XPLORLABS

FIRE FORENSICS: CLAIMS & EVIDENCE

EDUCATOR

INVESTIGATION 1: THE FIRE TRIANGLE

CASE STUDY OF SCIENCE AND ENGINEERING

SCIENTISTS ASK WHY. ENGINEERS ASK HOW.

AGE GROUP
Middle School

CATEGORY
Fire Forensics

COMPLETION TIME
2 Class Periods

Enduring understanding: To investigate a fire, we must understand ignition and combustion principles. To solve a case, we must understand how to build a claim supported by evidence and reason.

INVESTIGATION 1: THE FIRE TRIANGLE

Note: Involves open flame and burning of small amounts of material in controlled lab setting.

FIRE INVESTIGATORS MUST UNDERSTAND:

- the three things fire must have to burn
- the fire triangle

Fire fighters and fire investigators need to know basic fire science to both fight fires and to uncover the source of a burn.

Exploration: What are the three things a fire must have to burn?

The TESTABLE question guiding our investigations is:

- What is the effect of limiting one leg of the fire triangle?

Essential knowledge and skills

We will look for students to understand:

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

  [Crosscutting Concepts (MS-PS1-4)

- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).

  [Crosscutting Concepts: Energy and Matter (MS-PS3- 5)

We will look for students to be able to:

- Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon. (MS-PS3-5)

ASSESSMENT: This understanding looks like

- Students can make a claim supported by evidence collected through visual observations and supported by reasoning based on understandings of the fire triangle.

- Students can apply knowledge/elaborate reasons that it is important for fire fighters and investigators to understand the fire triangle.

SUMMARY OF LAB

Using a candle, students conduct four experiments to limit one side of the fire triangle at a time – oxygen, fuel, and heat - to understand the needs of fire. Then, using a metal screen, students look at a candle flame to observe combustion.

Please take all precautions for safety as recommended for middle school lab classrooms. If you do not have the proper equipment or ventilation for fire testing, please use the video as it demonstrates the concepts and allows for students to make predictions and see results.

EXPLORING THE ISSUE

Background information

The fire triangle is defined by the three needs of fire – oxygen, fuel, and heat.

A BURNING CANDLE

When we light a candle, the oxygen is provided by what is in the room. The fuel is the solid wax, and the heat is from the burning wick.

How do we light the candle?	What is the fuel in the lighter?	What is the ignition source?
We use a lighter – another example of the fire triangle.	Gas (butane).	The spark when you pull the trigger on the lighter. Holes at the end of the lighter supplied oxygen, providing a pre-mixed flame.

LIMITING OXYGEN

Oxygen is supplied by what is available in the atmosphere – 21% of room air is comprised of oxygen. The rest of air is made up of nitrogen, an inert gas that does not burn.

When a glass is lowered over a candle flame and a gap is left, the smoke pushes out underneath because the hot gases in the glass expand and create a higher pressure than the atmosphere. The high pressure will not let the oxygen in even though there is a gap at the bottom of the glass.

LIMITING FUEL

The candle flame's fuel is provided when the wax is heated. Solid wax doesn't provide the fuel, it is only the melted wax that is providing flammable gases that burn. To limit fuel to the candle's flame, a flat piece of aluminum foil slid between the wick and the melted wax cuts off the amount of heat that can get back to the wax by closing the gap around the wick. Without heat, the fire's fuel supply is limited and heat can't get back to generate more fuel to the fire.

Another way to explore this is by observing smoke, a product of combustion, as fuel. When we blow out a candle, the wick will produce smoke. When we hold an open flame, like a long-reach lighter, to the smoke, the smoke ignites by burning the gases in the combustion product and travelling down to re-light the wick.

Student question: How do we take wax away from a burning candle?
Can heat travel down wick to inside of wax? The heat wants to travel up because the hot gases are going up – buoyant.

LIMITING HEAT

The candle's heat is provided by the burning wick. The metal on a screwdriver is cold, or at least room temperature. Metal absorbs heat. When we hold the screwdriver's metal end to the flame, touching the flame without touching the wick, the metal absorbs the heat taking the heat out of the candle wick (the source energy) and limiting the wax (fuel) getting to the wick.

