UL XPLORLABS

FIRE FORENSICS: CLAIMS & EVIDENCE

EDUCATOR

TEACHER OVERVIEW OF THE MODULE

CASE STUDY OF SCIENCE AND ENGINEERING

SCIENTISTS ASK WHY. ENGINEERS ASK HOW.

AGE GROUP
Middle School

CATEGORY
Fire Forensics

COMPLETION TIME
2 - 4 Class Periods

HOW DO CLAIMS AND EVIDENCE SUPPORT THE PROCESS OF FORENSICS IN FIRE INVESTIGATION?

This module is designed to provide students with the understanding of fire, fire dynamics, and fire behavior so that they can read a fire scene and build a claim for the fire's location of origin and cause.

The videos and interactive investigations within the online digital platform Fire Forensics: Claims and Evidence module are designed to be applicable for a whole-class setting or for students to engage with independently. Classroom investigations, including detailed teacher guides and student pages, provide opportunities to deepen student understandings through hands-on experiences of fire science principles introduced in the module, along with practice building claims from evidence gathered through observations and measurement.

The following guide provides an overview of each section for you, the educator, to provide a road map of the module and supporting content from the fire lab.

Next Generation Science Standards alignment

Fire Forensics: Claims and Evidence supports students understanding of the Disciplinary Core Ideas (DCI) from NGSS Middle School Physical Science:
MS-PS1: Matter and its Interactions. The DCI's address in this module include:

- **Structures and properties of matter**
- **Chemical reactions**
- **Definitions of energy**

MS-PS3: Energy. The DCI's addressed in this module include:

- **Definitions of energy**
- **Conservation of energy and energy transfer**
- **Relationship between energy and forces**

Fire Forensics: Claims and Evidence contributes to student understandings of the difference between energy and temperature and the process of thermal energy transfer.

The module addresses and reinforces the cross-cutting concepts of cause and effect, scale, structure and function, systems and system models. Performance expectations for students include engaging in analyzing and interpreting data, argument from evidence, and use of these practices to demonstrate understandings of core ideas in PS1 and PS3. These assessments are built into the main module and are included in the "evaluate" section of each classroom investigation.

CLAIMS, EVIDENCE & REASONING (CER)

Claims, evidence, and reasoning is a strategy for students to explain the results of an investigation. This is the language of scientists and engineers who's practice centers on arguing claims supported by evidence. The fire researchers formulate a question that is meaningful to the fire community, test it, make a claim, or several claims based on the evidence they find. They apply their reasoning based on their expertise in fire science.

Throughout the module, we discuss CER in fire forensics as entering the story at the end of the book, then by putting the pieces of evidence together in a storyline that makes sense to explain the beginning of the story – where and how a fire started. The beginning of the story is the claim. The building of the storyline from end to beginning is the chain of evidence collected based on knowledge and understanding of fire behavior and fire science.

CLAIMS

A claim is a students' statement about the results or findings from an investigation, it's their answer to the question being tested or researched. A student, or scientists, can argue for their claim when they have strong evidence to support it. Without evidence, a claim is just that. Fire investigation offers students the opportunity to present their claim – how and where a fire started based on the evidence uncovered in the burn scene.

EVIDENCE AND REASONING

Not all data is evidence. Hand and Keys argue that without reasoning, evidence is just data. Nothing models this concept better than fire forensics. When a fire investigator enters a burn scene, data is everywhere. Evidence comes from the critical reasoning about the data including the knowledge of fire science and fire behavior that informs what the fire investigator is finding and how it is evidence to argue for the point of origin and cause of a fire.

The process of CER allows students to argue their understandings based on their findings, mirroring the process of science and engineering in the real world. As learners are expected to process unlimited information in the technical age, understanding claims, evidence, and reasoning supports not only the formulation of solid arguments grounded in evidence, but also builds expectations of all others to do the same.

This module includes a rubric for assessing students CER's.

WELCOME TO THE UL FIRE LAB!

There's been a fire. Your students' job will be to solve the case, to figure out where did the fire start (point of origin) and how (cause)? To do this your students must learn the basic science of fire -- how it behaves and the evidence it leaves left behind, and then apply that knowledge to solve the case.

