Developing the M-E-F poster

In order to explain many natural phenomena, students need to be able to connect their observations with evidence of mechanisms that they cannot see directly. These observations usually take the form of changes in matter within a system or between systems, and the mechanisms might involve energy transfer due to unbalanced forces acting in the system. To integrate these ideas into a sensemaking framework, we introduce a chart that will anchor instruction across the course, the Matter, Energy, and Forces poster, abbreviated as the **M-E-F poster,** also referred to as the **M-E-F triangle**.

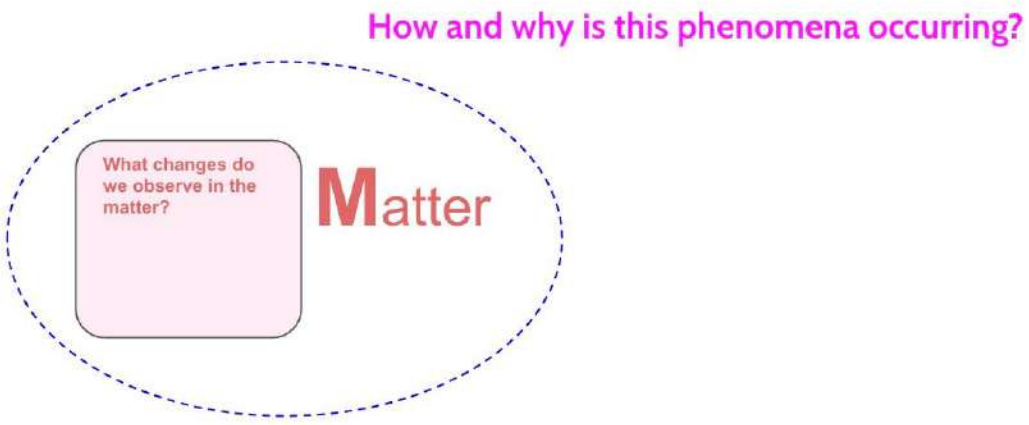
The M-E-F triangle is a public tool to support developing explanations of the natural phenomena that we explore in OpenSciEd high school. This tool encourages students to answer questions about changes that are happening in the system from either a matter, energy, and/or forces perspective. By asking these questions over and over throughout this course, this tool will support students in learning to apply these fundamental physics lenses to identify areas of phenomena that require further exploration.

While the ideas and questions included in the M-E-F poster are originally developed in *OpenSciEd Unit P.2: How forces in Earth's interior determine what will happen to its surface? (Earth's Interior Unit)*, the following guidance will help you develop it with your students over the course of this unit. We recommend that you add parts to the poster as they come up, rather than starting with the full poster in Lesson 1. Below are suggestions for where different parts of the poster could be added.

Development of the M-E-F poster in this unit

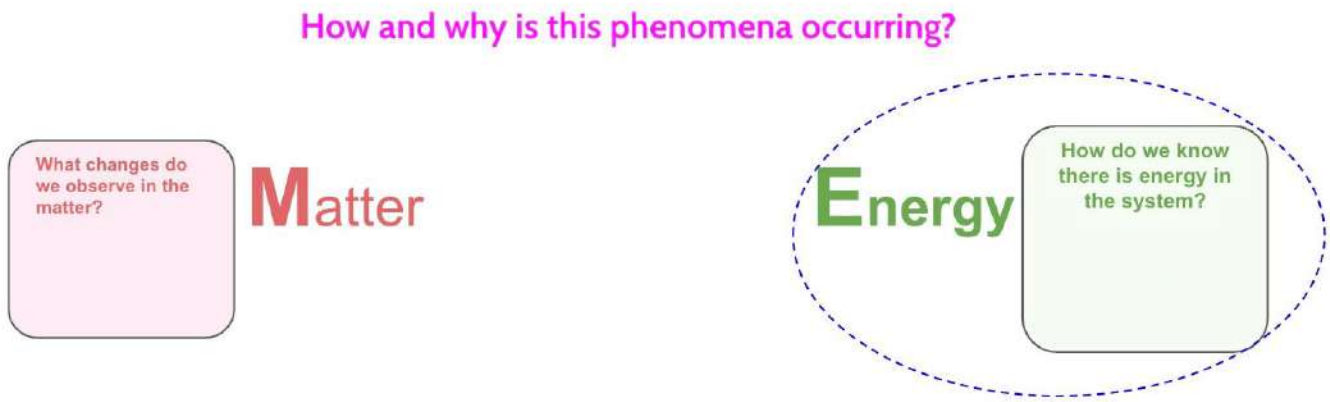
Lesson 1: During day 2, after the class has conducted the second demonstration with the food inside the microwave oven, students are asked to develop a model of the parts and interactions in the system that will explain how the microwave oven heats food/liquid and why the music was affected when the device was inside the microwave oven. When asked to provide feedback on a peer's model, do not ask students to use a force frame, as they have not developed ideas that help them connect forces with energy transfer. After developing the Consensus Model with the class, introduce the idea that looking at changes in matter seems to be a first step to understanding why this phenomenon is occurring. Add the following prompt to the poster:

- "Matter" and "What changes do we observe in the matter?"