COMBUSTION

A candle is solid, but solids don't burn. Gases burn. Heat causes pyrolysis, the change of solids to combustible gases. The melted wax is transferring heat to the fire and it's melting the wax.

It is possible to see combustion as it occurs in the case of the candle. When you lower a small, non-flammable screen over a candle flame, the screen limits the energy and quenches the flame above the screen, cutting off the top of the flame. This provides the opportunity to see a cross section of the flame.

When you look at the flame, you can see through it at the bottom because that is where the fuel is, most of the combustion is happening where the candle flame is clear. The yellow in the flame is carbon particles in a high state of energy hitting each other so hard that they are breaking bonds and creating heat and light. Observe that the flame looks hollow in the center. This is because the center is fuel rich, and the fuel gases are coming through the screen and can be lit but the fire has been made less efficient because it needs another ignition source or more oxygen to allow it to burn. Around the edges of the flame where it looks like a halo, the screen absorbed the heat and broke down into the gaseous fuel. The gaseous fuel is in the middle and the circle of flame around the edges is the fire triangle, the visual emission of light and heat.

Where the screen turned black is called soot, these are carbon particles. To see soot in another way, hold a ceramic tile close to the flame. The tile will not ignite (no fuel), but the soot from the candle will make patterns on the tile.

FIRE INVESTIGATION

The fire triangle is critical to fire fighting and fire investigation. Fire professionals must understand what a fire needs to burn and how eliminating one leg of the fire triangle can extinguish a fire. Why do fire fighters use water to put out a fire? What leg of the fire triangle are they eliminating? They are taking away the fire's heat.

Just like a candle flame can leave a soot pattern on a ceramic tile, fire investigators look for these types of patterns on walls, furniture, and other parts of structures to help them determine the point of origin of the fire, or the location where the fire started. Knowing where a fire started helps investigators understand how it was caused.

MATERIALS

(one set per group of students or one set for teacher's demonstration)

- ◯ **Long reach lighter**
- ◯ **Pillar candle or small candle**
- ◯ **Metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material) – place candle in pan**
- ◯ **Metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material) with 1-2" of water**
- ◯ **Aluminum foil pieces (2) 2 cm x 2 cm with small slit (1/2") cut in the middle of one side**
- ◯ **Glass jar or drinking glass**
- ◯ **Small (5 cm x 5 cm) metal screen (non-flammable)**
- ◯ **Tongs to handle materials that are hot or briefly flaming – plastic/heat resistant coated handles**
- ◯ **Large screwdriver with plastic (non-heat conducting) handle**
- ◯ **Ceramic tile**
- ◯ **Xplorlabs video: Investigation 1**

SAFETY CONSIDERATIONS

- Hair pulled back and sleeves rolled up
- Safety glasses on
- Fire retardant surfaces – table tops or go outside in schoolyard on open concrete or asphalt avoiding vegetation and structures overhead

ROLES

THE STUFF SUPERVISOR

Gathers and cleans up materials

THE EXPERIMENT EXEC

Runs the experiment

THE DIRECTOR OF DOCUMENTS

Reads the procedure to the group and helps the group members with data collection

THE PRINCIPAL PRESENTER

Shares the group's work with the rest of the class

PROCEDURE - EDUCATOR

ENGAGE

WHAT EDUCATOR DOES

What are the key components a fire needs to burn?
If we use a candle as an example, what is the fuel, heat, and oxygen supply?

Pose the testable question: What is the effect of limiting one leg of the fire triangle?

WHAT STUDENTS DO

Make predictions in Student Xplorlab pages using prior knowledge or information from Xplorlabs Fire Forensics Investigator's Notebook.

EXPLORE

WHAT EDUCATOR DOES

Identify the needs of fire by limiting variables in the conditions of a burning candle.

How can we limit one variable to test three sides of the triangle?

A) BELOW ARE POSSIBLE WAYS FOR STUDENTS TO EXPLORE – ***With more time available,*** let students brainstorm ideas for testing question, show students available materials (listed above), students design procedures, approve procedures, then carry out test. Five groups of students can test one variable each and report out, or with more time, each small group can test each variable.

With less time available, give small groups of students procedures for each test. Four groups of students can test one variable each or each group can test each variable, and report out.

WHAT STUDENTS DO

A. Limiting oxygen –
1. Remove the oxygen leg of the fire triangle by placing a glass jar over a lit candle on a non-flammable plate.