Welcome to the Firefighters Safety Research Institute where fire researchers study fire forensics giving fire investigators the knowledge and skills to build and prove a claim about the fire's cause and origin. As fire burns, it leaves clues in its path — evidence visible only to trained fire investigators. With an understanding of fire science basics, fire investigators hunt for clues, collect evidence and report on what happened.

Fire investigation is like reading a story backwards. Imagine entering the story on the last page, seeing only the end result: huge piles of charred debris. Fire investigators have to rely on their training and work backwards — using the scientific method to fill in the story by examining the clues left behind as evidence is gathered and analyzed.

INVESTIGATORS ACADEMY

The Investigators Academy is the training students need in fire science before they enter their first burn scene to solve a case.

Below, each section of the Academy is summarized with definitions and key takeaways. This content is also included in each section on screen. The Key Takeaways are found by clicking the arrow at the top right side of the screen and are listed here for your reference.

THE INVESTIGATORS ACADEMY EXPLORES:

1. What is fire – a gas-phase chemical reaction that emits heat and light
Key takeaways:

- During a fire, solids and flammable liquids do not burn. Fire burns the gases created by heat.
- Pyrolysis is a process where heat breaks down solids into fuel gases. When the solids are broken down into fue gases, and those fuel gases mix with oxygen, the mixture can ignite by heat which results in fire. A video extra is provided to observe a lampshade pyrolyze, then the gases ignite.
- Another word for fire is combustion, when the fuel gases mix with oxygen and are ignited by heat which results in flames. We'll learn more about fuel in the next section.

2. What's needed to create and sustain fire - Three elements must be present for a fire to start and continue burning, known as the fire triangle: oxygen, heat, and fuel.
Key takeaways:

- Heat is the thermal energy needed to produce the fuel that combines with oxygen. Heat promotes fire growth and the spread of flames by maintaining a continuous cycle of fuel production and ignition.
- When heated, fuels create gases and combine with oxygen. With the heat, the gases ignite and release light, heat and smoke. This is fire.
- Fuels are different. The amount of energy stored in a fuel varies based on the fuel itself. Synthetic or man-made fuels may have 2-3 times more stored energy per pound than a natural fuel such as wood. Higher energy fuels tend to generate more smoke.
- Heat transfers by conduction, convection, or radiation.

3.Four stages of fire development – ignition, growth, development, and decay
Key takeaways:

- IGNITION - the gas-phase chemical reaction causes the fire to start.
- GROWTH - the fuel load will continue to burn because oxygen is available.
- FULL DEVELOPMENT - If a steady supply of oxygen exists, all the combustible fuels will be consumed in the fire.
- DECAY - without oxygen, heat, or fuel fire will extinguish or go out.

4. How fire behaves – during a fire, gases and smoke move because of differences in temperature, density, and pressure
Key takeaways:

- To be a fire investigator you must understand how fires behave inside a building.
- The thermal plume leaves a V-shaped pattern of soot and ash

5. How does ventilation impact fire – ventilation is the exchange of hot fuel gases and air. An open window or door provides outside air with a fresh supply of oxygen (one leg of the fire triangle).
Key takeaways:

- Ventilation is the exchange of hot fuel gases and air. Any opening in a structure can allow ventilation to occur.
- During ventilation, hot gases flow out (exhaust) and cooler air enters (intake) the room, which works like a pump feeding a fresh source of oxygen to the fire.
- With good ventilation, or a steady source of oxygen, a fire can grow until flashover occurs. Flashover causes everything in the room to pyrolyze and ignite all at the same time. Ventilation often makes a fire
  bigger, especially in structures with large amounts of synthetic material as potential fuel.
- Ventilation is a phenomenon being studied intensively in the Fire Lab so firefighters can understand it better and make safe choices on a fire scene.

LIVE BURNS

The UL Fire Lab burns full-sized structures under different experimental conditions. Students will observe data and video from side-by-side burns in the fire lab changing only one variable - ventilation. UL fire scientists explain what you can observe in each burn.

Investigation 4: Fire Lab Data Analysis allows your class to take a longer look at the fire lab data.