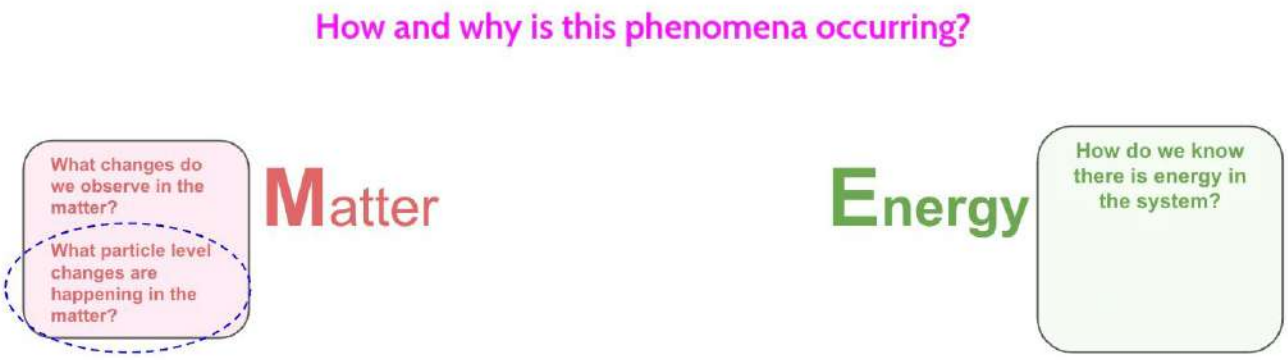
Then suggest that energy seems to be an important factor that we need to focus on as well, as we have evidence of energy transfer in different parts of the system. Add the following prompt to the poster:

- "Energy" and "How do we know there is energy in the system?"



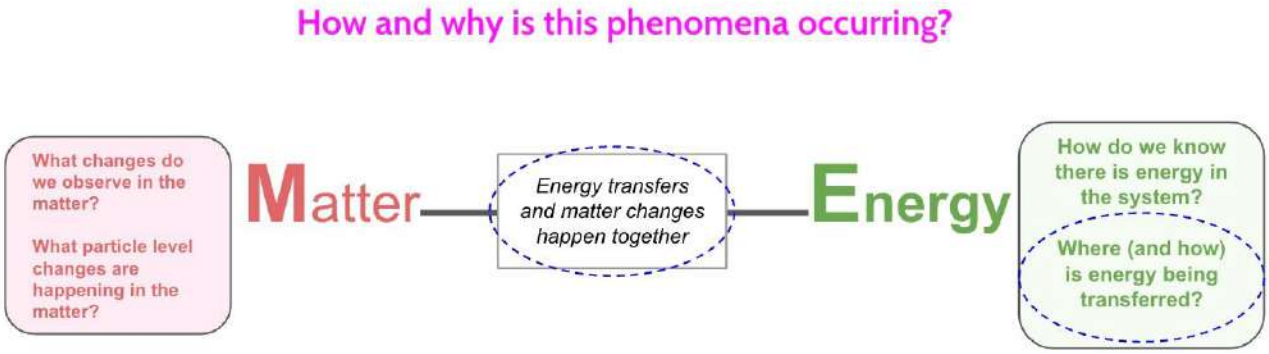
Lesson 2: After students read about the magnetron and discuss the role of electrons in the system, bring the idea that paying attention to changes at the particle level helped us understand phenomena better in the past. Add the following prompt to remind us of that going forward:

- "What particle-level changes are happening?"



