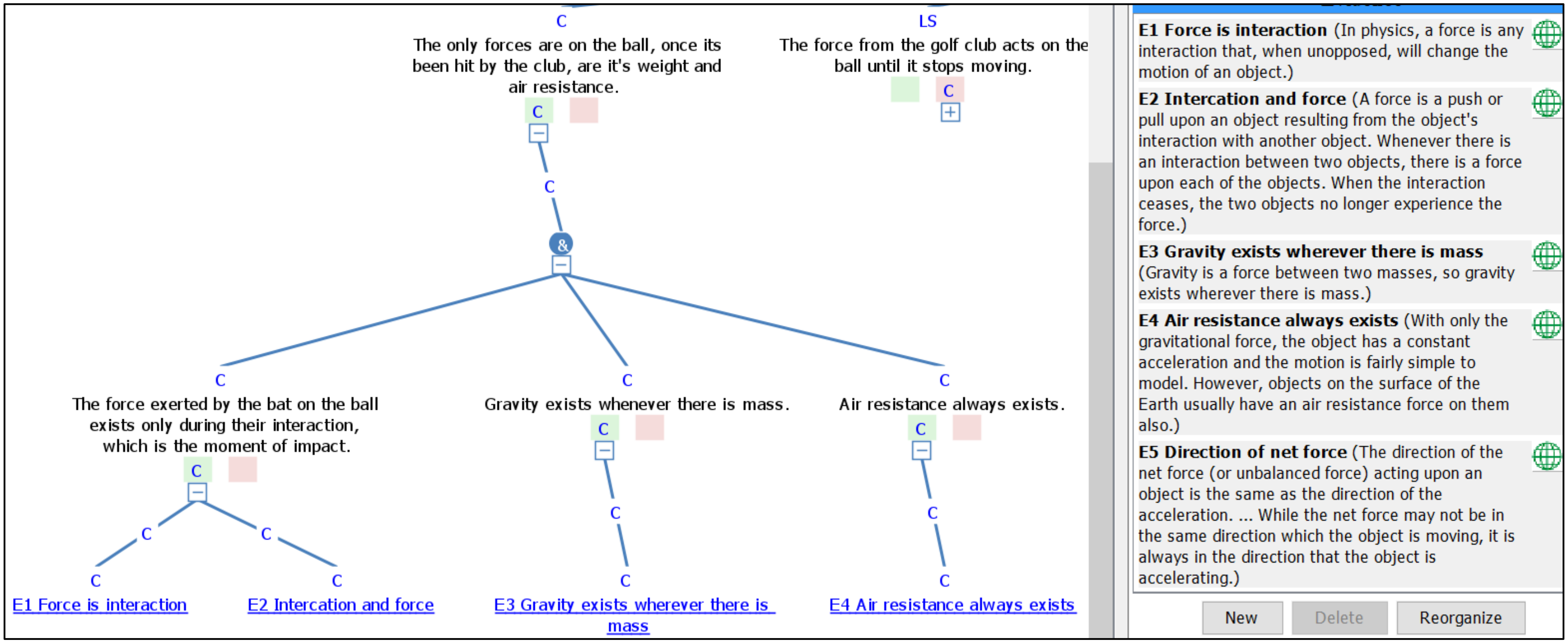
This exercise, adapted from (Osbome et al., 2004, pp.56-58), considers the situation where a golfer has driven a golf ball and the ball is falling freely onto the green. The students are asked to develop evidence-based argumentations in order to determine the truthfulness of a number of statements. The students will need to have some knowledge of the concepts of force, velocity, distance, weight, air resistance and speed.

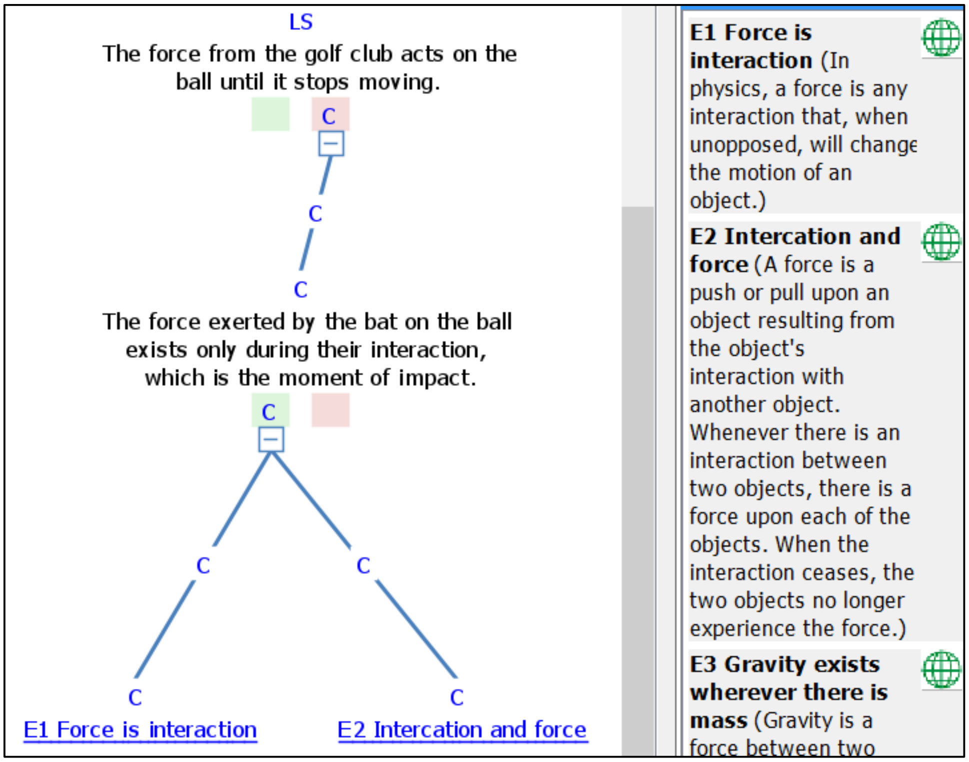
8.2.1. Inquiry

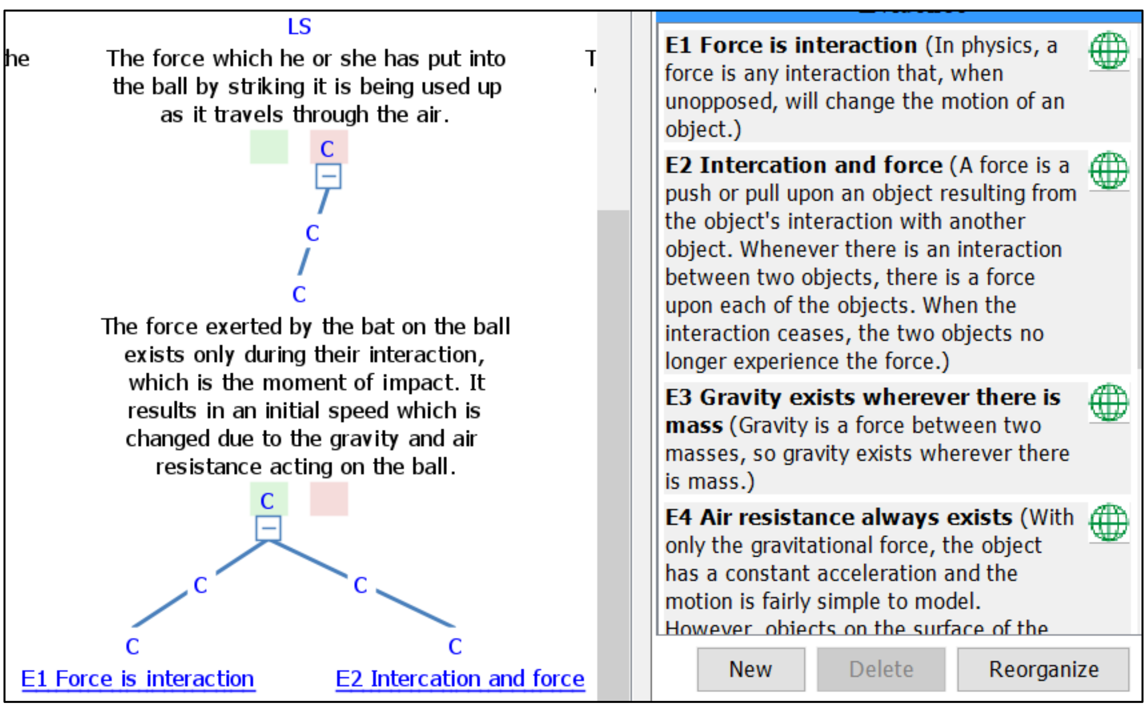
Which of the following statements are true and which are false?

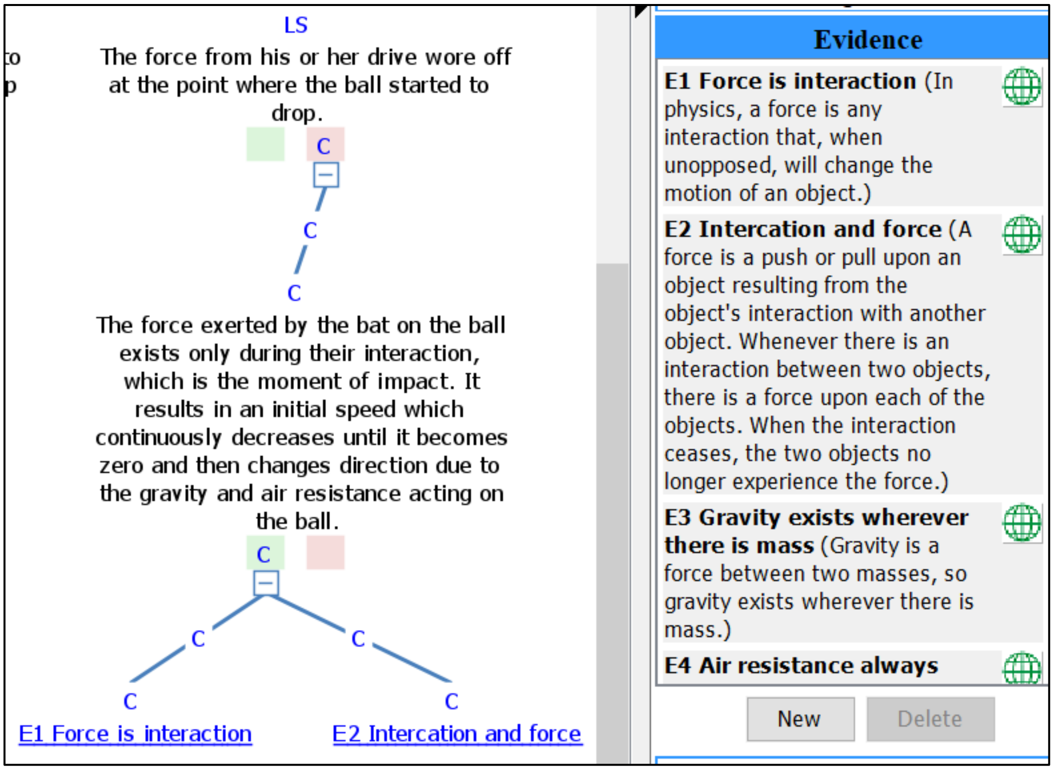
- The only forces on the ball, once it's been hit by the club, are its weight and air resistance.
- The force from the golf club acts on the ball until it stops moving.
- The force which he or she has put into the ball by striking it is being used up as it travels through the air.
- The force from his or her drive wore off at the point where the ball started to drop.
- The net force is always in the same direction as the ball is moving.
- The various forces on the ball can't be thought of as one single net force.

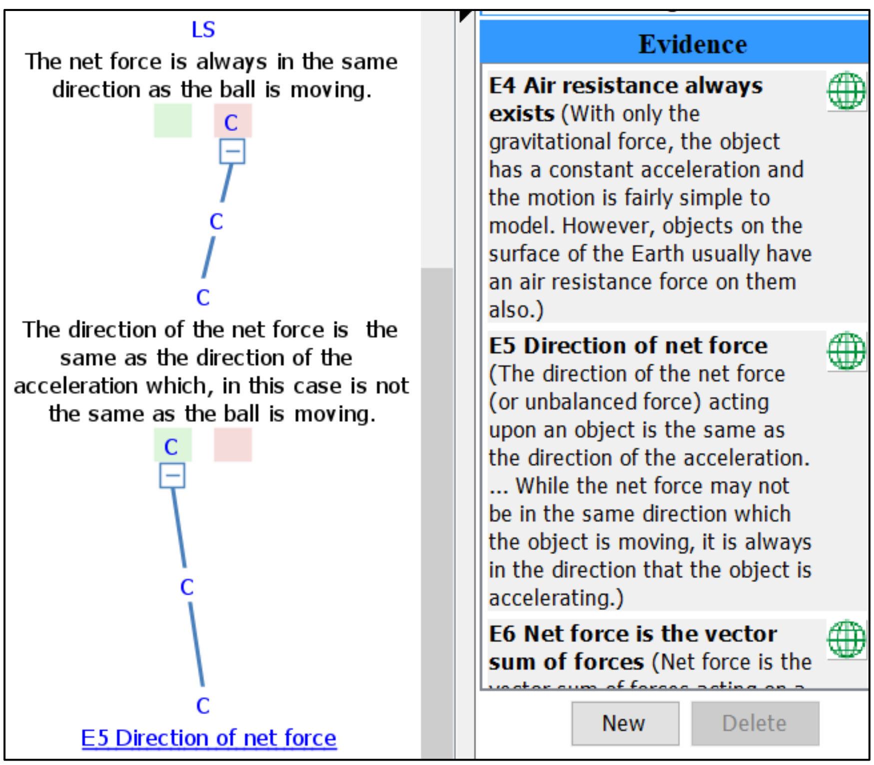
8.2.2. Argumentations

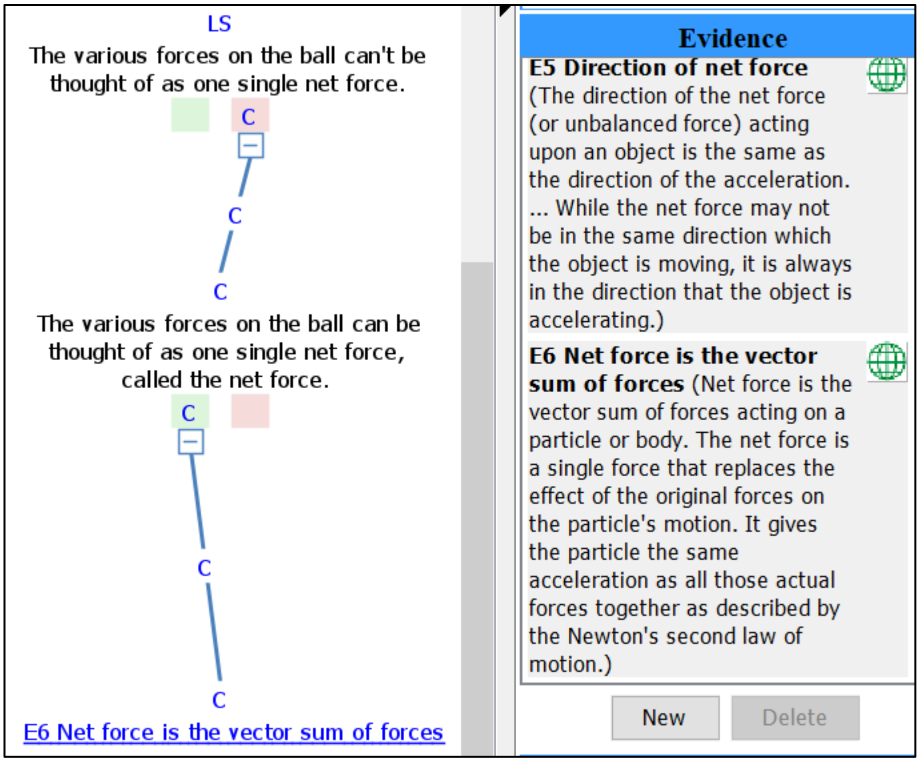



LS
The force from the golf club acts on the ball until it stops moving.
C
C
C
The force exerted by the bat on the ball exists only during their interaction, which is the moment of impact.
C
C
C
C
C
E1 Force is interaction
E2 Intercation and force
E1 Force is interaction (In physics, a force is any interaction that, when unopposed, will change the motion of an object.)
E2 Intercation and force (A force is a push or pull upon an object resulting from the object's interaction with another object. Whenever there is an interaction between two objects, there is a force upon each of the objects. When the interaction ceases, the two objects no longer experience the force.)
E3 Gravity exists wherever there is mass (Gravity is a force between two


LS
The force which he or she has put into the ball by striking it is being used up as it travels through the air.
C
C
C
The force exerted by the bat on the ball exists only during their interaction, which is the moment of impact. It results in an initial speed which is changed due to the gravity and air resistance acting on the ball.
C
C
C
C
C
E1 Force is interaction
E2 Intercation and force
E1 Force is interaction (In physics, a force is any interaction that, when unopposed, will change the motion of an object.)
E2 Intercation and force (A force is a push or pull upon an object resulting from the object's interaction with another object. Whenever there is an interaction between two objects, there is a force upon each of the objects. When the interaction ceases, the two objects no longer experience the force.)
E3 Gravity exists wherever there is mass (Gravity is a force between two masses, so gravity exists wherever there is mass.)
E4 Air resistance always exists (With only the gravitational force, the object has a constant acceleration and the motion is fairly simple to model.
New
Delete
Reorganize


LS
The force from his or her drive wore off at the point where the ball started to drop.
C
C
C
The force exerted by the bat on the ball exists only during their interaction, which is the moment of impact. It results in an initial speed which continuously decreases until it becomes zero and then changes direction due to the gravity and air resistance acting on the ball.
C
C
C
C
C
E1 Force is interaction
E2 Intercation and force
Evidence
E1 Force is interaction (In physics, a force is any interaction that, when unopposed, will change the motion of an object.)
E2 Intercation and force (A force is a push or pull upon an object resulting from the object's interaction with another object. Whenever there is an interaction between two objects, there is a force upon each of the objects. When the interaction ceases, the two objects no longer experience the force.)
E3 Gravity exists wherever there is mass (Gravity is a force between two masses, so gravity exists wherever there is mass.)
E4 Air resistance always
New
Delete


LS
The net force is always in the same direction as the ball is moving.
C
C
C
The direction of the net force is the same as the direction of the acceleration which, in this case is not the same as the ball is moving.
C
C
C
E5 Direction of net force
Evidence
E4 Air resistance always exists (With only the gravitational force, the object has a constant acceleration and the motion is fairly simple to model. However, objects on the surface of the Earth usually have an air resistance force on them also.)
E5 Direction of net force (The direction of the net force (or unbalanced force) acting upon an object is the same as the direction of the acceleration. ... While the net force may not be in the same direction which the object is moving, it is always in the direction that the object is accelerating.)
E6 Net force is the vector sum of forces (Net force is the
New
Delete



9. Classifying an Organism

The aim of this exercise, adapted from (Osbome et al., 2004, pp.26-30), is to determine whether the single cell organism euglena is a plant, an animal, or another type of organism, by developing an evidence-based argumentation.