2. Lower glass until 1" away from table (caution! Glass may become hot).

B. Limiting fuel – Remove the fuel leg of the fire triangle by placing a piece of aluminum foil between the flame and the wax of the candle – removing the fuel by separating the wax from the wick.

C. Limiting fuel – Remove the fuel leg of the fire triangle by blowing out the candle, then bring an open flame (lit/long reach lighter) to smoke as it rises out of the extinguished candle. The flame will travel down the smoke and attach to the wick, relighting the candle. Also provides evidence that smoke is fuel.

D. Limiting heat – Remove the fuel leg of the fire triangle by placing the metal end of the screwdriver next to the lit wick of the candle.

PROCEDURE - EDUCATOR

EXPLORE CONT.

WHAT EDUCATOR DOES CONT.

1. What will happen when we put the jar over the candle, leaving a small gap?

2. What will happen when we place a piece of aluminum foil between the flame and the wax of a lit tea light (candle)?

3. What will happen when we put a flame to the smoke of a blown out candle?

4. What will happen when we place a drop of water or a piece of aluminum foil next to the lit wick of a tea light (candle)?

B) Teacher uses following procedures to demonstrate for students.

WHAT STUDENTS DO CONT.

1. Make predictions based on learning from Investigator's Academy, background knowledge, or prior experiences. "I think....because...."

2. Read "Open or Closed Door" in Student Pages and answer questions, highlight new vocabulary.

3. Share answers as a class and discuss new vocabulary.

EXPLORE

WHAT EDUCATOR DOES

Pose the question: Based on our observations, what is the effect of taking away one leg of the fire triangle?

Explanations of investigations:
A. Limiting oxygen – Once trapped oxygen is consumed by chemical reaction (fire), flame will extinguish.

B. Limiting fuel – Aluminum reflects heat from the candle up and away from wax – without the thermal feedback, the fuel supply (liquid wax to wick) will cease and flame will extinguish.

C. Limiting fuel – Smoke is fuel. Smoke is generally considered to be the collection of the solid, liquid, and gaseous products of incomplete combustion.

D. Limiting heat – If the item placed next to the wick removes heat faster than the fire can supply it, the flame will extinguish.

WHAT STUDENTS DO

Partner, Present and Respond in C/E/R format:

Claim – A statement or conclusion that answers the question.

Evidence – Observations that support the claim; data is appropriate and sufficient to support the claim.

Reasoning – student's explanations, including if evidence supports or challenges hypothesis and shows why the data counts as evidence by using appropriate and sufficient scientific principles.

PROCEDURE - EDUCATOR

EXPLORE/EXPLAIN

WHAT EDUCATOR DOES

Testable Question: What will happen when we lower a small metal screen (non-flammable) onto the flame of the candle and observe?

Combustion – The screen limits energy and quenches flame above the screen, cutting off the top of the flame. The gaseous fuel is in the middle and the circle of flame around the edges is the fire triangle, the visual emission of light and heat.

WHAT STUDENTS DO

Combustion – To see the combustion as it occurs, lower a small metal screen (non-flammable) onto the flame of the candle and observe. The best place to observe is looking down on the candle.

ELABORATE

WHAT EDUCATOR DOES

How does knowing this help fire fighters?
How does knowing this help fire investigators?

WHAT STUDENTS DO

Think – Pair – Share ideas on how this applies to fire fighting and fire investigation.

EVALUATE

WHAT EDUCATOR DOES

Using the C/E/R rubric, assess quality and accuracy of responses and provide feedback to students.

WHAT STUDENTS DO

Question: What is the effect of limiting one leg of the fire triangle?
Based on our observations in this investigation, what can we claim about limiting one leg of the fire triangle?
What is our evidence for these claims?
What is the reasoning for the evidence?
Why is this important for fire investigators to understand?

**If time, students use the C/E/R rubric to do self-assessment or peer assessment and provide feedback to one another*

*From NSTACER Claim-Evidence-Reasoning Rubric, Integrated Middle School Science Partnership,https://www.mydigitalchalkboard.org/portal/default/Content/Viewer/Content;jsessionid=L4aR+6npImtOAEAlSb3zog**?action=2&scId=504488&scild=17987.