Exploration:
What does the fire lab data tell us about a fire? Summary of lab: Students look at oxygen concentrations from ignition from the fire lab in a controlled house fire where the variable being tested is ventilation – one data set is with an open door and one data set is from a burn with the door closed. Students can also explore data sets indicating temperature and pressure from each fire.

GUIDED INVESTIGATION

Learn how fire investigators build a claim explaining the cause of a fire based on the kinds of evidence they look for at a fire scene and how they find it.

Students get a guided look at the evidence left behind after a bedroom fire with research engineer Dan Madrzykowski to learn how fire investigators move through a burn scene and find evidence in the debris to support a claim for the fire's cause and origin. The guided investigation provides support for students as they get ready to move into their own investigation of a kitchen fire.

INDEPENDENT INVESTIGATION

Armed with the understandings from the Investigator's Academy and example of how investigators work through a fire scene, students are ready to solve their first case. A kitchen fire set in the fire lab holds evidence pointing to the origin and cause. Students work their way through the burned structure to seek out every piece of evidence needed to determine the fire's cause and place of origin, then using the interactive features of the module, they build a claim explaining how the fire started. This claim can be shared in the challenge section of the module as part of the UL XplorLabs community.

CHALLENGE

State your claim and provide your evidence! What are your conclusions on the origin and cause of the independent investigation kitchen fire (in the previous section of the module)?

Once students share their answer to the case, research engineer Dan Madrzykowski will share the origin and cause of the fire so students can match up their answers to see if they were correct! Students can also explore other students' claims to see how they compare.

CLASSROOM INVESTIGATIONS

Four investigations support the 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.

Each investigation is designed to deepen student understandings and include videos of the experiments for classrooms without the proper lab setup to conduct tests with open flames and smoke. Investigations also include a teacher guide with procedures and relevant background information and student pages including tables to gather data where appropriate.

All investigations are developed to give students practice in developing claims based on evidence and reasoning and connect to the context of fire investigation. All investigations are correlated to the Next Generation Science Standards middle school benchmarks in physical science. See the teacher's guide for each investigation for specific alignment to NGSS.

Most investigations can be completed in 1-3 classroom periods depending on the length of class time and depth to which you explore the tests with your students.

INVESTIGATIONS:

- **The fire triangle**
- **Heat transfer and ignition**
- **Energy and combustion**
- **Fire lab data analysis (referenced above as part of the live burn section of the module)**

CER RUBRIC FOR FIRE FORENSICS: CLAIMS AND EVIDENCE

	EXCEEDS EXPECTATIONS	MEETS EXPECTATIONS	REACHING EXPECTATIONS
Claim statement of conclusion that answers questions/provides explanation	Claim includes language from the question	Claim is clearly written Claim provides a clear explanation or answer to the question Claim is accurate and complete	Claim provides part of explanation or answer to the question, or is unclear Claim is more of a general statement that does not answer the question
Evidence Appropriate and sufficient data to support the claim	Evidence is described in a way that clearly supports the claim Includes evidence that was ruled out as support-ive of claim and why	Evidence that supports claim is included and accurate Evidence is clearly stated or listed Evidence is based on data and observation, not inferences	Evidence is not clearly stated Evidence does not support the claim Provides reasoning for some of the evidence
Reasoning Justification of how the evidence supports the claim; includes why data counts as evidence	Detailed explanation of how the evidence supports the claim using fire science vocabulary in the correct way	Reasoning is clearly stated for all/most of the evidence and how evidence supports claim Explanation includes understanding of fire science Clearly explains the fire science that supports the reason	Provides evidence without reasons for how evidence supports the claim Reasoning is inappro-priate or does not support the claim Explanation is unclear

SAFETY IN THE UL FIRE LABS

While the UL fire researchers and engineers are doing more complex tests on fire than you will be in your classroom, it is helpful to see the basic guidelines for fire lab safety. 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 videos to investigate fire.

1. We always begin with a review of Safety Data Sheets (SDS) to identify the various hazards of the product being burned. Each type of product poses different safety hazards: batteries (projectiles and toxic gases), fuels (low flashpoints), and aerosol cans (explosion hazards), plastics (toxic gases), etc.

