Heating Ice to Steam

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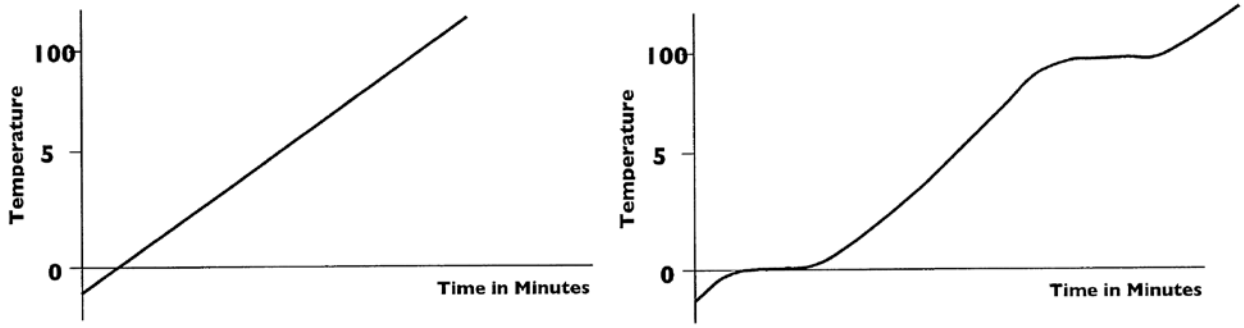
1. Introduction

This exercise was adapted from:
Jonathan Osbome, Sibel Erduran, Shirley Simon, *Ideas, Evidence & Argument in Science* (IDEAS), King's College London, 2004, pp. 59-62, https://www.stem.org.uk/elibrary/collection/3308
https://www.stem.org.uk/resources/elibrary/resource/28125/ideas-resources

The students are presented with the following contrasting graphs of temperature against time as ice is heated to water vapor, reproduced from (Osbome, Erduran, and Simon, 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 statements that may support one graph or the other.

Section 2 presents the inquiry and Section 3 presents the corresponding argumentation developed with the sInvestigator system. sInvestigator may be downloaded from http://lac.gmu.edu/sInvestigator/ The knowledge base containing the argumentation may be downloaded from http://lac.gmu.edu/sInvestigator/CaseStudies.html