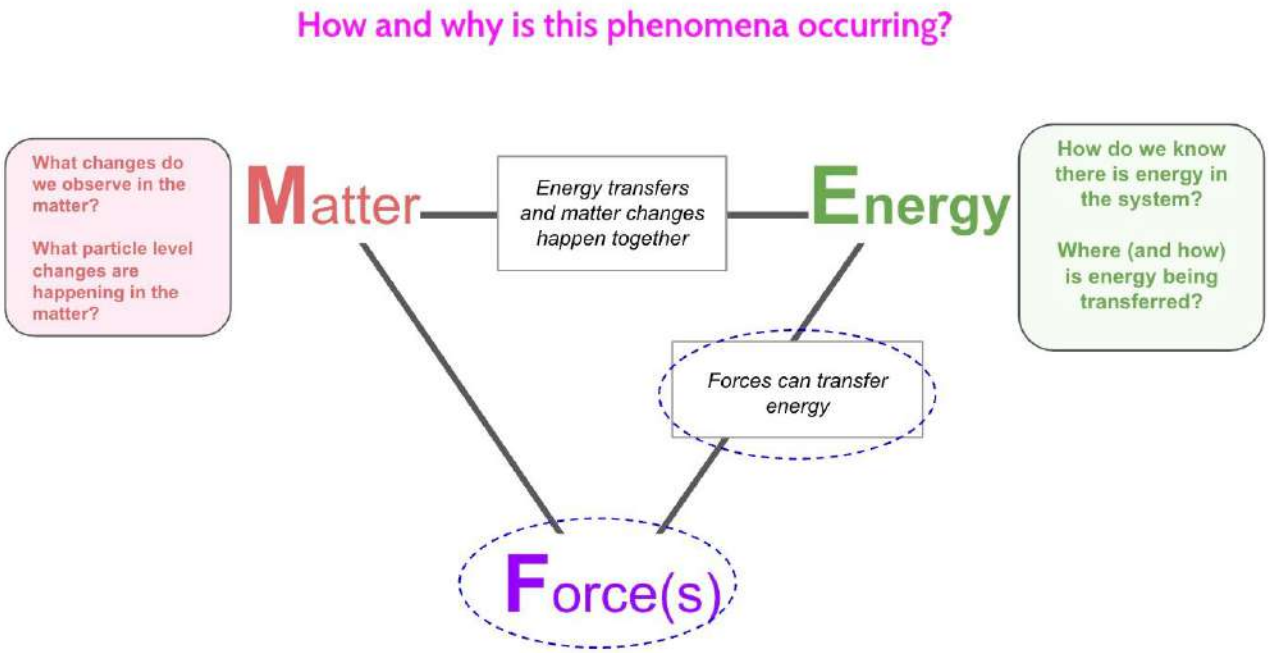
Lesson 3: After the class develops an energy transfer model to explain how waves can transfer energy, add the following panel and prompt to the poster

- "Energy transfers and matter changes happen together"
- Where is energy being transferred?



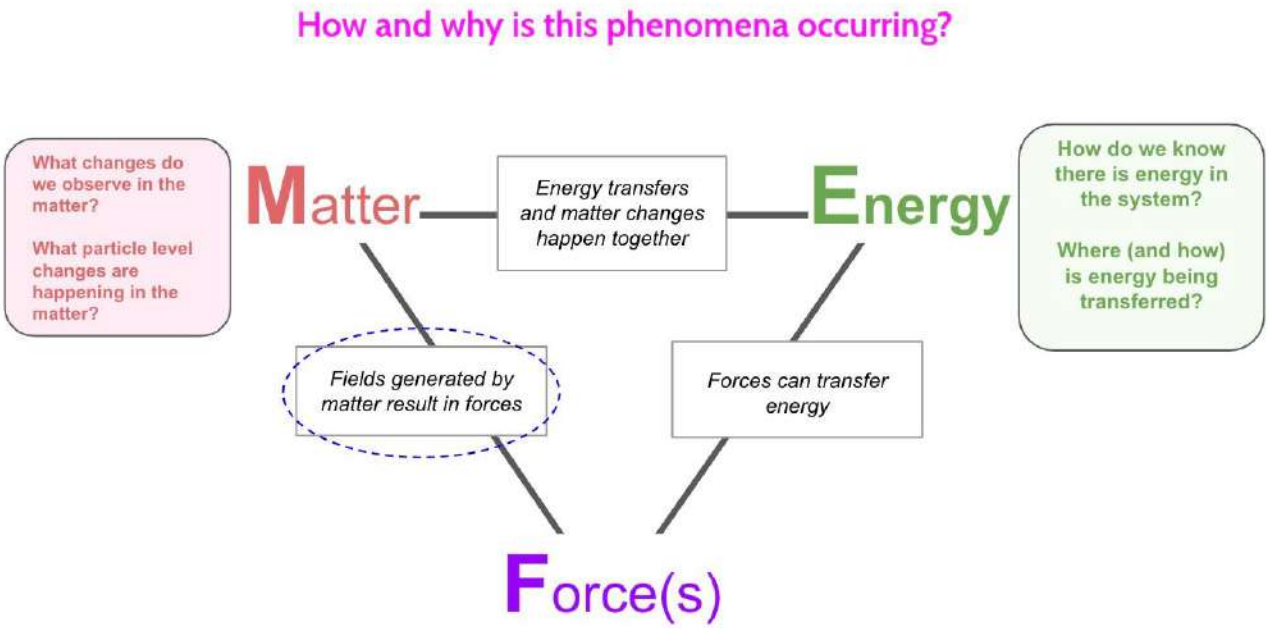
Add the panel with "Force(s)" on it to the bottom black line that connects it to "Matter". In addition add the following panel on the line between the "Forces" and "Energy" panels:

- Forces can transfer energy



Lesson 4: After students see the forces generated by fields, add the following panel between the "Matter" and "Force(s)" panels on the line connecting them on the M-E-F poster:

- "Fields generated by matter result in forces"



Lesson 7: After students review matter-electric field interactions, synthesize the role of forces acting on a system by adding the following prompt to the M-E-F poster:

- "What forces are acting on the matter?"