9.1. Inquiry: What type of organism is Euglena?

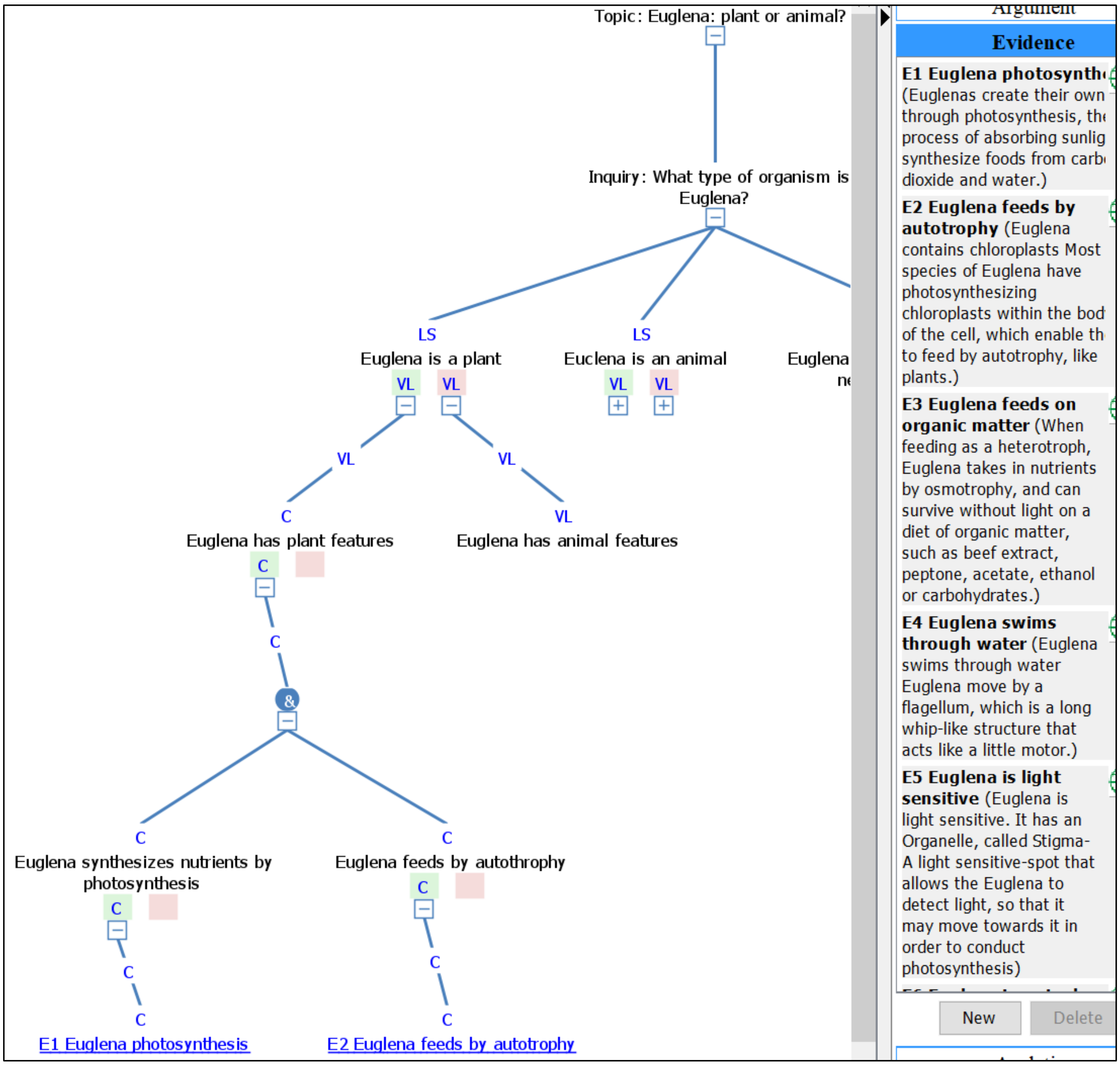
Euglena is an organism that has both plant and animal characteristics, including the following ones:

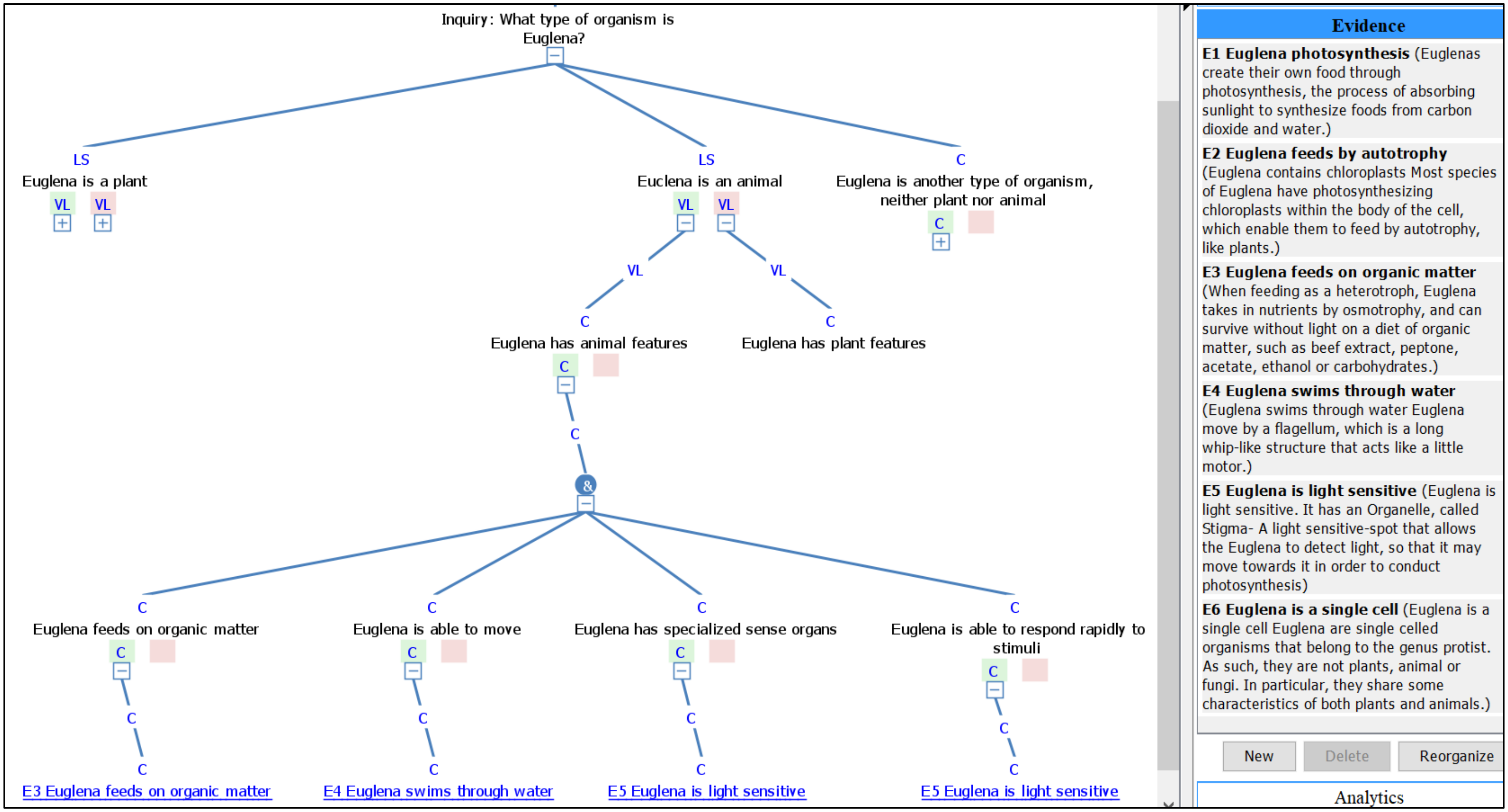
- Euglena has two outer layers.
- Euglena contains chloroplasts.
- Euglena has a nucleus.
- Euglena is a single cell.
- Euglena can absorb food from its surrounding.
- Euglena confused early scientists.
- Euglena is normally green.
- The nucleus contains DNA and controls the cell activities.
- Chloroplasts enable a cell to photosynthesize.
- A vacuole controls the amount of liquid in a cell.
- Euglena swims through water.
- Euglena can make its own food.

Develop argumentations to determine which of the following hypothesis is true:

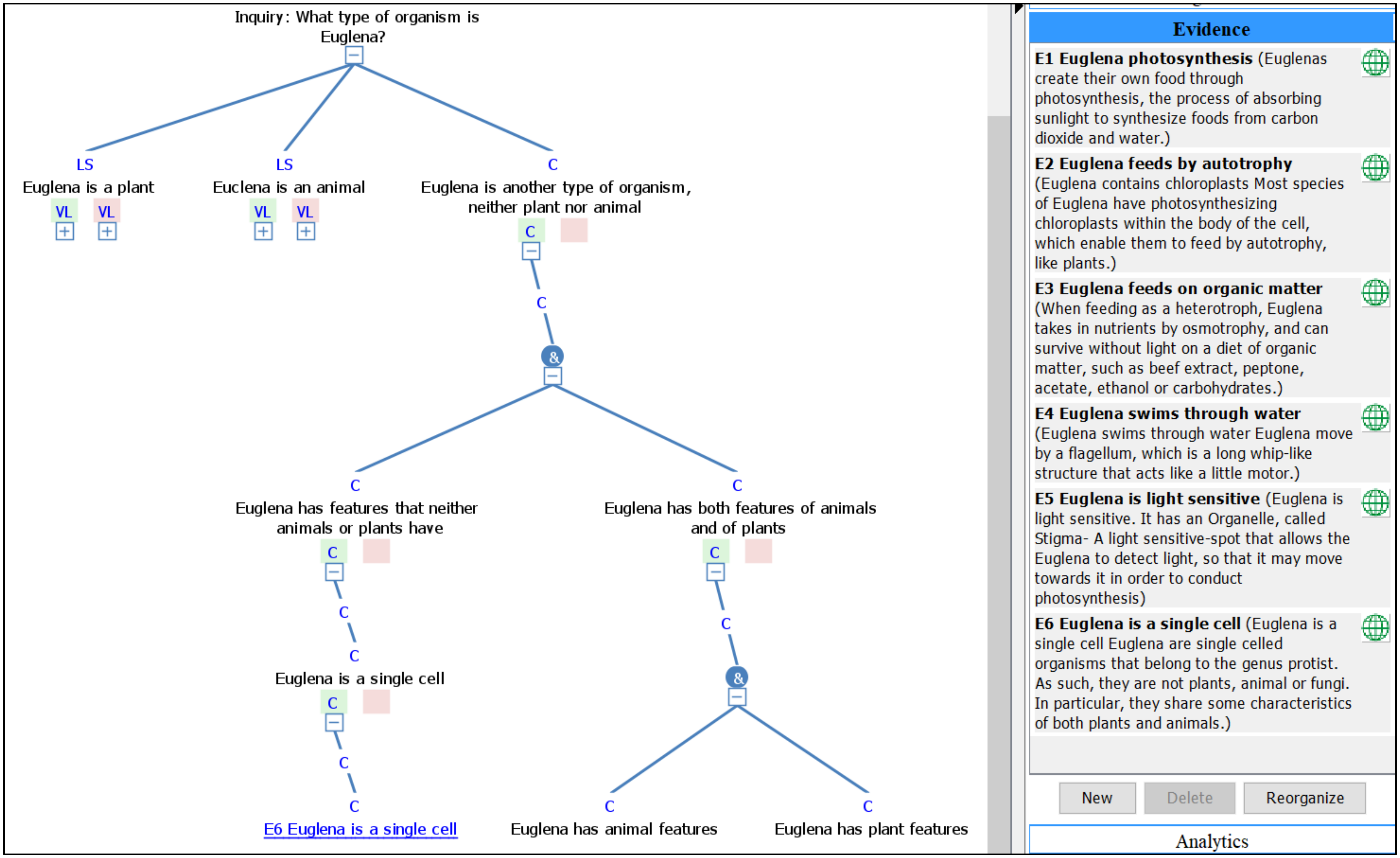
- Euglena is a plant
- Euglena is an animal
- Euglena is another type of organism, neither plant nor animal

9.2. Argumentations





Inquiry: What type of organism is Euglena?
LS
Euglena is a plant
VL
VL
LS
Euclena is an animal
VL
VL
C
Euglena is another type of organism, neither plant nor animal
C
VL
VL
C
Euglena has animal features
C
Euglena has plant features
C
C
&
C
Euglena feeds on organic matter
C
Euglena is able to move
C
Euglena has specialized sense organs
C
Euglena is able to respond rapidly to stimuli
C
C
C
C
C
C
C
C
C
C
C
E3 Euglena feeds on organic matter
E4 Euglena swims through water
E5 Euglena is light sensitive
E5 Euglena is light sensitive
Evidence
E1 Euglena photosynthesis (Euglenas create their own food through photosynthesis, the process of absorbing sunlight to synthesize foods from carbon dioxide and water.)
E2 Euglena feeds by autotrophy (Euglena contains chloroplasts Most species of Euglena have photosynthesizing chloroplasts within the body of the cell, which enable them to feed by autotrophy, like plants.)
E3 Euglena feeds on organic matter (When feeding as a heterotroph, Euglena takes in nutrients by osmotrophy, and can survive without light on a diet of organic matter, such as beef extract, peptone, acetate, ethanol or carbohydrates.)
E4 Euglena swims through water (Euglena swims through water Euglena move by a flagellum, which is a long whip-like structure that acts like a little motor.)
E5 Euglena is light sensitive (Euglena is light sensitive. It has an Organelle, called Stigma- A light sensitive-spot that allows the Euglena to detect light, so that it may move towards it in order to conduct photosynthesis)
E6 Euglena is a single cell (Euglena is a single cell Euglena are single celled organisms that belong to the genus protist. As such, they are not plants, animal or fungi. In particular, they share some characteristics of both plants and animals.)
New
Delete
Reorganize
Analytics


Inquiry: What type of organism is Euglena?
LS
Euglena is a plant
VL
VL
LS
Euclena is an animal
VL
VL
C
Euglena is another type of organism, neither plant nor animal
C
C
&
C
Euglena has features that neither animals or plants have
C
C
C
Euglena is a single cell
C
C
C
E6 Euglena is a single cell
C
Euglena has both features of animals and of plants
C
C
&
C
Euglena has animal features
C
Euglena has plant features
Evidence
E1 Euglena photosynthesis (Euglenas create their own food through photosynthesis, the process of absorbing sunlight to synthesize foods from carbon dioxide and water.)
E2 Euglena feeds by autotrophy (Euglena contains chloroplasts Most species of Euglena have photosynthesizing chloroplasts within the body of the cell, which enable them to feed by autotrophy, like plants.)
E3 Euglena feeds on organic matter (When feeding as a heterotroph, Euglena takes in nutrients by osmotrophy, and can survive without light on a diet of organic matter, such as beef extract, peptone, acetate, ethanol or carbohydrates.)
E4 Euglena swims through water (Euglena swims through water Euglena move by a flagellum, which is a long whip-like structure that acts like a little motor.)
E5 Euglena is light sensitive (Euglena is light sensitive. It has an Organelle, called Stigma- A light sensitive-spot that allows the Euglena to detect light, so that it may move towards it in order to conduct photosynthesis)
E6 Euglena is a single cell (Euglena is a single cell Euglena are single celled organisms that belong to the genus protist. As such, they are not plants, animal or fungi. In particular, they share some characteristics of both plants and animals.)
New
Delete
Reorganize
Analytics

10. Arguing about a Socio-Scientific Issue

The aim of this exercise, adapted from (Osbome et al., 2004, pp.37-39), is to provide an opportunity for students to engage in argumentation about a socio-scientific issue - the funding of a new zoo - and to provide justifications for their point of view by doing internet research to construct arguments, justified with evidence, either for or against the new zoo.

10.1. Inquiry: Should we have a new zoo?

To facilitate students' Internet research and the development of their argumentation, they are asked to consider the following sets of questions.