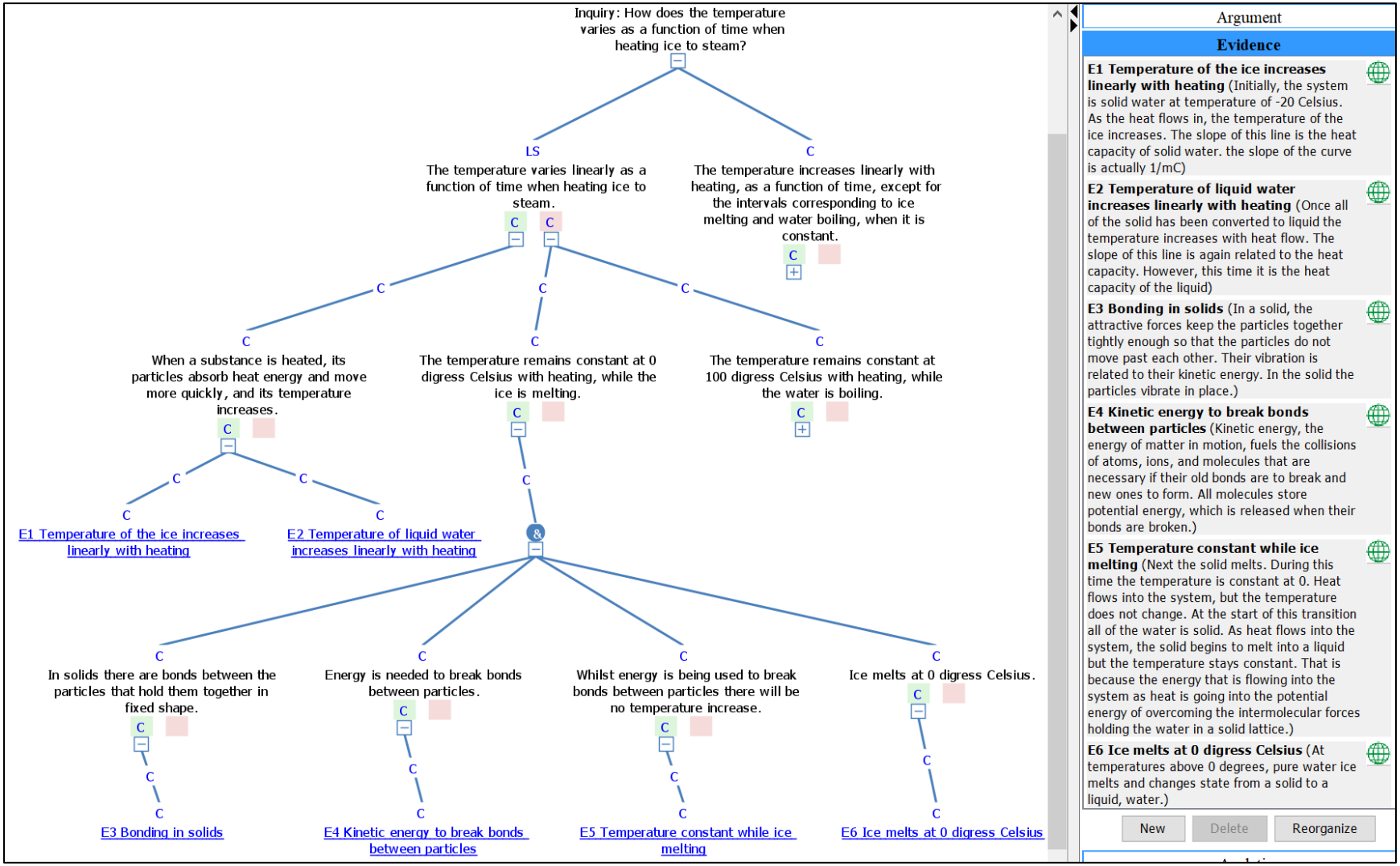
2. Inquiry

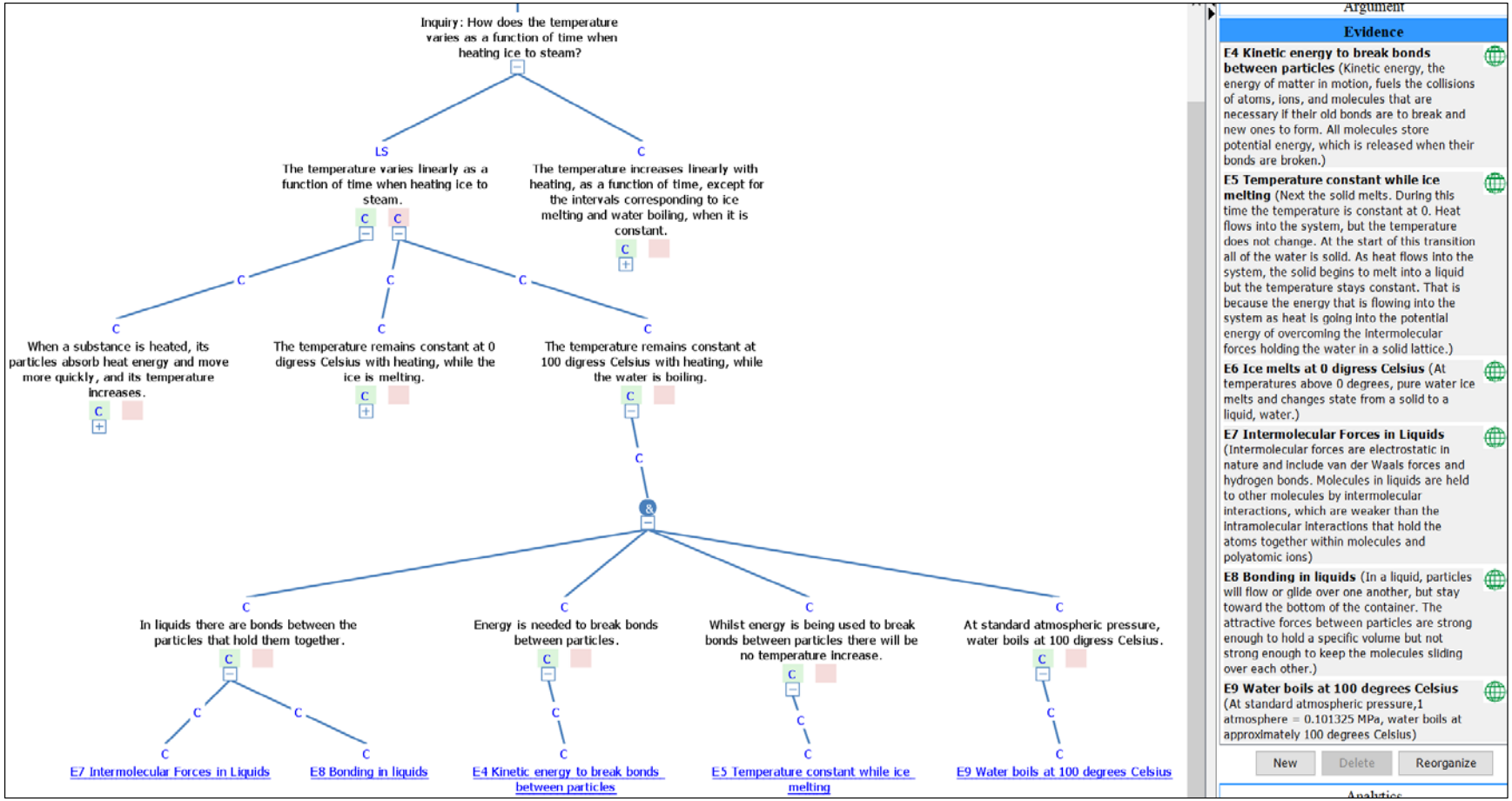
How does the temperature varies as a function of time when heating ice to steam?