2. Based on the information gathered from the SDS we need to determine a safety plan for all steps of the testing process (e.g. set up, test itself and clean up). We need to determine the proper equipment to use, personal protective equipment, ventilation, exit strategies, worst case scenarios, disposal requirements, etc.)

3. Ensure emergency response procedures are established and understood by all involved.

4.We always ensure adequate training has been conducted before use of heavy equipment, power tools and hand tools (e.g. forklifts, aerial lifts, drills, saws, utility knifes, etc.)

*In the classroom you will not be using heavy equipment, but it is always important to ensure the students fully understand how to use each tool or instrument works, before using it themselves.

5. When in the lab, all personnel are required to wear the following personal protective equipment (PPE): safety shoes, hard hats and safety glasses. When loud tasks are occurring hearing protection is also required.

*Establish minimum personal protective requirements while conducting classroom lab experiments.

6. All technicians involved in fighting fires are required to wear full firefighting gear. This includes: bunker gear, boots, gloves, firefighter helmet, self-contained breathing apparatus (SCBA). There may be additional gear required depending on the material being burned.

*In the classroom you will never need this amount of gear, but you may need heat resistant gloves or tinted safety glasses. Always assess this need.

7. Before each test we ensure our building ventilation system is on which removes the smoke from the building and filters it appropriately to ensure we are not damaging the environment.

*If burn experiments are being conducted ensure they are conducted in a room with adequate ventilation.

8. A communication system is established between the control room and all fire technicians (e.g radios). Test the communication system before beginning testing to ensure it is effective. This is not only important for ensuring a smooth test, it is important in case something goes wrong.

*Although radios will not be needed in the classroom, establish the importance of clear communication between the students.

9. At Ehe conclusion of every test we analyze the effectiveness of our safety plan and identify items that can be improved for the next test.

*Even if the test went smooth with no problems, there is always room for improvements.

INVESTIGATIONS

At A Glance	Investigation 1	Investigation 2	Investigation 3	Investigation 4
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.				
	The Fire Triangle The basics of fire behavior. *involves candle and open flame.*	Heat Transfer and Ignition Conduction, convection, and radiation. *involves open flame and burning of small amounts of material in controlled lab setting.*	Energy and Combustion Potential energy in a fuel and measuring energy transfer. *includes video of fire and fire data; optional burn of small materials in controlled lab setting*	Fire Lab Data Analysis Live Burn Video: Fire Forensics
Grade Level **Estimated Time Required** (Duration based on 60 min periods)	Middle School (6/7/8) 2 class periods	Middle School (6/7/8) 2-4 class periods	Middle School (6/7/8) 2-4 class periods	Middle School (6/7/8) 1-2 class periods
Group Size and roles (see ROLES document)	2-4 students Stuff Supervisor, Experiment Exec*, Principal Presenter, Director of Documents *safety*	2-4 students Stuff Supervisor, Experiment Exec*, Principal Presenter, Director of Documents *safety*	2-4 students Stuff Supervisor, Experiment Exec*, Principal Presenter, Director of Documents *safety*	2-4 Students Stuff Supervisor, Principal Presenter, Director of Documents
Exploration	What are the three things a fire must have to burn?	A. How do fires spread? B. How do fires start?	What is heat release rate and how is it measured?	What does the fire lab data tell us about a fire?
Relevance to Fire Forensics	Firefighters and fire investigators need to know basic fire science to both fight fires and to uncover the source of a burn.	When we know how heat is transferred, we can better understand the fire scene. Knowing the ignition of different materials helps fire investigators understand/read a burn scene.	When fire investigators know how different fuels ignite and combust, they can better understand a burn scene and can build stronger claims based on a knowledge of types of evidence and patterns of fuels.	Fire investigators must understand the effect of ventilation on a fire and what happens when a door or window is left open during a fire.
Testable Question(s)	What is the effect of limiting one leg of the fire triangle?	A) How does heat transfer between materials? B) Does shape and size effect ignition (catching fire) and combustion (burning)? Does material effect ignition (catching fire) and combustion (burning)?	Does material effect the amount of heat energy released during combustion (burning)?	What is the impact of ventilation on a house fire?