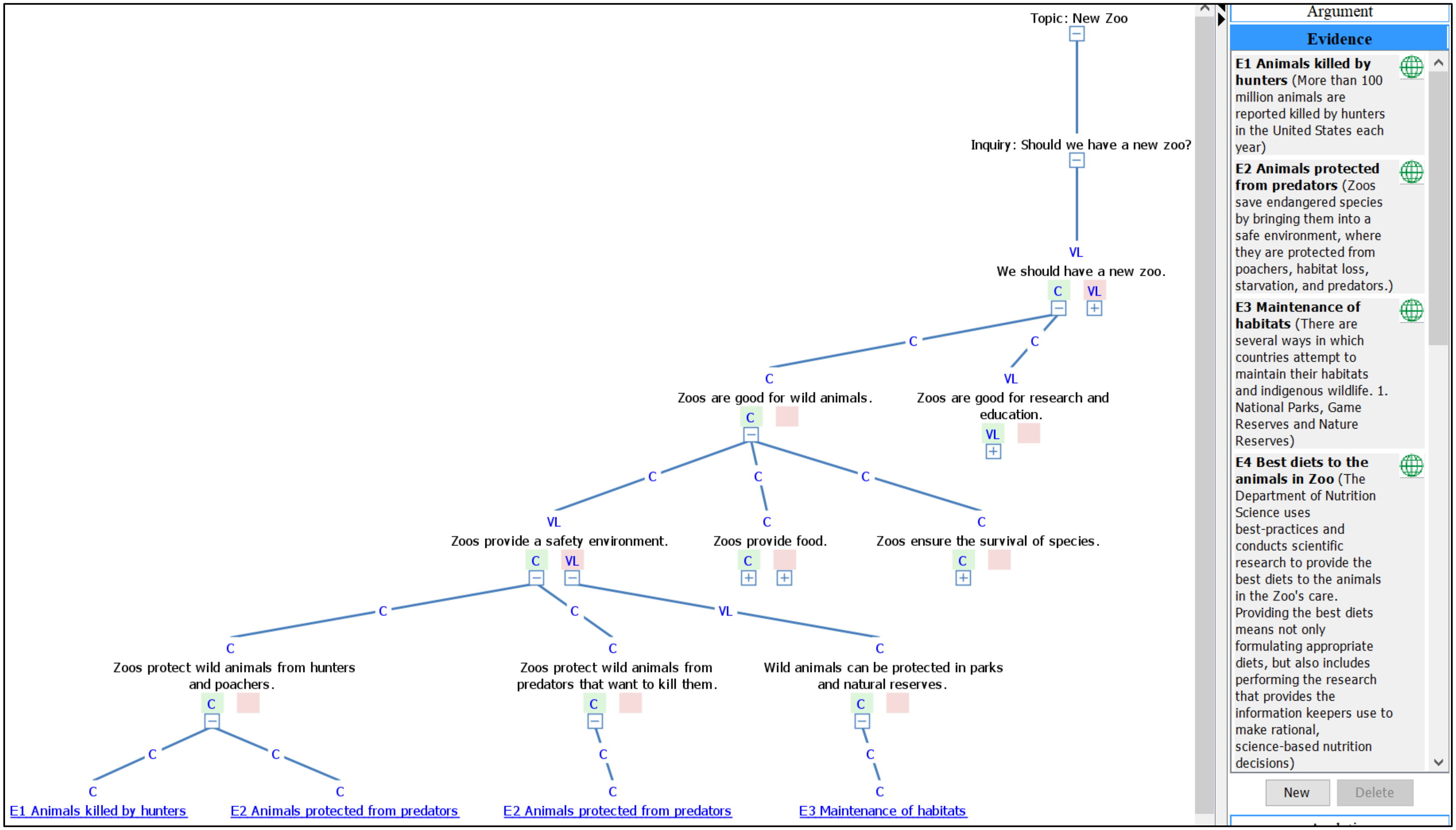
Questions to stimulate agreement with zoos:

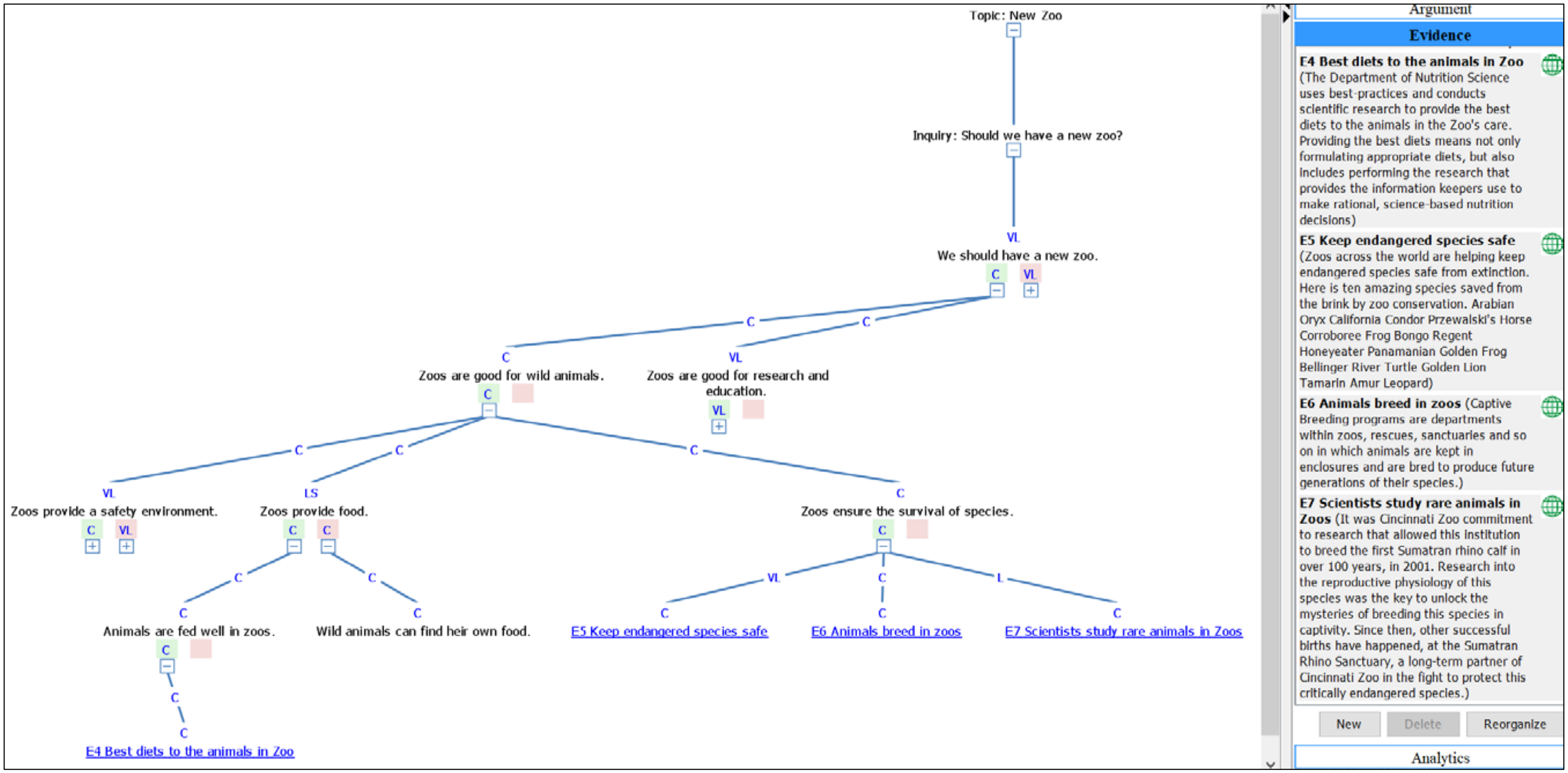
- Are wild animals killed by hunters and poachers?
- Are animals in zoos well fed?
- Are animals in zoos safe from predators that want to kill them?
- Do zoos allow you to see a large number of different animals?
- Would animals have become extinct if it wasn't for zoos?
- Can you see wild animals on the television living in their natural homes?
- Do wild animals have to find their own food?
- Can zoos release animals back to the wild?
- Do zoos allow scientists to study rare animals?

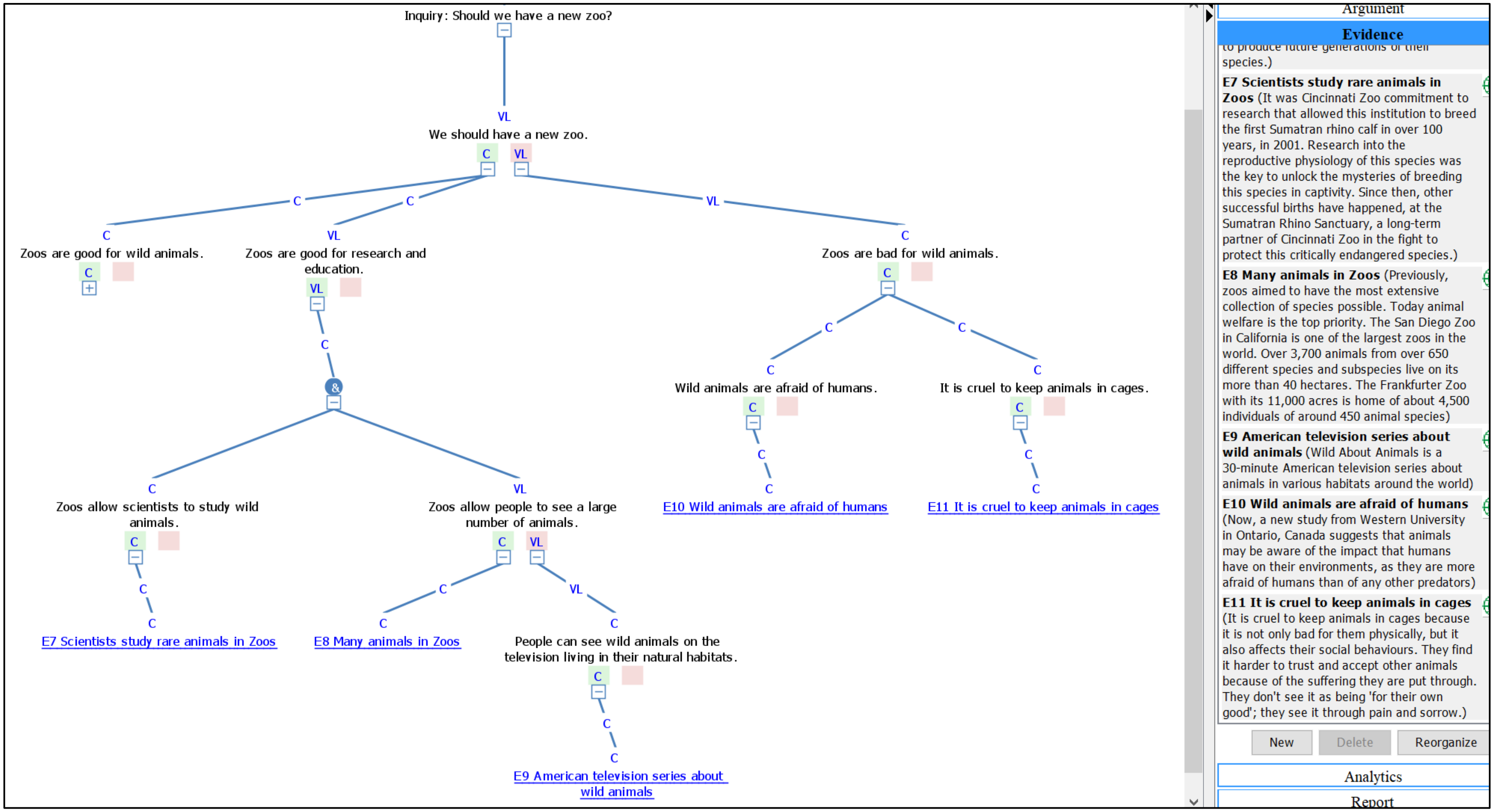
Questions to stimulate disagreement with zoos

- Do animals in the wild have lots of places to live in?
- Is it cruel to keep animals in cages?
- Can wild animals be protected in parks and nature reserves?
- Are wild animals afraid of human beings?
- Can animals be bored and lonely in zoos?
- Can animals breed in zoos?

10.2. Argumentation




Topic: New Zoo
Inquiry: Should we have a new zoo?
VL
We should have a new zoo.
C
VL
C
C
C
VL
Zoos are good for wild animals.
Zoos are good for research and education.
C
VL
C
C
C
VL
LS
C
Zoos provide a safety environment.
Zoos provide food.
Zoos ensure the survival of species.
C
VL
C
C
C
C
C
VL
C
L
C
C
C
C
Animals are fed well in zoos.
Wild animals can find heir own food.
E5 Keep endangered species safe
E6 Animals breed in zoos
E7 Scientists study rare animals in Zoos
C
C
C
E4 Best diets to the animals in Zoo
Argument
Evidence
E4 Best diets to the animals in Zoo
(The Department of Nutrition Science uses best-practices and conducts scientific research to provide the best diets to the animals in the Zoo's care. Providing the best diets means not only formulating appropriate diets, but also includes performing the research that provides the information keepers use to make rational, science-based nutrition decisions)
E5 Keep endangered species safe
(Zoos across the world are helping keep endangered species safe from extinction. Here is ten amazing species saved from the brink by zoo conservation. Arabian Oryx California Condor Przewalski's Horse Corroboree Frog Bongo Regent Honeyeater Panamanian Golden Frog Bellinger River Turtle Golden Lion Tamarin Amur Leopard)
E6 Animals breed in zoos (Captive Breeding programs are departments within zoos, rescues, sanctuaries and so on in which animals are kept in enclosures and are bred to produce future generations of their species.)
E7 Scientists study rare animals in Zoos (It was Cincinnati Zoo commitment to research that allowed this institution to breed the first Sumatran rhino calf in over 100 years, in 2001. Research into the reproductive physiology of this species was the key to unlock the mysteries of breeding this species in captivity. Since then, other successful births have happened, at the Sumatran Rhino Sanctuary, a long-term partner of Cincinnati Zoo in the fight to protect this critically endangered species.)
New
Delete
Reorganize
Analytics


Inquiry: Should we have a new zoo?
VL
We should have a new zoo.
C
VL
C
C
VL
C
Zoos are good for wild animals.
C
VL
Zoos are good for research and education.
VL
C
&
C
Zoos allow scientists to study wild animals.
C
C
C
E7 Scientists study rare animals in Zoos
VL
Zoos allow people to see a large number of animals.
C
VL
C
C
E8 Many animals in Zoos
VL
C
People can see wild animals on the television living in their natural habitats.
C
C
C
E9 American television series about wild animals
C
Zoos are bad for wild animals.
C
C
C
C
Wild animals are afraid of humans.
C
C
C
E10 Wild animals are afraid of humans
C
It is cruel to keep animals in cages.
C
C
C
E11 It is cruel to keep animals in cages
Argument
Evidence
to produce future generations of their species.)
E7 Scientists study rare animals in Zoos (It was Cincinnati Zoo commitment to research that allowed this institution to breed the first Sumatran rhino calf in over 100 years, in 2001. Research into the reproductive physiology of this species was the key to unlock the mysteries of breeding this species in captivity. Since then, other successful births have happened, at the Sumatran Rhino Sanctuary, a long-term partner of Cincinnati Zoo in the fight to protect this critically endangered species.)
E8 Many animals in Zoos (Previously, zoos aimed to have the most extensive collection of species possible. Today animal welfare is the top priority. The San Diego Zoo in California is one of the largest zoos in the world. Over 3,700 animals from over 650 different species and subspecies live on its more than 40 hectares. The Frankfurter Zoo with its 11,000 acres is home of about 4,500 individuals of around 450 animal species)
E9 American television series about wild animals (Wild About Animals is a 30-minute American television series about animals in various habitats around the world)
E10 Wild animals are afraid of humans (Now, a new study from Western University in Ontario, Canada suggests that animals may be aware of the impact that humans have on their environments, as they are more afraid of humans than of any other predators)
E11 It is cruel to keep animals in cages (It is cruel to keep animals in cages because it is not only bad for them physically, but it also affects their social behaviours. They find it harder to trust and accept other animals because of the suffering they are put through. They don't see it as being 'for their own good'; they see it through pain and sorrow.)
New
Delete
Reorganize
Analytics
Report

11. Exploring a Mystery

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).

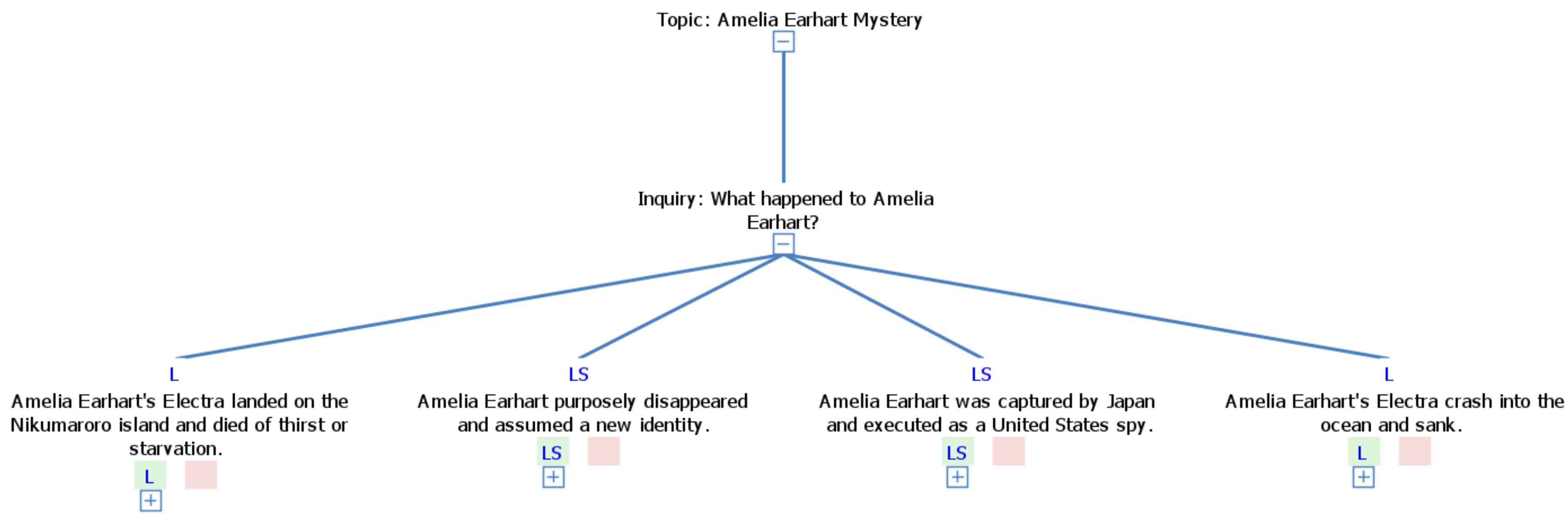
11.1. Inquiry: What happened to Amelia Earhart?