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 digress Celsius and boils at 100 digress 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.

3. Analysis


Inquiry: How does the temperature varies as a function of time when heating ice to steam?
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.
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.
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.)
New
Delete
Reorganize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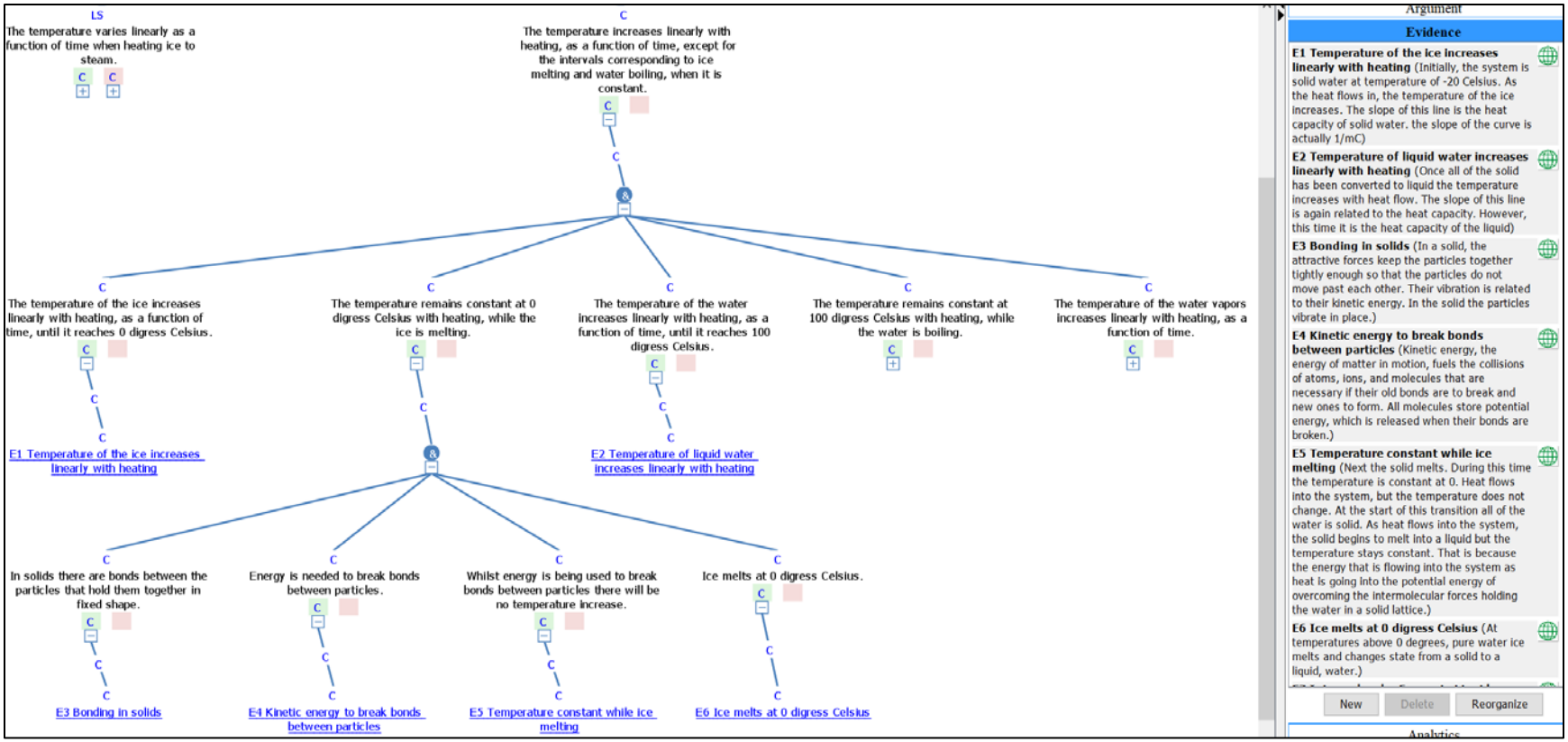
The temperature remains constant at 100 digress Celsius with heating, while the water is boiling.
&
In liquids there are bonds between the particles that hold them together.
Energy is needed to break bonds between particles.
Whilst energy is being used to break bonds between particles there will be no 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.
