The Science of Thermal Runaway: Engineering Safe Solutions

Welcome to the UL Xplorlabs: The Science of Thermal Runaway, Engineering Safe Solutions

The world we live in is dependent upon portable electric power, specifically lithium-ion batteries. Underwriters Laboratories' (UL) The Science of Thermal Runaway pathway provides opportunity for students to make sense of the science related to lithium-ion battery-powered devices and the phenomena of thermal runaway. As students interact with the pathway content they will make their thinking visible through models, discussion, and ideation of possible solutions about the following:

- Interactions of matter and energy in lithium-ion battery-powered devices
- Cause and effects of energy transformations when using lithium-ion battery-powered devices
- System and system models in the problem definition of the engineering design challenge

A Problem Based Learning Unit

This unit is structured like a PBL that begins and ends with an engineering design challenge connected to the problem of thermal runaway. Driving questions guide students through digital content to explore science concepts related to thermal runaway. Challenges associated with safe battery enclosures are explored in the driving questions, with subsequent learning cycles designed for students to make ongoing connections to the engineering challenge's problem definition. After the pathway, students apply their problem definition to complete the engineering design challenge to design, test and optimize a battery enclosure for a lithium-ion battery-powered device. For more details on the engineering design process, see the teacher guide for Engineering Safe Solutions. In The Science of Thermal Runaway we encourage explicit teaching and learning of all three dimensions in science and engineering. [Additional details of this design are outlined in Table 1: Next Generation Science Standards]. An option for how this instruction could flow in your classroom is shown below.

Introduction to thermal runaway and the engineering design challenge.	→	DQ1: How does a lithium-ion battery work?	→	DQ2: How is overcharge connected to thermal runaway?	→	DQ3: Why do battery -powered devices need to be designed to minimize damage?	→	DQ4: How does thermal runaway spread?	→	Complete the scenario assessment that relates to the problem.	→	Complete the engineering design challenge.

Introduction to Thermal Runaway:

Students record observations from lab tests conducted at the UL Electrochemical Safety Research Institute and then share their wonderings about a lithium-ion battery-powered device that is on fire. These wonderings, become driving questions that serve as a guide to the remainder of the learning cycle. Students are aware that their exploration of the digital content will support their ability to engineering a safe solution for a safe battery enclosure.

Driving Question 1: How does a lithium-ion battery work?

Students observe energy transformations that occur because of lithium-ion batteries, paying particular attention to the byproduct of thermal energy. Specifically, students use online animations of lithium-ion batteries to complete circuits that support direct observations of transformations of energy and then explain how lithium-ion batteries transform energy.

Driving Question 3: Why do battery powered devices need to be designed to minimize damage?

Students watch video examples of how safety engineers construct conditions to test batteries to the point of failure. Then, student carry out a digitally simulated investigation to see how dropping a device impacts the likelihood of thermal runaway. Through this driving question students explain how damage can lead to the internal short circuits that cause thermal runaway.

Driving Question 4: How does thermal runaway spread?

Students view real UL Lab Experiments that place batteries in extreme heat to observe the likelihood they will release high pressure gas and become airborne. Through this driving question, students understand how build-up of gas inside the confined volume of the battery can lead to spread of fire, as well as how excessive heat of one battery in thermal runaway can spread to other cells.

Scenario Asseeement:

In this scenario-based assessment, students revisit the indroduction video showing a lithium-ion battery-powered device in thermal runaway. This time, they can navigate the video's interface and explore possible causes for the explosion. They will weigh potential causes for the fire and explosion and construct an explanation for the event based on one or more of the following: transfers of energy, mismatched chargers (overcharging), potential damage, excessive internal or external temperatures.

The Engineering Design Challenge:

Throughout the digital content in the driving questions students will identify challenges facing lithium-ion batteries used in portable electric powered devices, like hoverboards, and significant criteria of a safe battery enclosure. They will continually return to the theme that battery enclosures for portable-electric powered devices need to manage the heat from a battery. In this engineering design challenge, students will follow a three-part engineering design process to define thermal properties of materials that are desirable for the design, develop solutions using these materials in a prototype, and optimize their designs based on data, repeated tests, and scientific understanding of thermal properties.