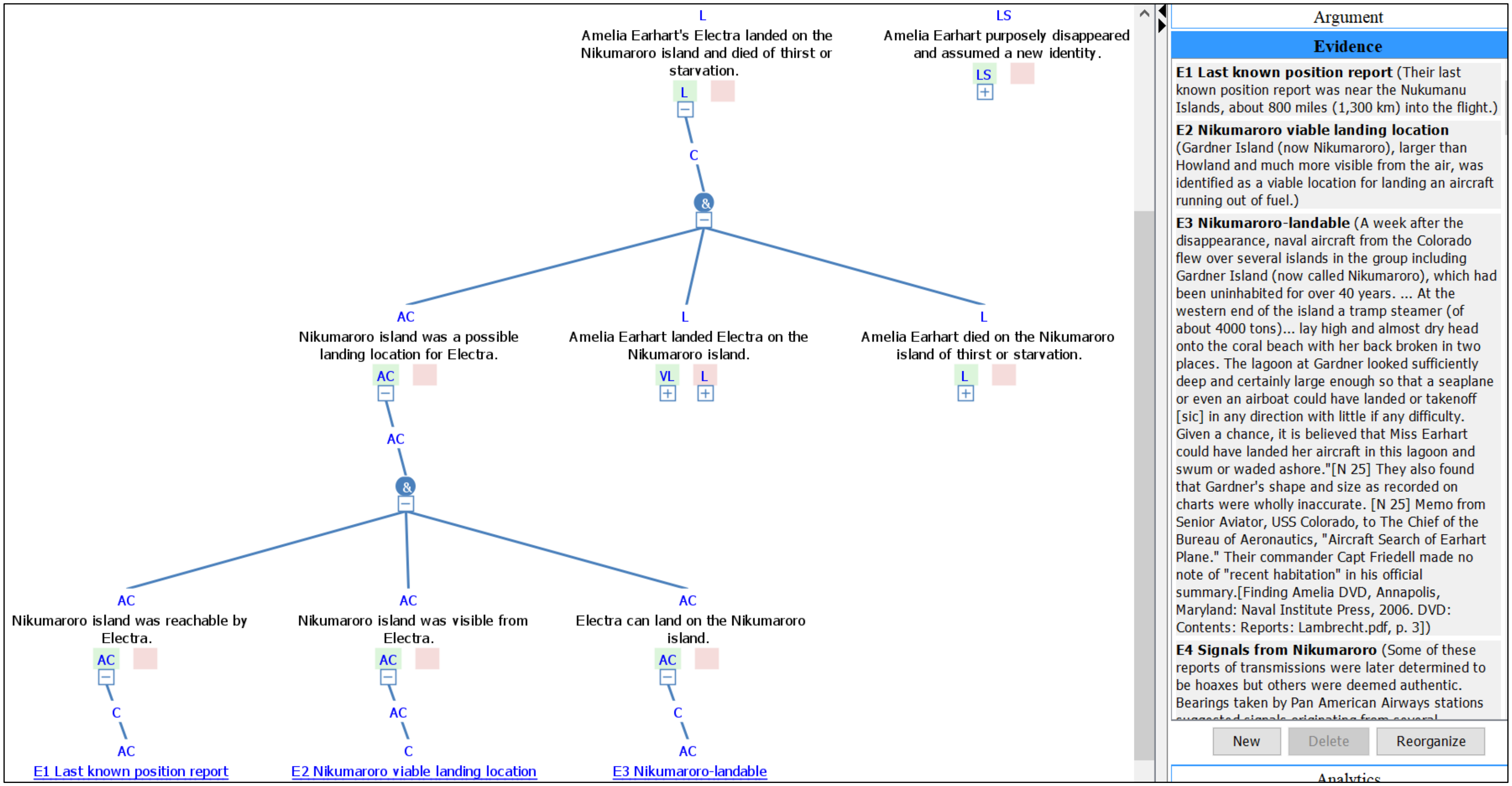
The aim of this exercise is to explore various theories on Amelia Earhart's disappearance by developing evidence-based argumentations.

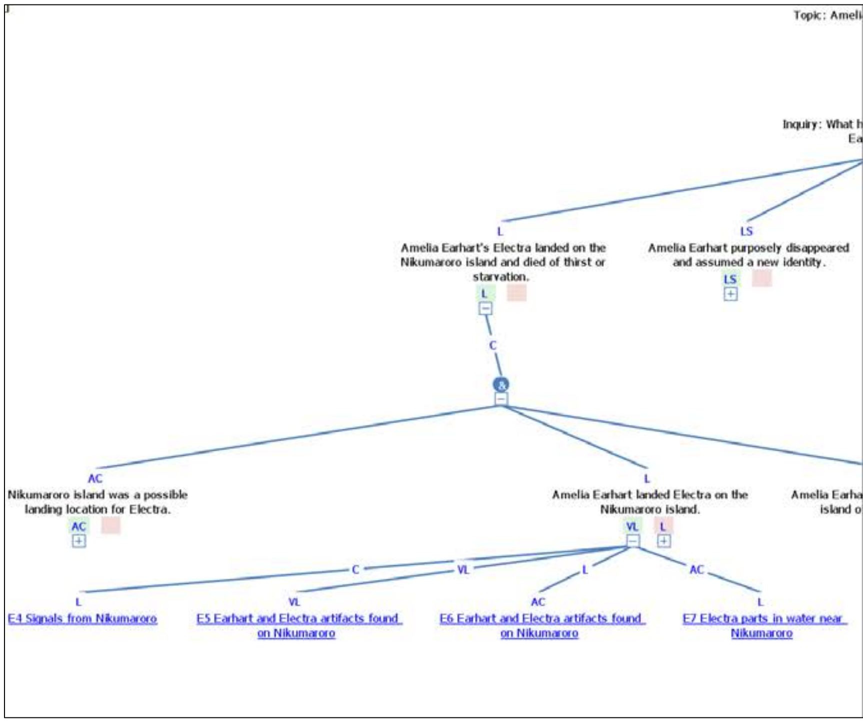
Four possible theories are to be explored:

- Amelia Earhart's Electra landed on the Nikumaroro Island and died of thirst or starvation.
- Amelia Earhart purposely disappeared and assumed a new identity.
- Amelia Earhart was captured by Japan and executed as a United States spy.
- Amelia Earhart's Electra crashed into the ocean and sank.

11.2. Argumentations




L
Amelia Earhart's Electra landed on the Nikumaroro island and died of thirst or starvation.
LS
Amelia Earhart purposely disappeared and assumed a new identity.
C
AC
Nikumaroro island was a possible landing location for Electra.
L
Amelia Earhart landed Electra on the Nikumaroro island.
VL
L
Amelia Earhart died on the Nikumaroro island of thirst or starvation.
AC
Nikumaroro island was reachable by Electra.
Nikumaroro island was visible from Electra.
Electra can land on the Nikumaroro island.
E1 Last known position report
E2 Nikumaroro viable landing location
E3 Nikumaroro-landable
Argument
Evidence
E1 Last known position report (Their last known position report was near the Nukumanu Islands, about 800 miles (1,300 km) into the flight.)
E2 Nikumaroro viable landing location (Gardner Island (now Nikumaroro), larger than Howland and much more visible from the air, was identified as a viable location for landing an aircraft running out of fuel.)
E3 Nikumaroro-landable (A week after the disappearance, naval aircraft from the Colorado flew over several islands in the group including Gardner Island (now called Nikumaroro), which had been uninhabited for over 40 years. ... At the western end of the island a tramp steamer (of about 4000 tons)... lay high and almost dry head onto the coral beach with her back broken in two places. The lagoon at Gardner looked sufficiently deep and certainly large enough so that a seaplane or even an airboat could have landed or takenoff [sic] in any direction with little if any difficulty. Given a chance, it is believed that Miss Earhart could have landed her aircraft in this lagoon and swum or waded ashore."[N 25] They also found that Gardner's shape and size as recorded on charts were wholly inaccurate. [N 25] Memo from Senior Aviator, USS Colorado, to The Chief of the Bureau of Aeronautics, "Aircraft Search of Earhart Plane." Their commander Capt Friedell made no note of "recent habitation" in his official summary.[Finding Amelia DVD, Annapolis, Maryland: Naval Institute Press, 2006. DVD: Contents: Reports: Lambrecht.pdf, p. 3])
E4 Signals from Nikumaroro (Some of these reports of transmissions were later determined to be hoaxes but others were deemed authentic. Bearings taken by Pan American Airways stations
New
Delete
Reorganize



Argument

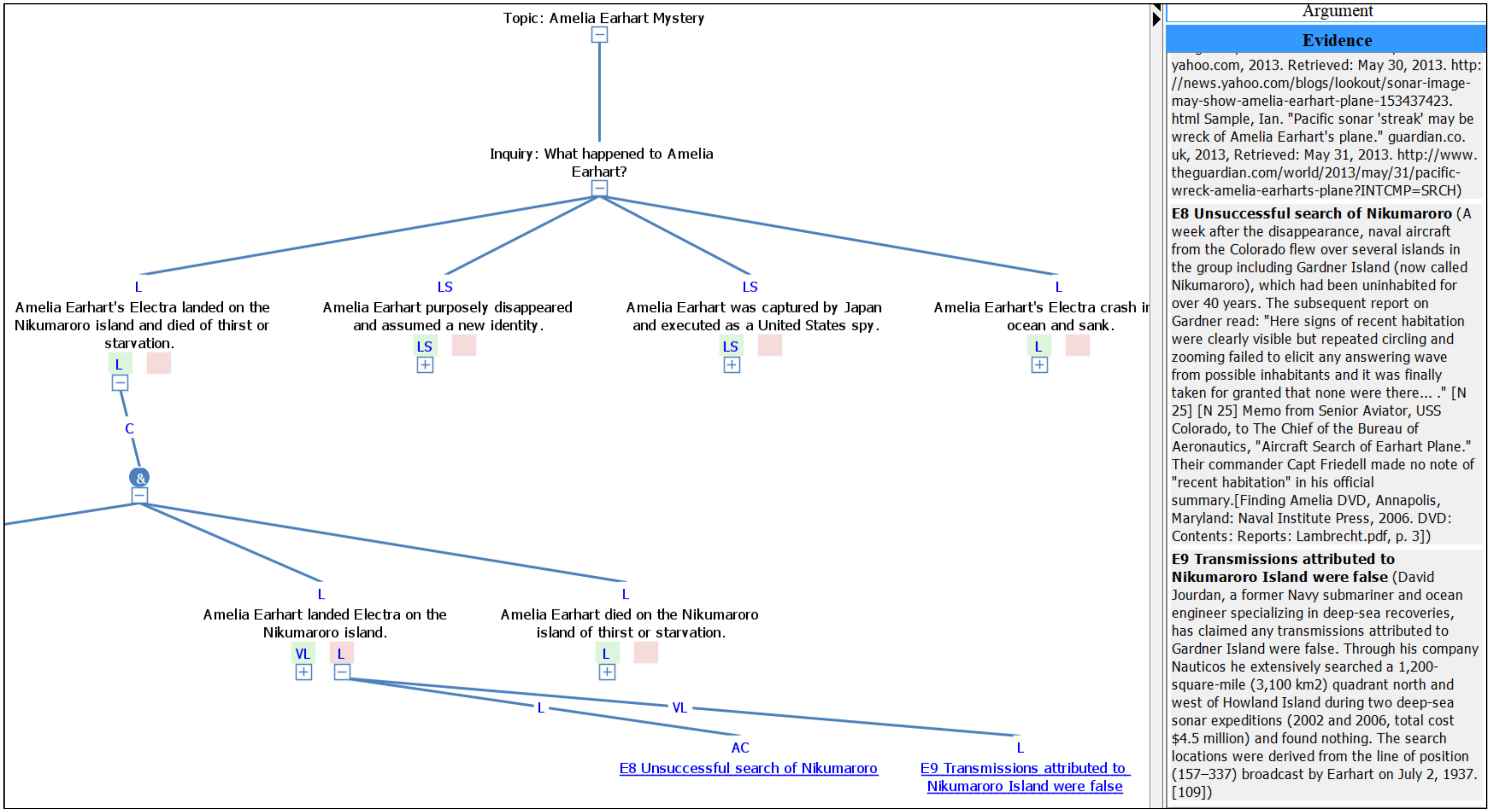
Evidence

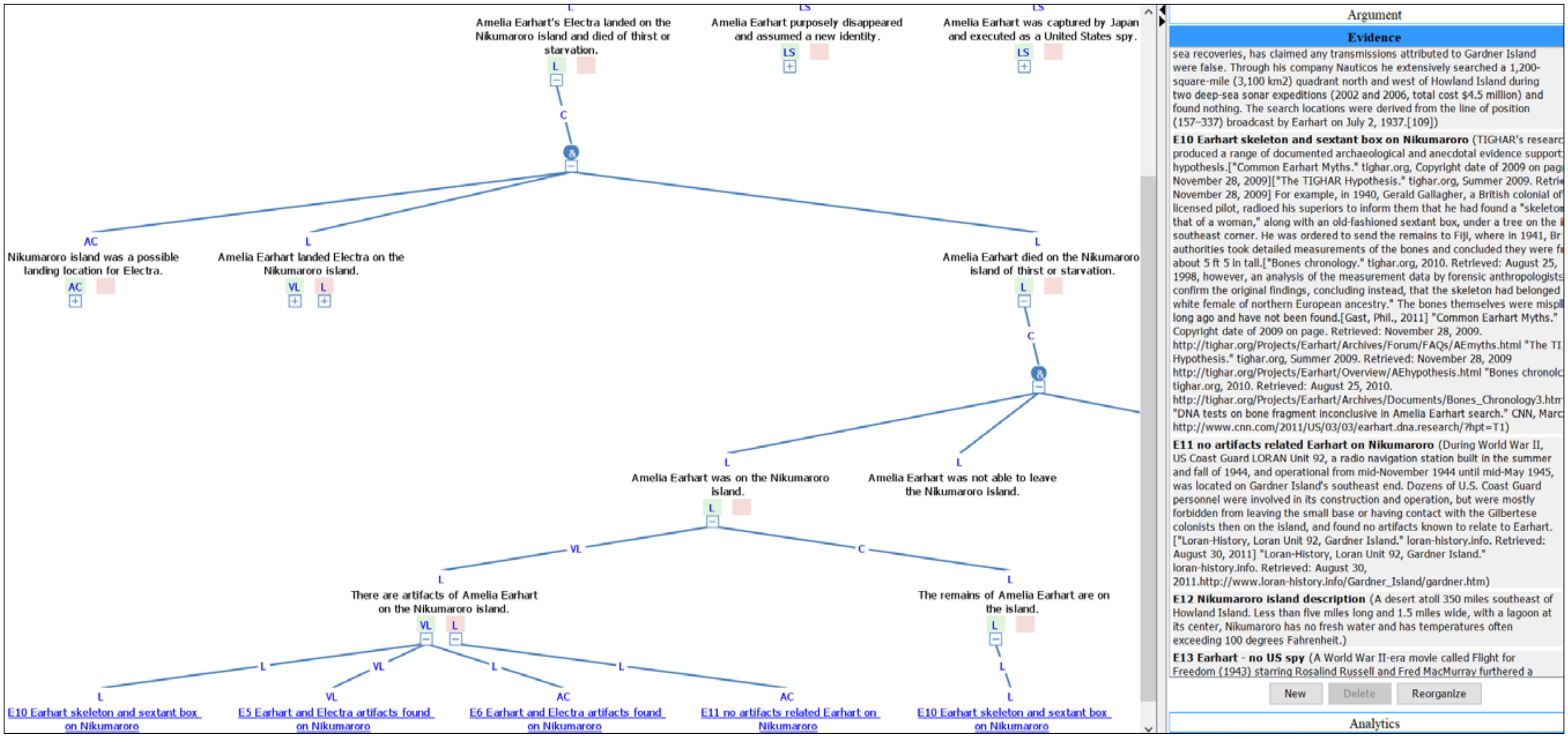
E4 Signals from Nikumaroro (Some of these reports of transmissions were later determined to be hoaxes but others were deemed authentic. Bearings taken by Pan American Airways stations suggested signals originating from several locations, including Gardner Island.[Gillespie 2006, p. 115][Strippel 1995, p. 18] It was noted at the time that if these signals were from Earhart and Noonan, they must have been on land with the aircraft since water would have otherwise shorted out the Electra's electrical system.[Gillespie 2006, diagram p. 190][N 22][Gillespie 2006, p. 140.][N 23] Sporadic signals were reported for four or five days after the disappearance but none yielded any understandable information.[Goldstein and Dillon 1997, p. 241][N 24] The captain of the USS Colorado later said "There was no doubt many stations were calling the Earhart plane on the plane's frequency, some by voice and others by signals. All of these added to the confusion and doubtfulness of the authenticity of the reports."[Gillespie 2006, p. 146] Gillespie, Ric. Finding Amelia: The True Story of the Earhart Disappearance. Annapolis, Maryland: Naval Institute Press, 2006. ISBN 1-59114-319-5. Strippel, Richard G. "Researching Amelia: A Detailed Summary for the Serious Researcher into the Disappearance of Amelia Earhart." Air Classics, Vol. 31, No. 11, November 1995. [N 22] The essential components were all mounted low, including the generator, batteries, dynamotor and transmitter. [N23] In order to operate the radio for any length of time, the aircraft would have had to be standing more or less upright on its landing gear with the right engine running in order to charge the 50-watt transmitter's battery, which would have consumed six gallons of fuel per hour. Goldstein, Donald M. and Katherine V. Dillon. Amelia: The Centennial Biography of an Aviation Pioneer. Washington, D.C.: Brassey's, 1997. ISBN 1-57488-134-5. [N 24] The first two days were marked by rumors and misinformation regarding radio transmission capabilities of the Lockheed Model 10 Electra that were finally resolved by the aircraft company. Gillespie, Ric. Finding Amelia: The True Story of the Earhart Disappearance. Annapolis, Maryland: Naval Institute Press, 2006. ISBN 1-59114-319-5.)