INVESTIGATIONS

At A Glance	Investigation 1	Investigation 2	Investigation 3	Investigation 4
Summary of Lab	Using a candle, students conduct four experiments to limit one of each side of the fire triangle – oxygen, fuel, and heat - to understand the needs of fire. Then, using a metal screen, students look at a candle flame to observe combustion.	Students make observations about how thermal energy is transferred and how transferred heat starts fires . Students compare the surface to mass ratio of a block of wood and a toothpick, then compare how easily they ignite. Students then make observations about how different materials ignite and burn.	Students watch the interactive video of our UL fire experts in the UL Firefighter Safety Research Institute (FSRI) lab to make observations of the timing, behavior, and smoke of different fuels as they burn. The video continues with the building of a calorimeter to measure the heat released from common household furnishings. If your classroom has the proper ventilation and equipment, directions are provided for building a calorimeter for classroom	Using the data from two burns in the UL FSRI lab, students will make conclusions about the impact of ventilation on a fire. Students will present their ideas about why this understanding is critical for both firefighters and the women and men investigating the fire's origin and cause.
Outcome - Students will know and be able to...	Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4) Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3- 5) 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)	The transfer of energy can be tracked as energy flows through a designed or natural system. (MS- PS1-6) The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample and the environment. (MS-PS3) When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2) 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)	Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. (MS-PS1-2) The transfer of energy can be tracked as energy flows through a designed or natural system. (MS- PS3-3) The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary to MS- PS1-4) 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)	Cause and effect relationships may be used to predict phenomena in natural or designed systems.(MS-PS1-4) Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2) 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 of outcomes	Claims/Evidence/Reasoning Rubric	Claims/Evidence/Reasoning Rubric	Claims/Evidence/Reasoning Rubric	Claims/Evidence/Reasoning Rubric

INVESTIGATIONS

At A Glance	Investigation 1	Investigation 2	Investigation 3	Investigation 4

Materials required	• Long reach lighter
	• Pillar candle or emergency 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 cm) 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
	• Student Xplorlab pages
	• Xplorlabs Video: Investigation 1
		• Pillar or small candle in center of metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material)
		• Beaker of ice water
		• 2 6" (15cm) lengths of copper wire
		• A block of lumber/wood cut in 2x 4" (5x10cm) (commonly used in construction, readily available at hardware store)
		• 2 oz. (28g) of sawdust (handful) (also available at hardware store by asking lumber department for sample) – place in center of metal/non-flammable pie pan or tray (Not plastic, paper or wax coated material!)
		• 5 popsicle sticks/also known as craft sticks (non-coated, not colored)
		• 4 index cards
		• Strip of carpet (small)
		• Polystyrene piece (small) (Styrofoam)
		• Brick or ceramic tile
		• Tongs to handle materials that are hot or briefly flaming
		• Long reach lighter
		• Metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material) with 1-2” (2.5 – 5cm) water
		• Student Xplorlab pages
		• Xplorlabs Video: Investigation 2
		
		Preparation.
		Dip a toothpick into hot wax and place a small drop of wax on one end of one piece of copper wire. Do the same with a popsicle stick/craft stick.
			• Beaker or soda can
			• Graduated cylinder (to measure water)
			• Water (50mL)
			• Small digital thermometer
			• Beaker stand (to hold beaker) or ring stand (to hold can)
			• Paper clip or straight pin
			• Cork
			• Assortment of real fuels found in the interior furnishings of a home**
			    • Wood*
			    • Foam insulation*
			    • Carpet*
			    • Gypsum board
			    • Scraps of carpet padding
			    • Wood paneling
			    • Plastic plumbing pipe
			    • Upholstery fabric
			• OR Assortment of food items
			    • Cheetos*
			    • Marshmallows*
			    • Potato chips*
			    • Hot dog pieces
			    • Baloney pieces
			    • Student Xplorlabs pages
			    • Xplorlabs Video: Investigation 3
			
			Notes:
			*materials used in Xplorlabs Video.
			**home materials can give off some even when burning small samples
				• Open or Closed Door student reading
				• Data sets – oxygen, temperature, air pressure for both vented and non-vented fires (download)
				• Markers/flip chart page
				• Xplorlabs Video: Live Burn

*For more on fire safety, visit Safety Smart at: ULSafetySmart.com and UL.com
*Closed captioning for videos may be accessed through YouTube.