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E2 Temperature of liquid water increases linearly with heating
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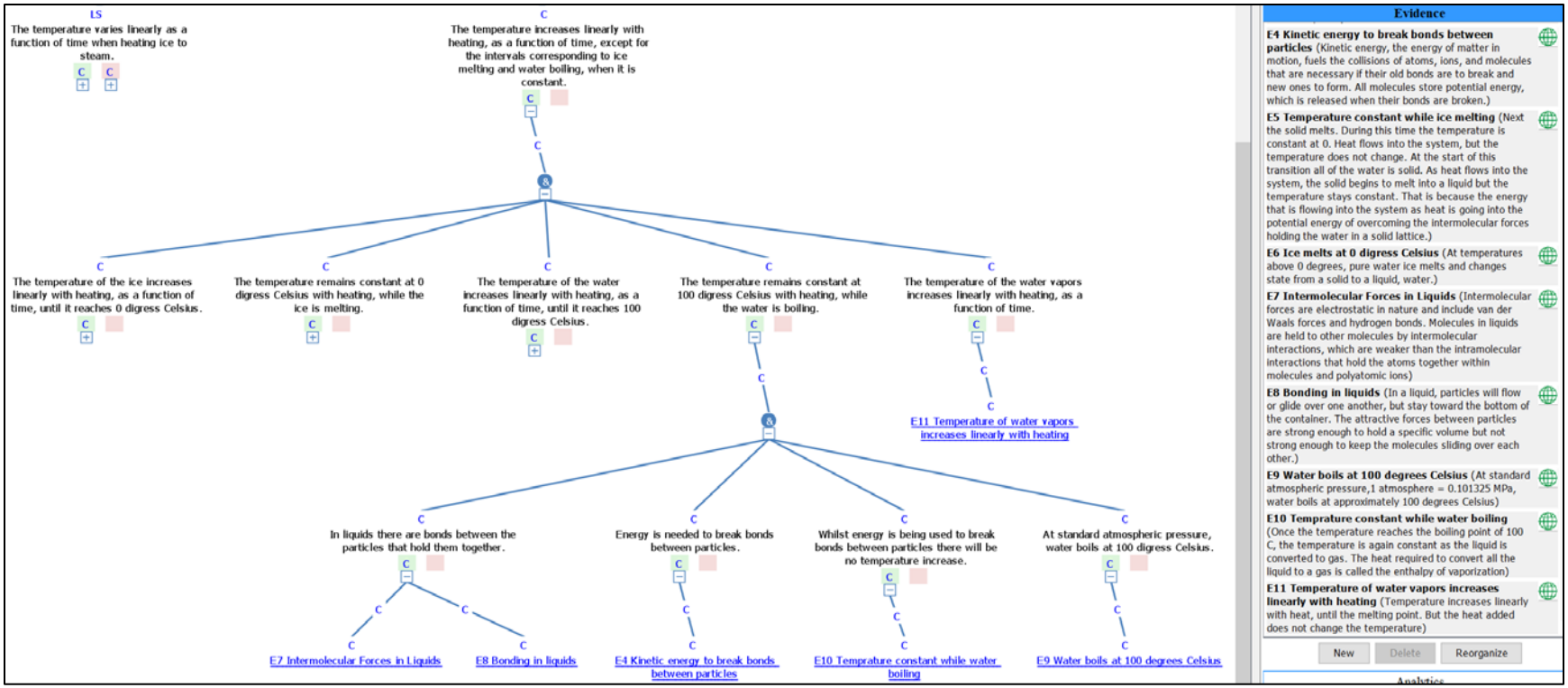
New
Delete
Reorganize
Analytics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The temperature of the water increases linearly with heating, as a function of time, until it reaches 100 digress Celsius.
The temperature remains constant at 100 digress Celsius with heating, while the water is boiling.
The temperature of the water vapors increases linearly with heating, as a function of time.
E11 Temperature of water vapors increases linearly with heating
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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
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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)
New
Delete
Reorganize
Analytics