E5 Earhart and Electra artifacts found on Nikumaroro (Artifacts discovered by TIGHAR on Nikumaroro have included improvised tools; an aluminum panel, pos
made using 1930s manufacturing specifications; an oddly cut piece of clear Plexiglas the same thickness and curvature of an Electra window; and a size 9 Cat's Paw h
1930s which resembles Earhart's footwear in world flight photos.[Pyle, Richard, 2007][N 27] The evidence remains circumstantial, but Earhart's surviving stepson, Ge
expressed support for TIGHAR's research.[Cruikshank, Joe, 2006] This evidence was further bolstered by a recently rediscovered photo of Earhart's Electra, which sh
similar in shape and size to the one found by TIGHAR had been used to seal a broken rear window in the plane just prior to departure. No other known photos show t
match the panel's rivet pattern to the photo are ongoing. [Foxnews.com, 2014] Pyle, Richard. "Diary a clue to Amelia Earhart mystery." AP via "Huffington Post," Mar
June 29, 2013.http://www.huffingtonpost.com/huff-wires/20070331/search-for-amelia/ [N 27] According to records, Noonan was 6 ft (1.8 m) tall and Earhart was 5 f
wore a size 6 shoe according to her sister. Cruikshank, Joe. "The Search for Earhart's Plane Continues." Treasure County Palm News, November 4, 2006. Retrieved: A
https://verify2.newsbank.com/ELinks/docreq/docreq.xml?docid=0000000000000000&siteid=TCNP&papercd=TCNP&from=&destination=http%3A%2F%2Fwww.news
Foxnews.com. "Report points to photo as possible new clue to Amelia Earhart's fate" FoxNews.com, July 1, 2014. Retrieved: July 1, 2014. http://www.foxnews.com/science/2014/07/01/photo-may-offer-crucial-clue-in-amelia-earhart-mystery-report/)

E6 Earhart and Electra artifacts found on Nikumaroro (In 2007, a TIGHAR expedition visited Nikumaroro searching for unambiguously identifiable aircraft artifacts and DNA. The group included engineers, technical experts, archaeologists, anthropologists, and researchers.[Pyle, Richard, 2007] They found artifacts of uncertain origin on the weather-ravaged atoll, including bronze bearings which may have belonged to Earhart's aircraft and a zipper pull which might have come from her flight suit.["TIGHAR 2007 Expedition Updates" tighar.org, 2007] In 2010, the research group said it had found bones that appeared to be part of a human finger. Subsequent DNA testing at the University of Oklahoma proved inconclusive as to whether the bone fragments were from a human or from a sea turtle.[Gast, Phil, 2011] Pyle, Richard. "New search begins in Earhart mystery." USA Today, July 12, 2007. Retrieved: June 29, 2013. http://usatoday30.usatoday.com/news/nation/2007-07-12-2214476002_x.htm "TIGHAR 2007 Expedition Updates" tighar.org, August, 2007. Retrieved: June 29, 2013. Gast, Phil."DNA tests on bone fragment inconclusive in Amelia Earhart search" www.cnn.com, March 3, 2011, Retrieved: March 3, 2011. http://www.cnn.com/2011/US/03/03/earhart.dna.research/?hpt=T1)

E7 Electra parts in water near Nikumaroro (July 2012, TIGHAR conducted an underwater expedition off the northwest reef of Nikumaroro, using sonar mapping. Some of the sonar images suggested a possible wreckage site,[Daily Mail, 2012] although Ric Gillespie, executive director of TIGHAR, cautioned that most of the Electra's parts would likely have disintegrated after 75 years in sea water.[Lorenzi, Rossella, 2012] Nevertheless, in May 2013, TIGHAR announced that professional analysis of a 32-foot (9.8 m) anomaly in the sonar images showed what could possibly be the aircraft.[Zap, Claudine, 2013][Sample, Ian, 2013] "Amelia Earhart Underwater video reveals evidence solves 75 year mystery aviators flight." Daily Mail, August 18, 2012. Retrieved: March 10, 2013. http://www.dailymail.co.uk/news/article-2190099/Amelia-Earhart-Underwater-video-reveals-evidence-solves-75-year-mystery-aviators-flight.html Lorenzi, Rossella. "Pieces of Amelia Earhart's plane located?" Discovery Communications, LLC, November 18, 2012. Retrieved: March 10, 2013. http://news.discovery.com/history/us-history/amelia-earhart-plane-located-120817.htm Zap, Claudine. "Sonar image may show Amelia Earhart's plane." News.yahoo.com, 2013. Retrieved: May 30, 2013. http://news.yahoo.com/blogs/lookout/sonar-image-may-show-amelia-earhart-plane-153437423.html Sample, Ian. "Pacific sonar 'streak' may be wreck of Amelia Earhart's plane." guardian.co.uk, 2013, Retrieved: May 31, 2013. http://www.theguardian.com/world/2013/may/31/pacific-wreck-amelia-earharts-plane?INTCMP=SRCH)


Topic: Amelia Earhart Mystery
Inquiry: What happened to Amelia Earhart?
L
Amelia Earhart's Electra landed on the Nikumaroro island and died of thirst or starvation.
LS
Amelia Earhart purposely disappeared and assumed a new identity.
LS
Amelia Earhart was captured by Japan and executed as a United States spy.
L
Amelia Earhart's Electra crash in ocean and sank.
L
LS
LS
L
C
&
L
Amelia Earhart landed Electra on the Nikumaroro island.
L
Amelia Earhart died on the Nikumaroro island of thirst or starvation.
VL
L
L
L
VL
AC
E8 Unsuccessful search of Nikumaroro
L
E9 Transmissions attributed to Nikumaroro Island were false
Argument
Evidence
yahoo.com, 2013. Retrieved: May 30, 2013. http://news.yahoo.com/blogs/lookout/sonar-image-may-show-amelia-earhart-plane-153437423.html Sample, Ian. "Pacific sonar 'streak' may be wreck of Amelia Earhart's plane." guardian.co.uk, 2013, Retrieved: May 31, 2013. http://www.theguardian.com/world/2013/may/31/pacific-wreck-amelia-earharts-plane?INTCMP=SRCH)
E8 Unsuccessful search of Nikumaroro (A week after the disappearance, naval aircraft from the Colorado flew over several islands in the group including Gardner Island (now called Nikumaroro), which had been uninhabited for over 40 years. The subsequent report on Gardner read: "Here signs of recent habitation were clearly visible but repeated circling and zooming failed to elicit any answering wave from possible inhabitants and it was finally taken for granted that none were there... ." [N 25] [N 25] Memo from Senior Aviator, USS Colorado, to The Chief of the Bureau of Aeronautics, "Aircraft Search of Earhart Plane." Their commander Capt Friedell made no note of "recent habitation" in his official summary.[Finding Amelia DVD, Annapolis, Maryland: Naval Institute Press, 2006. DVD: Contents: Reports: Lambrecht.pdf, p. 3])
E9 Transmissions attributed to Nikumaroro Island were false (David Jourdan, a former Navy submariner and ocean engineer specializing in deep-sea recoveries, has claimed any transmissions attributed to Gardner Island were false. Through his company Nauticos he extensively searched a 1,200-square-mile (3,100 km2) quadrant north and west of Howland Island during two deep-sea sonar expeditions (2002 and 2006, total cost $4.5 million) and found nothing. The search locations were derived from the line of position (157–337) broadcast by Earhart on July 2, 1937.[109])


Amelia Earhart's Electra landed on the Nikumaroro island and died of thirst or starvation.
Amelia Earhart purposely disappeared and assumed a new identity.
Amelia Earhart was captured by Japan and executed as a United States spy.
Nikumaroro island was a possible landing location for Electra.
Amelia Earhart landed Electra on the Nikumaroro island.
Amelia Earhart died on the Nikumaroro island of thirst or starvation.
Amelia Earhart was on the Nikumaroro island.
Amelia Earhart was not able to leave the Nikumaroro island.
There are artifacts of Amelia Earhart on the Nikumaroro island.
The remains of Amelia Earhart are on the island.
E10 Earhart skeleton and sextant box on Nikumaroro
E5 Earhart and Electra artifacts found on Nikumaroro
E6 Earhart and Electra artifacts found on Nikumaroro
E11 no artifacts related Earhart on Nikumaroro
E10 Earhart skeleton and sextant box on Nikumaroro
Argument
Evidence
sea recoveries, has claimed any transmissions attributed to Gardner Island were false. Through his company Nauticos he extensively searched a 1,200-square-mile (3,100 km2) quadrant north and west of Howland Island during two deep-sea sonar expeditions (2002 and 2006, total cost $4.5 million) and found nothing. The search locations were derived from the line of position (157–337) broadcast by Earhart on July 2, 1937.[109])
E10 Earhart skeleton and sextant box on Nikumaroro (TIGHAR's researc
produced a range of documented archaeological and anecdotal evidence support
hypothesis.["Common Earhart Myths." tighar.org, Copyright date of 2009 on pag
November 28, 2009]["The TIGHAR Hypothesis." tighar.org, Summer 2009. Retri
November 28, 2009] For example, in 1940, Gerald Gallagher, a British colonial of
licensed pilot, radioed his superiors to inform them that he had found a "skeleto
that of a woman," along with an old-fashioned sextant box, under a tree on the
southeast corner. He was ordered to send the remains to Fiji, where in 1941, Br
authorities took detailed measurements of the bones and concluded they were f
about 5 ft 5 in tall.["Bones chronology." tighar.org, 2010. Retrieved: August 25,
1998, however, an analysis of the measurement data by forensic anthropologists
confirm the original findings, concluding instead, that the skeleton had belonged
white female of northern European ancestry." The bones themselves were mispl
long ago and have not been found.[Gast, Phil., 2011] "Common Earhart Myths."
Copyright date of 2009 on page. Retrieved: November 28, 2009.
http://tighar.org/Projects/Earhart/Archives/Forum/FAQs/AEmyths.html "The TI
Hypothesis." tighar.org, Summer 2009. Retrieved: November 28, 2009
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tighar.org, 2010. Retrieved: August 25, 2010.
http://tighar.org/Projects/Earhart/Archives/Documents/Bones_Chronology3.htm
"DNA tests on bone fragment inconclusive in Amelia Earhart search." CNN, Marc
http://www.cnn.com/2011/US/03/03/earhart.dna.research/?hpt=T1)
E11 no artifacts related Earhart on Nikumaroro (During World War II, US Coast Guard LORAN Unit 92, a radio navigation station built in the summer and fall of 1944, and operational from mid-November 1944 until mid-May 1945, was located on Gardner Island's southeast end. Dozens of U.S. Coast Guard personnel were involved in its construction and operation, but were mostly forbidden from leaving the small base or having contact with the Gilbertese colonists then on the island, and found no artifacts known to relate to Earhart. ["Loran-History, Loran Unit 92, Gardner Island." loran-history.info. Retrieved: August 30, 2011] "Loran-History, Loran Unit 92, Gardner Island." loran-history.info. Retrieved: August 30, 2011.http://www.loran-history.info/Gardner_Island/gardner.htm)
E12 Nikumaroro island description (A desert atoll 350 miles southeast of Howland Island. Less than five miles long and 1.5 miles wide, with a lagoon at its center, Nikumaroro has no fresh water and has temperatures often exceeding 100 degrees Fahrenheit.)
E13 Earhart - no US spy (A World War II-era movie called Flight for Freedom (1943) starring Rosalind Russell and Fred MacMurray furthered a
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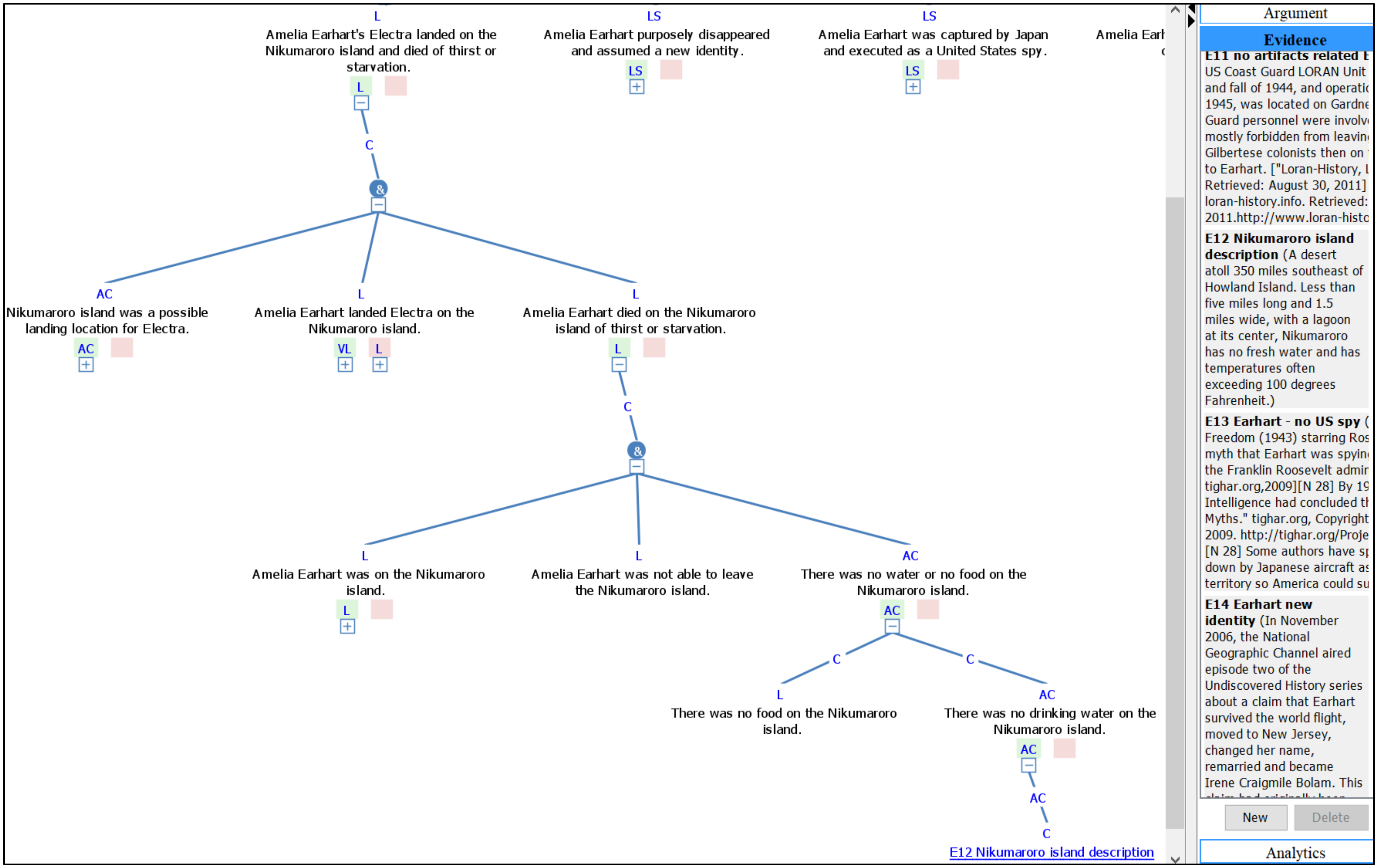
L
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LS
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L
Amelia Earhart died on the Nikumaroro island of thirst or starvation.
L
Amelia Earhart was on the Nikumaroro island.
L
Amelia Earhart was not able to leave the Nikumaroro island.
AC
There was no water or no food on the Nikumaroro island.
L
There was no food on the Nikumaroro island.
AC
There was no drinking water on the Nikumaroro island.
E12 Nikumaroro island description
Argument
Evidence
E12 Nikumaroro island description (A desert atoll 350 miles southeast of Howland Island. Less than five miles long and 1.5 miles wide, with a lagoon at its center, Nikumaroro has no fresh water and has temperatures often exceeding 100 degrees Fahrenheit.)
E14 Earhart new identity (In November 2006, the National Geographic Channel aired episode two of the Undiscovered History series about a claim that Earhart survived the world flight, moved to New Jersey, changed her name, remarried and became Irene Craigmile Bolam. This
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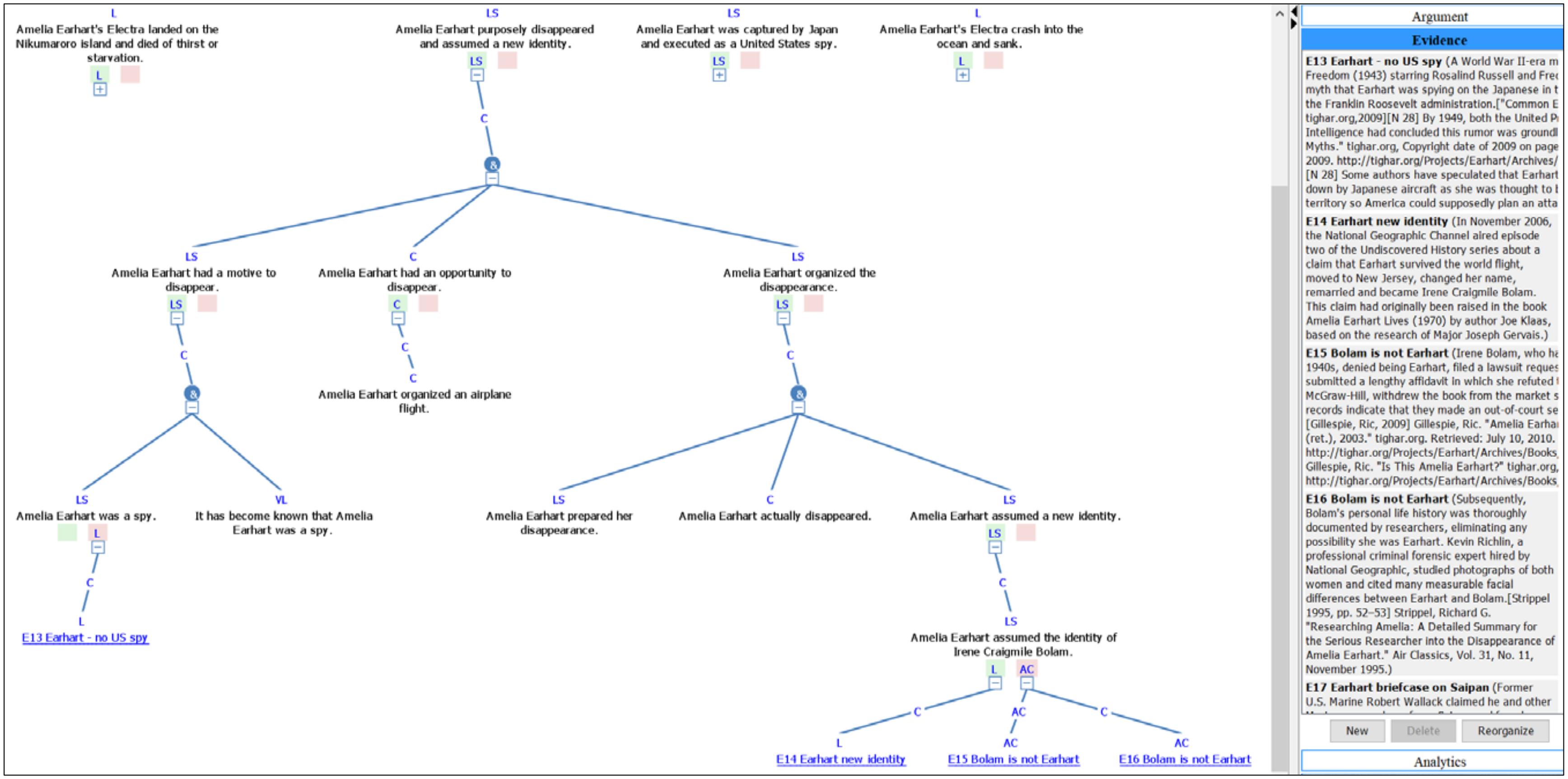

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LS
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L
Amelia Earhart's Electra crash into the ocean and sank.
LS
Amelia Earhart had a motive to disappear.
C
Amelia Earhart had an opportunity to disappear.
LS
Amelia Earhart organized the disappearance.
Amelia Earhart organized an airplane flight.
LS
Amelia Earhart was a spy.
VL
It has become known that Amelia Earhart was a spy.
LS
Amelia Earhart prepared her disappearance.
C
Amelia Earhart actually disappeared.
LS
Amelia Earhart assumed a new identity.
LS
Amelia Earhart assumed the identity of Irene Craigmile Bolam.
E13 Earhart - no US spy
E14 Earhart new identity
E15 Bolam is not Earhart
E16 Bolam is not Earhart
Argument
Evidence
E13 Earhart - no US spy (A World War II-era m Freedom (1943) starring Rosalind Russell and Fre myth that Earhart was spying on the Japanese in t the Franklin Roosevelt administration.["Common E tighar.org,2009][N 28] By 1949, both the United P Intelligence had concluded this rumor was ground Myths." tighar.org, Copyright date of 2009 on page 2009. http://tighar.org/Projects/Earhart/Archives/ [N 28] Some authors have speculated that Earhart down by Japanese aircraft as she was thought to l territory so America could supposedly plan an atta
E14 Earhart new identity (In November 2006, the National Geographic Channel aired episode two of the Undiscovered History series about a claim that Earhart survived the world flight, moved to New Jersey, changed her name, remarried and became Irene Craigmile Bolam. This claim had originally been raised in the book Amelia Earhart Lives (1970) by author Joe Klaas, based on the research of Major Joseph Gervais.)
E15 Bolam is not Earhart (Irene Bolam, who h 1940s, denied being Earhart, filed a lawsuit reques submitted a lengthy affidavit in which she refuted McGraw-Hill, withdrew the book from the market s records indicate that they made an out-of-court se [Gillespie, Ric, 2009] Gillespie, Ric. "Amelia Earha (ret.), 2003." tighar.org. Retrieved: July 10, 2010. http://tighar.org/Projects/Earhart/Archives/Books Gillespie, Ric. "Is This Amelia Earhart?" tighar.org, http://tighar.org/Projects/Earhart/Archives/Books
E16 Bolam is not Earhart (Subsequently, Bolam's personal life history was thoroughly documented by researchers, eliminating any possibility she was Earhart. Kevin Richlin, a professional criminal forensic expert hired by National Geographic, studied photographs of both women and cited many measurable facial differences between Earhart and Bolam.[Strippel 1995, pp. 52–53] Strippel, Richard G. "Researching Amelia: A Detailed Summary for the Serious Researcher into the Disappearance of Amelia Earhart." Air Classics, Vol. 31, No. 11, November 1995.)
E17 Earhart briefcase on Saipan (Former U.S. Marine Robert Wallack claimed he and other
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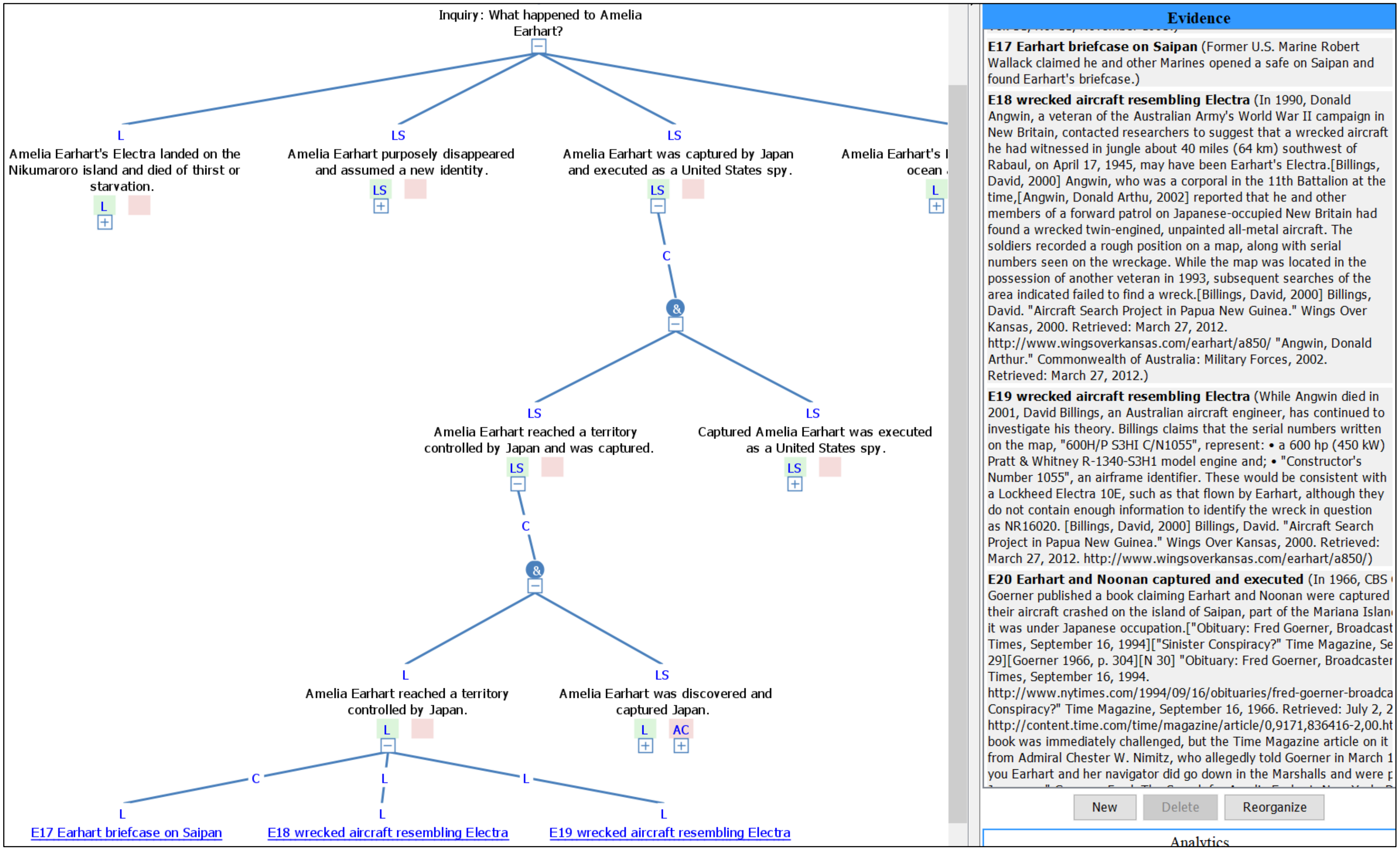
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LS
C
&
LS
Amelia Earhart reached a territory controlled by Japan and was captured.
LS
C
&
L
Amelia Earhart reached a territory controlled by Japan.
L
C
L
L
E17 Earhart briefcase on Saipan
L
E18 wrecked aircraft resembling Electra
L
E19 wrecked aircraft resembling Electra
LS
Amelia Earhart was discovered and captured Japan.
L
AC
LS
Captured Amelia Earhart was executed as a United States spy.
LS
Evidence
E17 Earhart briefcase on Saipan (Former U.S. Marine Robert Wallack claimed he and other Marines opened a safe on Saipan and found Earhart's briefcase.)
E18 wrecked aircraft resembling Electra (In 1990, Donald Angwin, a veteran of the Australian Army's World War II campaign in New Britain, contacted researchers to suggest that a wrecked aircraft he had witnessed in jungle about 40 miles (64 km) southwest of Rabaul, on April 17, 1945, may have been Earhart's Electra.[Billings, David, 2000] Angwin, who was a corporal in the 11th Battalion at the time,[Angwin, Donald Arthu, 2002] reported that he and other members of a forward patrol on Japanese-occupied New Britain had found a wrecked twin-engined, unpainted all-metal aircraft. The soldiers recorded a rough position on a map, along with serial numbers seen on the wreckage. While the map was located in the possession of another veteran in 1993, subsequent searches of the area indicated failed to find a wreck.[Billings, David, 2000] Billings, David. "Aircraft Search Project in Papua New Guinea." Wings Over Kansas, 2000. Retrieved: March 27, 2012. http://www.wingsoverkansas.com/earhart/a850/ "Angwin, Donald Arthur." Commonwealth of Australia: Military Forces, 2002. Retrieved: March 27, 2012.)
E19 wrecked aircraft resembling Electra (While Angwin died in 2001, David Billings, an Australian aircraft engineer, has continued to investigate his theory. Billings claims that the serial numbers written on the map, "600H/P S3HI C/N1055", represent: • a 600 hp (450 kW) Pratt & Whitney R-1340-S3H1 model engine and; • "Constructor's Number 1055", an airframe identifier. These would be consistent with a Lockheed Electra 10E, such as that flown by Earhart, although they do not contain enough information to identify the wreck in question as NR16020. [Billings, David, 2000] Billings, David. "Aircraft Search Project in Papua New Guinea." Wings Over Kansas, 2000. Retrieved: March 27, 2012. http://www.wingsoverkansas.com/earhart/a850/)
E20 Earhart and Noonan captured and executed (In 1966, CBS
Goerner published a book claiming Earhart and Noonan were captured
their aircraft crashed on the island of Saipan, part of the Mariana Islan
it was under Japanese occupation.["Obituary: Fred Goerner, Broadcast
Times, September 16, 1994]["Sinister Conspiracy?" Time Magazine, Se
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book was immediately challenged, but the Time Magazine article on it
from Admiral Chester W. Nimitz, who allegedly told Goerner in March 1
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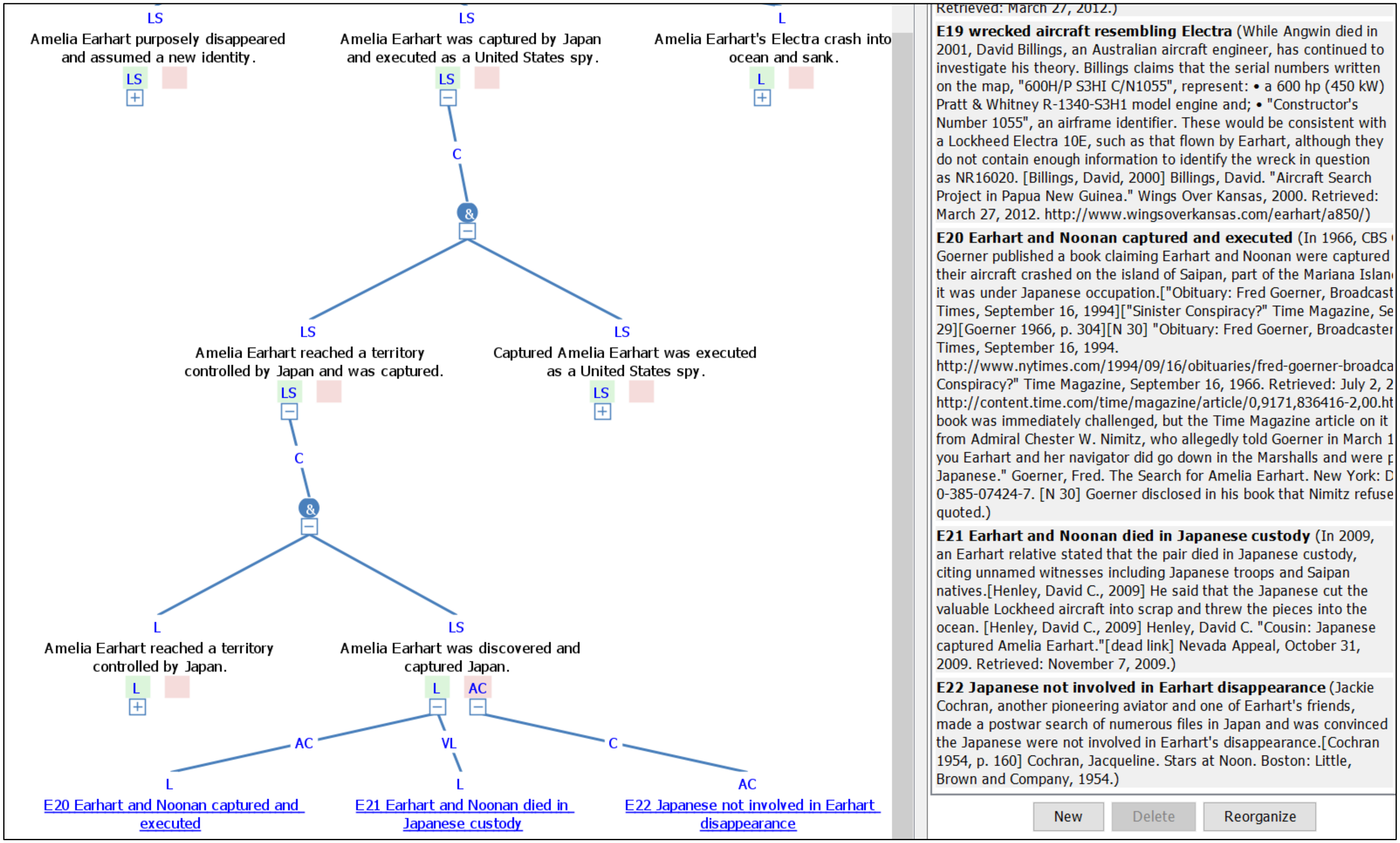
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Captured Amelia Earhart was executed as a United States spy.
C
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Amelia Earhart reached a territory controlled by Japan.
LS
Amelia Earhart was discovered and captured Japan.
AC
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E21 Earhart and Noonan died in Japanese custody (In 2009, an Earhart relative stated that the pair died in Japanese custody, citing unnamed witnesses including Japanese troops and Saipan natives.[Henley, David C., 2009] He said that the Japanese cut the valuable Lockheed aircraft into scrap and threw the pieces into the ocean. [Henley, David C., 2009] Henley, David C. "Cousin: Japanese captured Amelia Earhart."[dead link] Nevada Appeal, October 31, 2009. Retrieved: November 7, 2009.)
E22 Japanese not involved in Earhart disappearance (Jackie Cochran, another pioneering aviator and one of Earhart's friends, made a postwar search of numerous files in Japan and was convinced the Japanese were not involved in Earhart's disappearance.[Cochran 1954, p. 160] Cochran, Jacqueline. Stars at Noon. Boston: Little, Brown and Company, 1954.)
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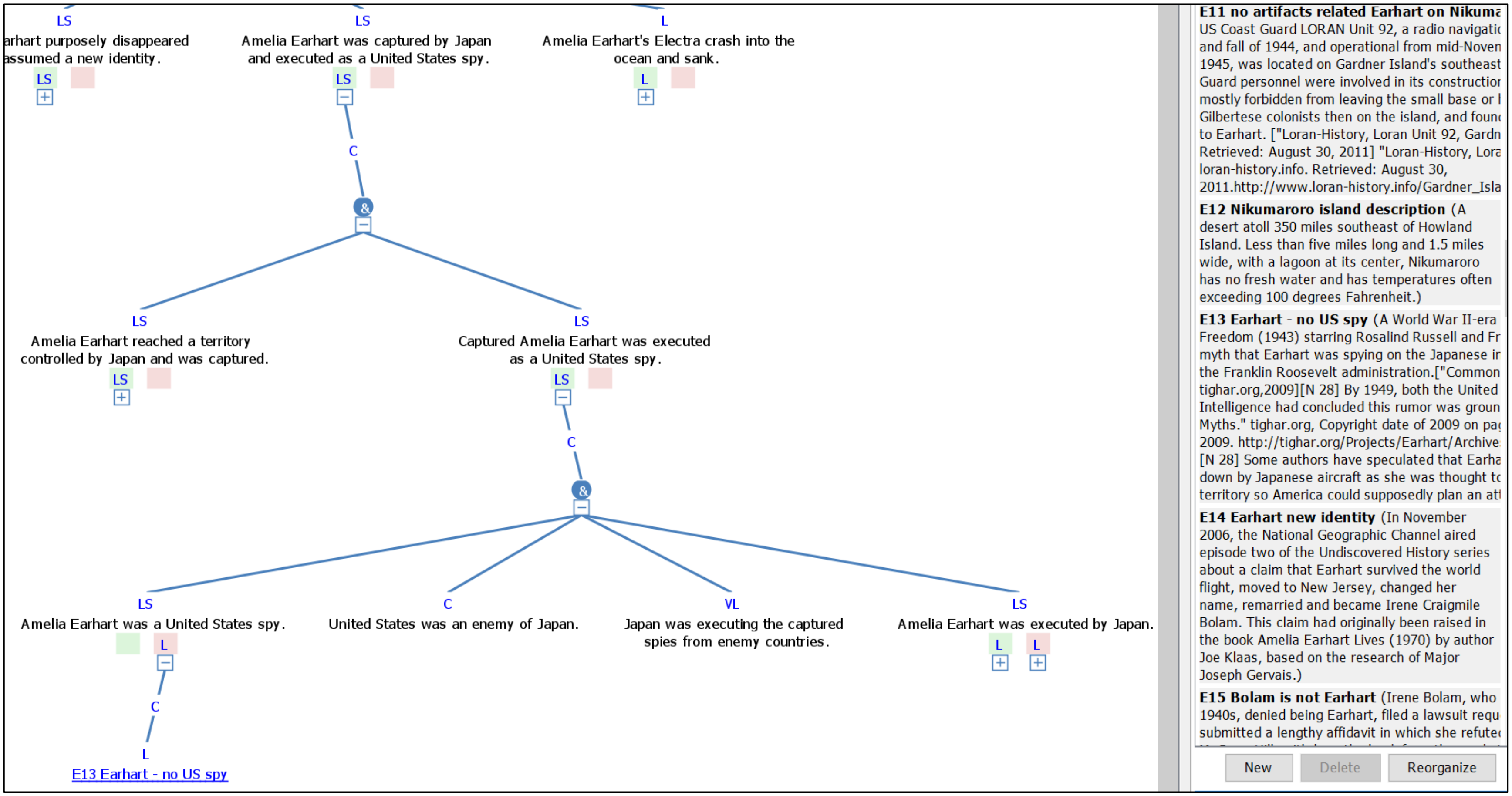
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assumed a new identity.
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Amelia Earhart was captured by Japan
and executed as a United States spy.
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ocean and sank.
C
&
LS
Amelia Earhart reached a territory
controlled by Japan and was captured.
LS
Captured Amelia Earhart was executed
as a United States spy.
C
&
LS
Amelia Earhart was a United States spy.
C
United States was an enemy of Japan.
VL
Japan was executing the captured
spies from enemy countries.
LS
Amelia Earhart was executed by Japan.
E13 Earhart - no US spy
E11 no artifacts related Earhart on Nikuma
US Coast Guard LORAN Unit 92, a radio navigatio
and fall of 1944, and operational from mid-Noven
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Myths." tighar.org, Copyright date of 2009 on pa
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E14 Earhart new identity (In November
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the book Amelia Earhart Lives (1970) by author
Joe Klaas, based on the research of Major
Joseph Gervais.)
E15 Bolam is not Earhart (Irene Bolam, who
1940s, denied being Earhart, filed a lawsuit requ
submitted a lengthy affidavit in which she refute
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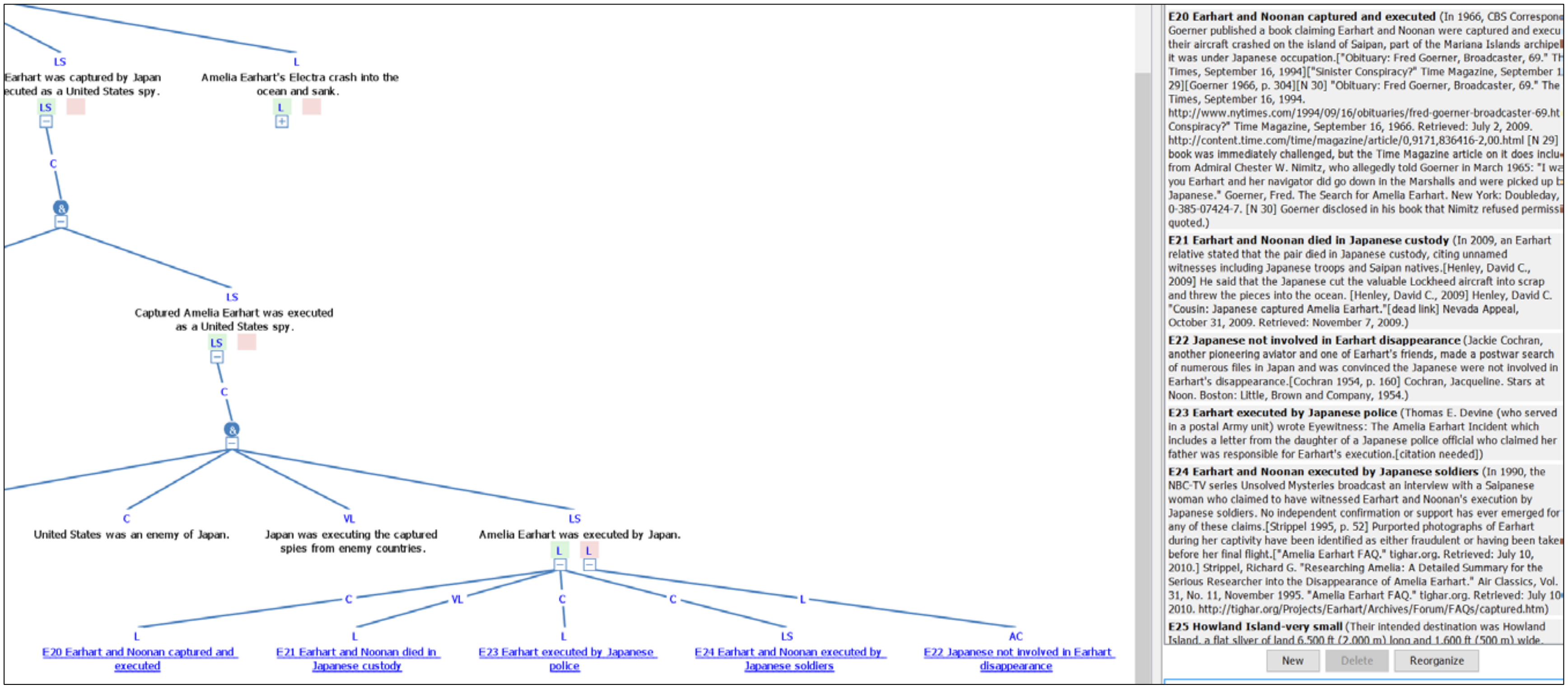
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L
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C
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C
United States was an enemy of Japan.
VL
Japan was executing the captured spies from enemy countries.
LS
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L
E20 Earhart and Noonan captured and executed
L
E21 Earhart and Noonan died in Japanese custody
L
E23 Earhart executed by Japanese police
LS
E24 Earhart and Noonan executed by Japanese soldiers
AC
E22 Japanese not involved in Earhart disappearance
E20 Earhart and Noonan captured and executed (In 1966, CBS
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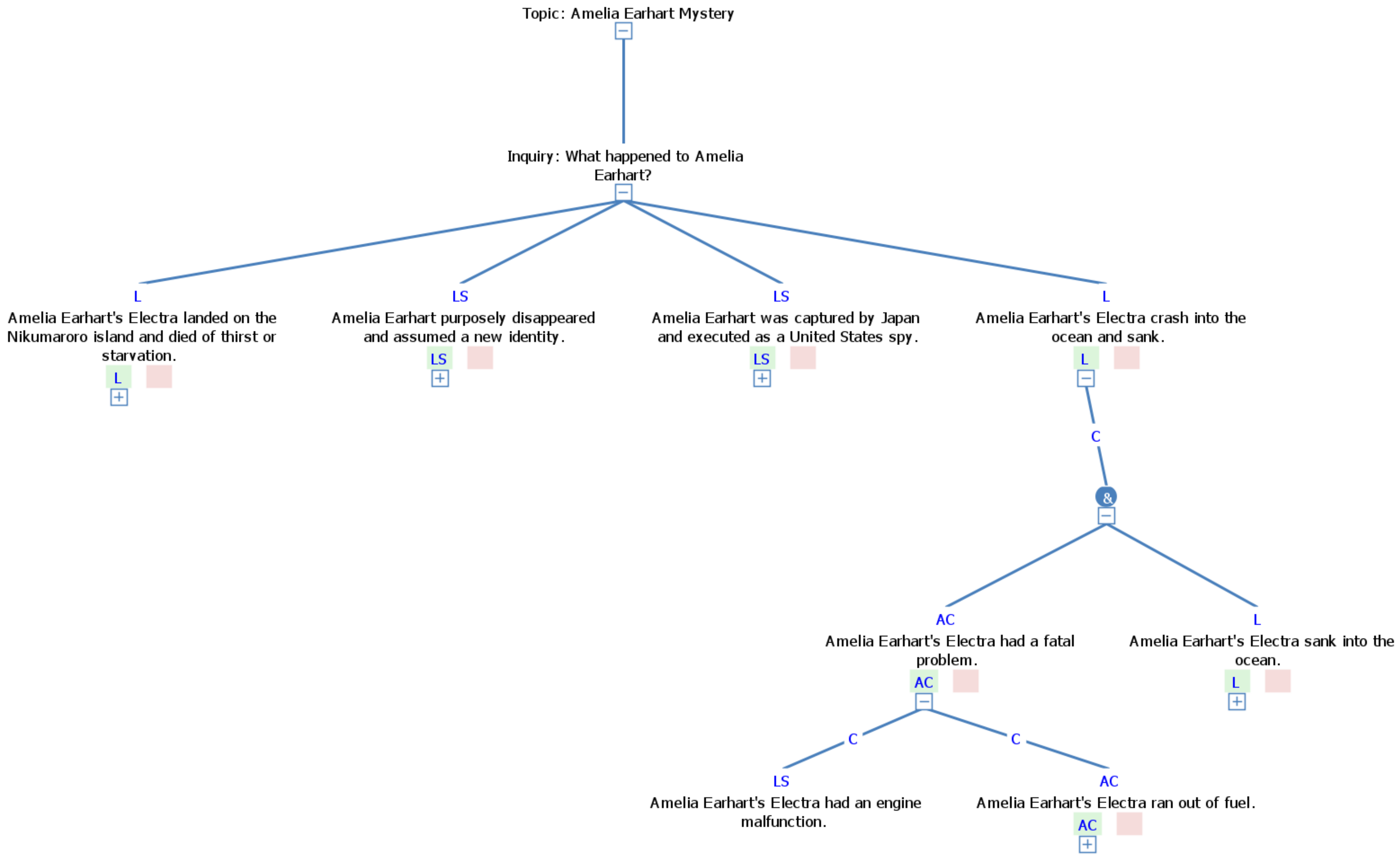
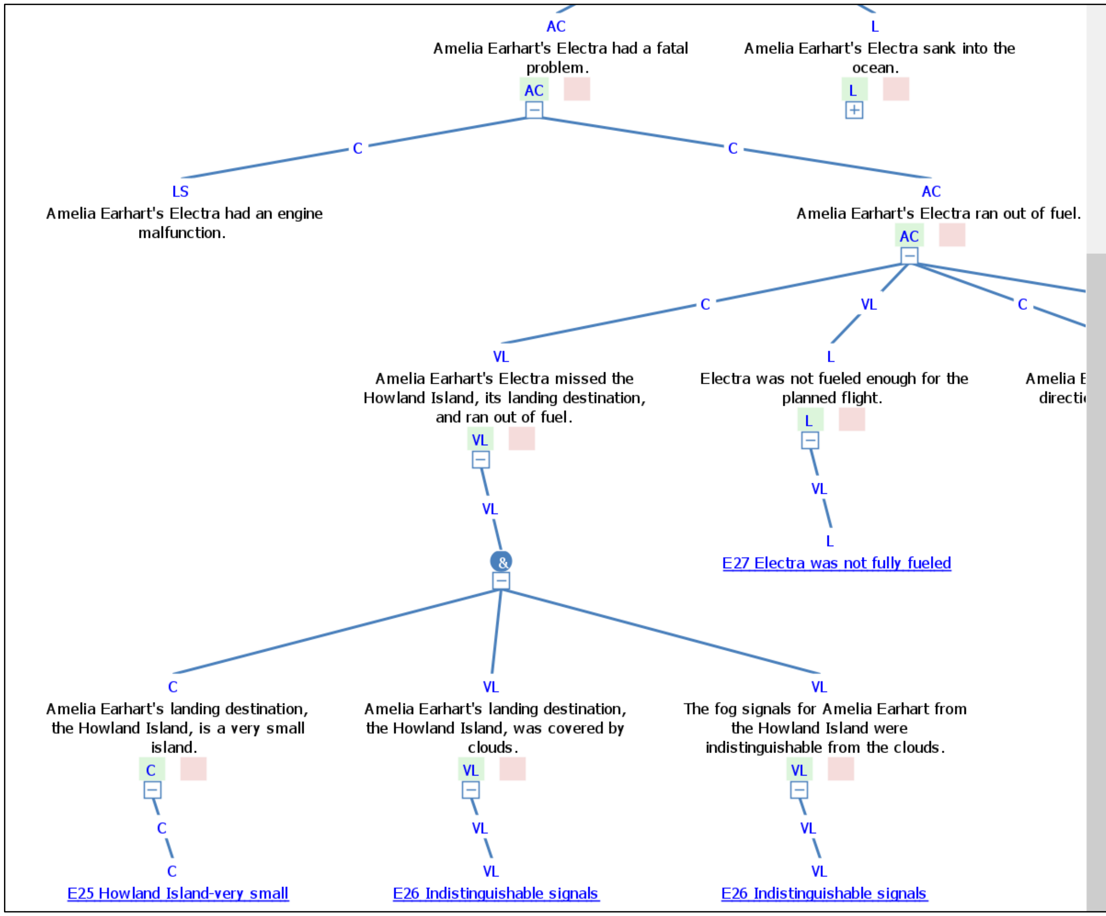
E21 Earhart and Noonan died in Japanese custody (In 2009, an Earhart relative stated that the pair died in Japanese custody, citing unnamed witnesses including Japanese troops and Saipan natives.[Henley, David C., 2009] He said that the Japanese cut the valuable Lockheed aircraft into scrap and threw the pieces into the ocean. [Henley, David C., 2009] Henley, David C. "Cousin: Japanese captured Amelia Earhart."[dead link] Nevada Appeal, October 31, 2009. Retrieved: November 7, 2009.)
E22 Japanese not involved in Earhart disappearance (Jackie Cochran, another pioneering aviator and one of Earhart's friends, made a postwar search of numerous files in Japan and was convinced the Japanese were not involved in Earhart's disappearance.[Cochran 1954, p. 160] Cochran, Jacqueline. Stars at Noon. Boston: Little, Brown and Company, 1954.)
E23 Earhart executed by Japanese police (Thomas E. Devine (who served in a postal Army unit) wrote Eyewitness: The Amelia Earhart Incident which includes a letter from the daughter of a Japanese police official who claimed her father was responsible for Earhart's execution.[citation needed])
E24 Earhart and Noonan executed by Japanese soldiers (In 1990, the NBC-TV series Unsolved Mysteries broadcast an interview with a Saipanese woman who claimed to have witnessed Earhart and Noonan's execution by Japanese soldiers. No independent confirmation or support has ever emerged for any of these claims.[Strippel 1995, p. 52] Purported photographs of Earhart during her captivity have been identified as either fraudulent or having been
before her final flight.["Amelia Earhart FAQ." tighar.org. Retrieved: July 10, 2010.] Strippel, Richard G. "Researching Amelia: A Detailed Summary for the Serious Researcher into the Disappearance of Amelia Earhart." Air Classics, Vol. 31, No. 11, November 1995. "Amelia Earhart FAQ." tighar.org. Retrieved: July
2010. http://tighar.org/Projects/Earhart/Archives/Forum/FAQs/captured.htm)
E25 Howland Island-very small (Their intended destination was Howland
New
Delete
Reorganize


Topic: Amelia Earhart Mystery
Inquiry: What happened to Amelia Earhart?
L
Amelia Earhart's Electra landed on the Nikumaroro island and died of thirst or starvation.
L
LS
Amelia Earhart purposely disappeared and assumed a new identity.
LS
LS
Amelia Earhart was captured by Japan and executed as a United States spy.
LS
L
Amelia Earhart's Electra crash into the ocean and sank.
L
C
&
AC
Amelia Earhart's Electra had a fatal problem.
AC
L
Amelia Earhart's Electra sank into the ocean.
L
C
LS
Amelia Earhart's Electra had an engine malfunction.
C
AC
Amelia Earhart's Electra ran out of fuel.
AC



"Amelia Earhart FAQ." tighar.org. Retrieved: July 10, 2010. http://tighar.org/Projects/Earhart/Archives/Forum/FAQs/captured.htm)

E25 Howland Island-very small (Their intended destination was Howland Island, a flat sliver of land 6,500 ft (2,000 m) long and 1,600 ft (500 m) wide, 10 ft (3 m) high and 2,556 miles (4,113 km) away.)

E26 Indistinguishable signals (The Itasca used her oil-fired boilers to generate smoke for a period of time but the fliers apparently did not see it. The many scattered clouds in the area around Howland Island have also been cited as a problem: their dark shadows on the ocean surface may have been almost indistinguishable from the island's subdued and very flat profile.)

E27 Electra was not fully fueled (British aviation historian Roy Nesbit interpreted evidence in contemporary accounts and Putnam's correspondence and concluded Earhart's Electra was not fully fueled at Lae.[Strippel 1995, p. 58] Strippel, Richard G. "Researching Amelia: A Detailed Summary for the Serious Researcher into the Disappearance of Amelia Earhart." Air Classics, Vol. 31, No. 11, November 1995.)

E28 Earhart expertise issues (uring the takeoff run, Earhart ground-looped, circumstances of which remain controversial. Some witnesses at Luke Field including the Associated Press journalist on the scene said they saw a tire blow.[Rich 1989, p. 245.] Earhart thought either the Electra's right tire had blown and/or the right landing gear had collapsed. Some sources, including Mantz, cited pilot error.[Rich 1989, p. 245.] Rich, Doris L. Amelia Earhart: A Biography. Washington, D.C.: Smithsonian Institution Press, 1989. ISBN 1-56098-725-1.)

E29 Earhart expertise (Some sources have noted Earhart's apparent lack of understanding of her direction-finding system, which had recently fitted to the aircraft just prior to the flight. The system was equipped with a new receiver from Bendix that operated on five wavelength "bands", marked 1 to 5. The loop antenna was equipped with a tuneable loading coil that changed the effective length of the antenna to allow it to work efficiently at different wavelengths. The tuner on the antenna was also marked with five settings, 1 to 5, but, critically, these were not the same frequency bands as the corresponding bands on the radio. The two were close enough for settings 1, 2 and 3, but the higher frequency settings, 4 and 5, were entirely different. Earhart's only training on the system was a brief introduction by Joe Gurr at the Lockheed factory, and the topic had not come up. A card displaying the band settings of the antenna was mounted so it was not visible. Gurr explained that higher frequency bands would offer better accuracy and longer range.[Elgen and Marie Long, "Amelia Earhart: The Mystery Solved", p. 116] Long, Elgen M. and Marie K. Amelia Earhart: The Mystery Solved. New York: Simon & Schuster, 1999. ISBN 0-684-86005-8.)

E30 Direction miscalculation (William L. Polhemous, the navigator on Ann Pellegreno's 1967 flight which followed Earhart and Noonan's original flight path, studied navigational tables for July 2, 1937 and thought Noonan may have miscalculated the "single line approach" intended to "hit" Howland.[Strippel 1995, pp. 58–60] Strippel, Richard G. "Researching Amelia: A Detailed Summary for the Serious

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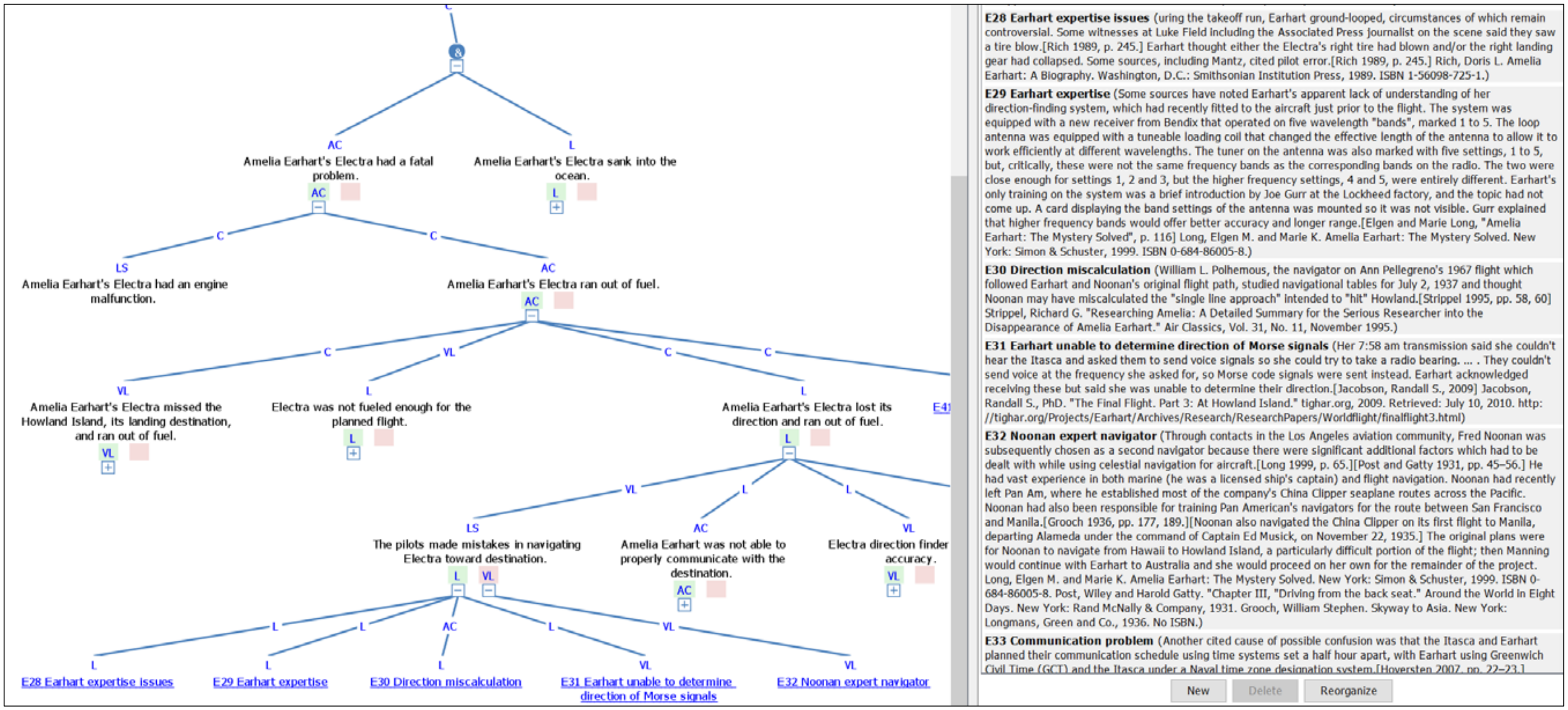

AC
Amelia Earhart's Electra had a fatal problem.
L
Amelia Earhart's Electra sank into the ocean.
LS
Amelia Earhart's Electra had an engine malfunction.
AC
Amelia Earhart's Electra ran out of fuel.
VL
Amelia Earhart's Electra missed the Howland Island, its landing destination, and ran out of fuel.
L
Electra was not fueled enough for the planned flight.
L
Amelia Earhart's Electra lost its direction and ran out of fuel.
LS
The pilots made mistakes in navigating Electra toward destination.
AC
Amelia Earhart was not able to properly communicate with the destination.
VL
Electra direction finder accuracy.
E28 Earhart expertise issues
E29 Earhart expertise
E30 Direction miscalculation
E31 Earhart unable to determine direction of Morse signals
E32 Noonan expert navigator
E28 Earhart expertise issues (uring the takeoff run, Earhart ground-looped, circumstances of which remain controversial. Some witnesses at Luke Field including the Associated Press journalist on the scene said they saw a tire blow.[Rich 1989, p. 245.] Earhart thought either the Electra's right tire had blown and/or the right landing gear had collapsed. Some sources, including Mantz, cited pilot error.[Rich 1989, p. 245.] Rich, Doris L. Amelia Earhart: A Biography. Washington, D.C.: Smithsonian Institution Press, 1989. ISBN 1-56098-725-1.)
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E31 Earhart unable to determine direction of Morse signals (Her 7:58 am transmission said she couldn't hear the Itasca and asked them to send voice signals so she could try to take a radio bearing. ... . They couldn't send voice at the frequency she asked for, so Morse code signals were sent instead. Earhart acknowledged receiving these but said she was unable to determine their direction.[Jacobson, Randall S., 2009] Jacobson, Randall S., PhD. "The Final Flight. Part 3: At Howland Island." tighar.org, 2009. Retrieved: July 10, 2010. http://tighar.org/Projects/Earhart/Archives/Research/ResearchPapers/Worldflight/finalflight3.html)
E32 Noonan expert navigator (Through contacts in the Los Angeles aviation community, Fred Noonan was subsequently chosen as a second navigator because there were significant additional factors which had to be dealt with while using celestial navigation for aircraft.[Long 1999, p. 65.][Post and Gatty 1931, pp. 45–56.] He had vast experience in both marine (he was a licensed ship's captain) and flight navigation. Noonan had recently left Pan Am, where he established most of the company's China Clipper seaplane routes across the Pacific. Noonan had also been responsible for training Pan American's navigators for the route between San Francisco and Manila.[Grooch 1936, pp. 177, 189.][Noonan also navigated the China Clipper on its first flight to Manila, departing Alameda under the command of Captain Ed Musick, on November 22, 1935.] The original plans were for Noonan to navigate from Hawaii to Howland Island, a particularly difficult portion of the flight; then Manning would continue with Earhart to Australia and she would proceed on her own for the remainder of the project. Long, Elgen M. and Marie K. Amelia Earhart: The Mystery Solved. New York: Simon & Schuster, 1999. ISBN 0-684-86005-8. Post, Wiley and Harold Gatty. "Chapter III, "Driving from the back seat." Around the World in Eight Days. New York: Rand McNally & Company, 1931. Grooch, William Stephen. Skyway to Asia. New York: Longmans, Green and Co., 1936. No ISBN.)
E33 Communication problem (Another cited cause of possible confusion was that the Itasca and Earhart planned their communication schedule using time systems set a half hour apart, with Earhart using Greenwich
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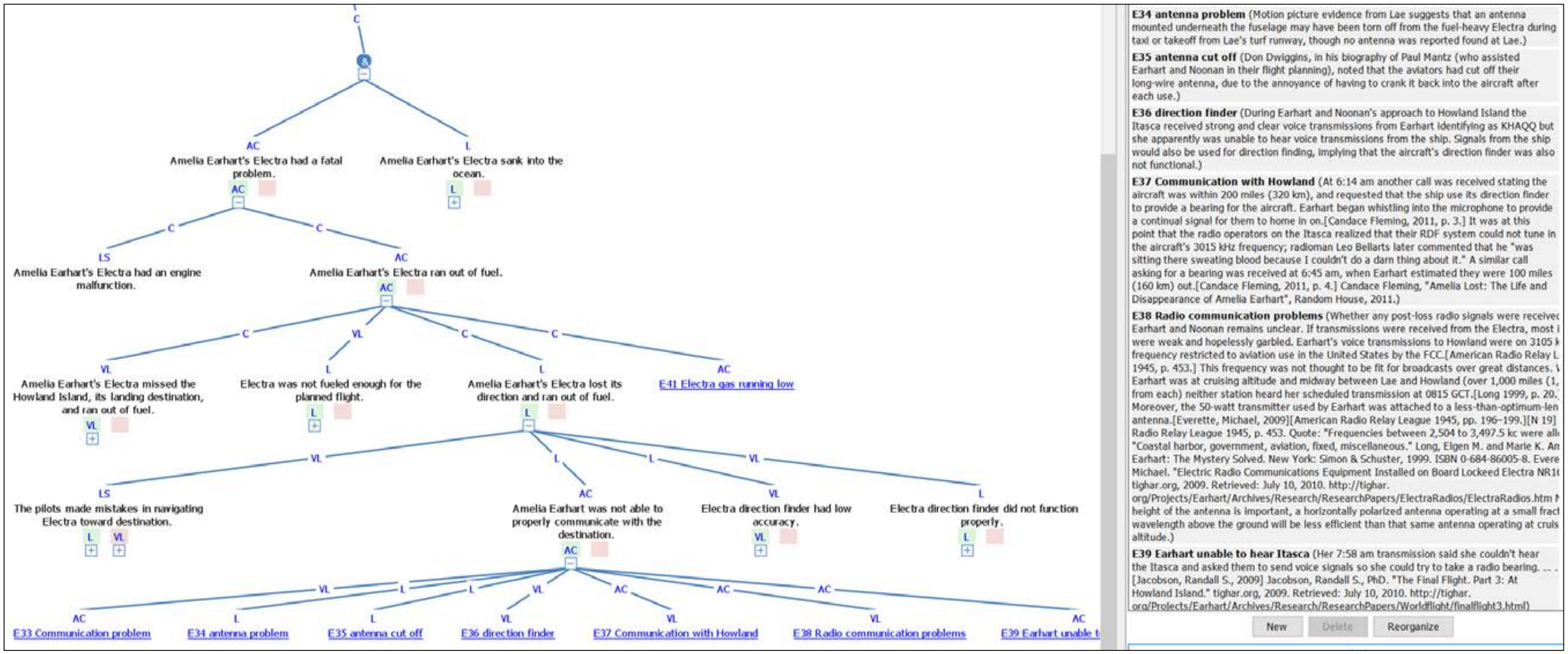
C
AC
Amelia Earhart's Electra had a fatal problem.
AC
L
Amelia Earhart's Electra sank into the ocean.
L
C
C
LS
Amelia Earhart's Electra had an engine malfunction.
AC
Amelia Earhart's Electra ran out of fuel.
AC
C
VL
C
C
VL
Amelia Earhart's Electra missed the Howland Island, its landing destination, and ran out of fuel.
VL
L
Electra was not fueled enough for the planned flight.
L
L
Amelia Earhart's Electra lost its direction and ran out of fuel.
L
AC
E41 Electra gas running low
VL
L
L
VL
LS
The pilots made mistakes in navigating Electra toward destination.
L VL
AC
Amelia Earhart was not able to properly communicate with the destination.
AC
VL
Electra direction finder had low accuracy.
VL
L
Electra direction finder did not function properly.
L
VL L L VL AC AC AC
AC
E33 Communication problem
L
E34 antenna problem
L
E35 antenna cut off
VL
E36 direction finder
VL
E37 Communication with Howland
VL
E38 Radio communication problems
AC
E39 Earhart unable t
E34 antenna problem (Motion picture evidence from Lae suggests that an antenna mounted underneath the fuselage may have been torn off from the fuel-heavy Electra during taxi or takeoff from Lae's turf runway, though no antenna was reported found at Lae.)
E35 antenna cut off (Don Dwiggins, in his biography of Paul Mantz (who assisted Earhart and Noonan in their flight planning), noted that the aviators had cut off their long-wire antenna, due to the annoyance of having to crank it back into the aircraft after each use.)
E36 direction finder (During Earhart and Noonan's approach to Howland Island the Itasca received strong and clear voice transmissions from Earhart identifying as KHAQQ but she apparently was unable to hear voice transmissions from the ship. Signals from the ship would also be used for direction finding, implying that the aircraft's direction finder was also not functional.)
E37 Communication with Howland (At 6:14 am another call was received stating the aircraft was within 200 miles (320 km), and requested that the ship use its direction finder to provide a bearing for the aircraft. Earhart began whistling into the microphone to provide a continual signal for them to home in on.[Candace Fleming, 2011, p. 3.] It was at this point that the radio operators on the Itasca realized that their RDF system could not tune in the aircraft's 3015 kHz frequency; radioman Leo Bellarts later commented that he "was sitting there sweating blood because I couldn't do a darn thing about it." A similar call asking for a bearing was received at 6:45 am, when Earhart estimated they were 100 miles (160 km) out.[Candace Fleming, 2011, p. 4.] Candace Fleming, "Amelia Lost: The Life and Disappearance of Amelia Earhart", Random House, 2011.)
E38 Radio communication problems (Whether any post-loss radio signals were receivec
Earhart and Noonan remains unclear. If transmissions were received from the Electra, most i
were weak and hopelessly garbled. Earhart's voice transmissions to Howland were on 3105 k
frequency restricted to aviation use in the United States by the FCC.[American Radio Relay L
1945, p. 453.] This frequency was not thought to be fit for broadcasts over great distances.
Earhart was at cruising altitude and midway between Lae and Howland (over 1,000 miles (1,
from each) neither station heard her scheduled transmission at 0815 GCT.[Long 1999, p. 20.
Moreover, the 50-watt transmitter used by Earhart was attached to a less-than-optimum-len
antenna.[Everette, Michael, 2009][American Radio Relay League 1945, pp. 196–199.][N 19]
Radio Relay League 1945, p. 453. Quote: "Frequencies between 2,504 to 3,497.5 kc were all
"Coastal harbor, government, aviation, fixed, miscellaneous." Long, Elgen M. and Marie K. An
Earhart: The Mystery Solved. New York: Simon & Schuster, 1999. ISBN 0-684-86005-8. Evere
Michael. "Electric Radio Communications Equipment Installed on Board Lockeed Electra NR1
tighar.org, 2009. Retrieved: July 10, 2010. http://tighar.
org/Projects/Earhart/Archives/Research/ResearchPapers/ElectraRadios/ElectraRadios.htm
height of the antenna is important, a horizontally polarized antenna operating at a small fract
wavelength above the ground will be less efficient than that same antenna operating at cruis
altitude.)
E39 Earhart unable to hear Itasca (Her 7:58 am transmission said she couldn't hear the Itasca and asked them to send voice signals so she could try to take a radio bearing. ... . [Jacobson, Randall S., 2009] Jacobson, Randall S., PhD. "The Final Flight. Part 3: At Howland Island." tighar.org, 2009. Retrieved: July 10, 2010. http://tighar.org/Projects/Earhart/Archives/Research/ResearchPapers/Worldflight/finalflight3.html)
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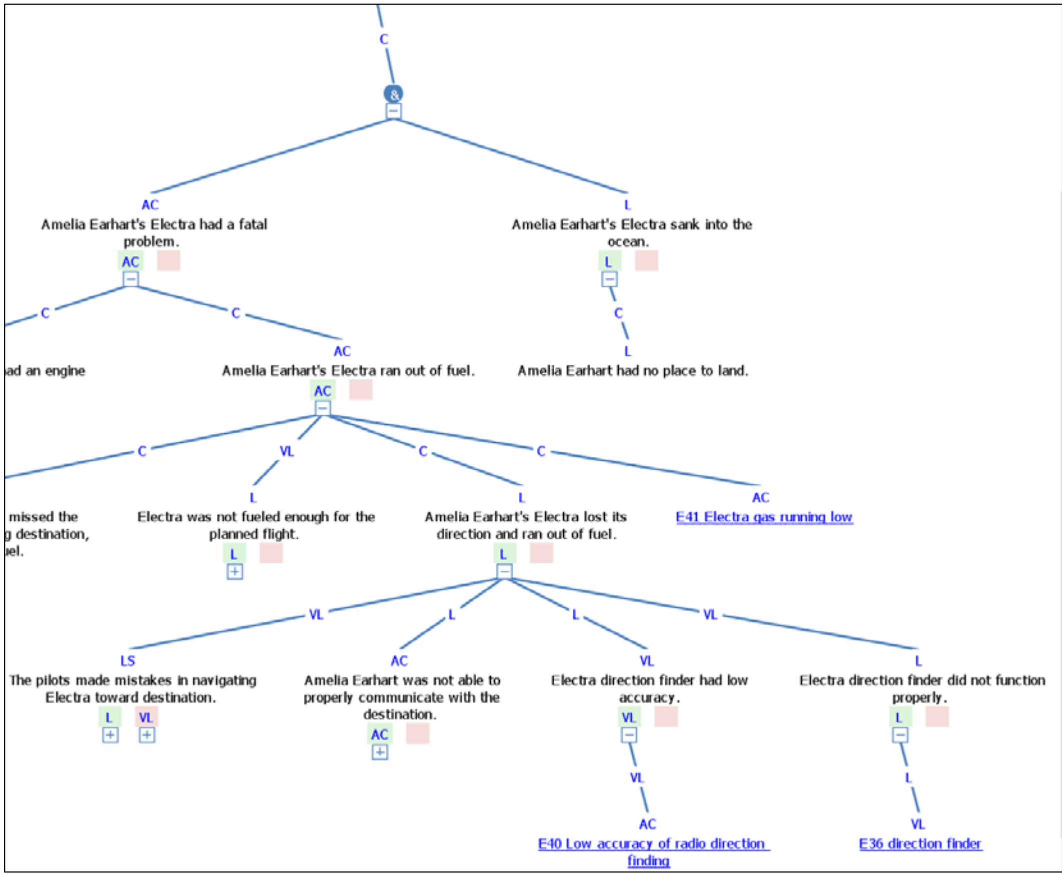

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E39 Earhart unable to hear Itasca (Her 7:58 am transmission said she couldn't hear the Itasca and asked them to send voice signals so she could try to take a radio bearing. ... .[Jacobson, Randall S., 2009] Jacobson, Randall S., PhD. "The Final Flight. Part 3: At Howland Island." tighar.org, 2009. Retrieved: July 10, 2010. http://tighar.org/Projects/Earhart/Archives/Research/ResearchPapers/Worldflight/finalflight3.html)

E40 Low accuracy of radio direction finding (Fred Noonan had earlier written about problems affecting the accuracy of radio direction finding in navigation.[Noonan, 1935] Noonan, Fred. Memo to Operations Manager, Pacific Division, Pan American Airlines, April 29, 1935: "The inaccuracies of direction finding bearings can be very definitely cataloged: twilight effects, faint signals, wide splits of minima and inaccurate calibration.")

E41 Electra gas running low (At 7:42 am Earhart radioed "We must be on you, but cannot see you—but gas is running low. ... .[Jacobson, Randall S., 2009] Jacobson, Randall S., PhD. "The Final Flight. Part 3: At Howland Island." tighar.org, 2009. Retrieved: July 10, 2010. http://tighar.org/Projects/Earhart/Archives/Research/ResearchPapers/Worldflight/finalflight3.html)

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Several exercises on the sInvestigator website and in this report are adaptations of those defined by Jonathan Osbome, Sibel Erduran and Shirley Simon (2004). Xiaohan Ding contributed to them.

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the U.S. Government.

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