Learning Plan

Day 9: What are some ways of thinking that scientists use when doing research?

Targeted Idea: Scientists may consider one or more Crosscutting Concepts in their approach to a research question. The CCCs are mental tools students can use to help them understand a phenomenon from a scientific point of view.

Overview of Day 9:

Students gather into their assigned groups and discuss their Case Studies through the lens of the Crosscutting Concepts (CCCs). In discussion, the students should think about the different approaches taken by the scientists; for example, did they try to determine if an object is changing or stable, or did they look at many objects at once to search for similarities (a pattern)? The groups reference the Student Support Guide for CCCs (from Days 7 & 8) as they discuss their Science Case Studies while considering the Crosscutting Concepts. Groups then present highlights of their discussion points. This is an opportunity to review all the Case Studies, discuss the various approaches that scientists may take, and discuss the general question of “What are scientists looking for when they study the Universe at multiple wavelengths?”

The class then overviews the unit organizer and does a final reflection on the Fancy Cameras Probe before receiving the final assignment.

Middle School Performance Expectations (PEs) and Disciplinary Core Ideas (DCIs) relevant to Day 9:

| PE MS-PS4-2 Waves and their Applications in Technologies for Information Transfer |
| Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] |

| DCI MS-PS4.B Electromagnetic Radiation |
| When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light. |

Students are building their understanding toward these High School Disciplinary Core Ideas (DCIs) during Day 9:

| PS4.B.1 Electromagnetic Radiation |
| Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation while the particle model explains other features. |

| PS4.A Wave Properties |
| Information can be digitized (e.g., a picture stored as the values of an array of pixels) in this form, it can be stored reliably in computer memory and sent over long distances as a series of waves. |
Pulses.

**PS4.C Information Technologies and Instrumentation**
Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

**PS4.B.4 Electromagnetic Radiation**
Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.

**ESS1.A The Universe and Its Stars**
The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.

**Students are building their skills in / understanding of these Science and Engineering Practices (SEPs) and Cross Cutting Concepts (CCCs) in Day 9:**

**SEPs**

**Analyzing and Interpreting Data**
- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

**Obtaining, Evaluating, and Communicating Information**
- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

**CCCs**

**Patterns**
- Empirical evidence is needed to identify patterns.

**Stability and Change**
- Much of science deals with constructing explanations of how things change and how they remain stable.
Electromagnetic Spectrum and Multi-wavelength Astronomy

### Instructional Materials

<table>
<thead>
<tr>
<th>Handouts:</th>
<th>Resources</th>
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<tr>
<td>• Infrared Discovery Matrix</td>
<td>• PowerPoint for Day 9</td>
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<tr>
<td>• Final Assignment</td>
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</tbody>
</table>

### Day 9

#### Teacher Role

- Distribute materials.
- Encourage students to use their own words, and find ways to summarize their own learning, especially during the review of the graphic organizer.

#### Student Role

- Contribute to group discussions.
- Listen to peer ideas.
- Make notes in preparation for sharing.

#### Steps to follow:

1. **Elaborate:** Students gather into their assigned groups and discuss their Case Study through the lens of the Crosscutting Concepts.
   - Student groups should review their assigned CCC answers to the questions from the Student Support Guide for CCC with the group.
   - Every group member should make careful notes in preparation for sharing with the class.
   - Each group shares their CCC discussion summary for both CCCs.

2. Staying in the same group, coach students to use their completed unit organizer and other aspects of the unit to create a 2-sentence response to the question, “What are scientists looking for when they study the Universe at multiple wavelengths?”

3. Share out.

4. Review the Fancy Camera Probe (Day 1). Take student responses by show of hands.

5. **Evaluate:** Assign homework: Day 9 Final Assignment. Distribute the Infrared Discovery Matrix for use in completing the final assignment.

6. If time allows: Hold a gallery walk to allow students an opportunity to see how other groups’ explanations with model and Claim Evidence Reasoning (CER). Allow students to place a check mark next to ideas that they also felt they now understood, and to add any further ideas to the bottom of the chart paper.
Learning Plan
Day 10: Final Assessment

Targeted Idea: How do scientists know what they know?

Overview of Day 10:

In this final day of the Electromagnetic Spectrum and Multi-wavelength Astronomy curriculum unit, students will hand in their final assignment. Students can then review the curriculum unit, including looking back to the Unit Graphic Organizer (Day 2), Case Study Focus Questions (Day 2), Student Support Guide for Crosscutting Concepts (Day 8), and Infrared Discovery Matrix (Day 9). Teachers may administer a summative assessment tool of their own design at this point.

Day 10

<table>
<thead>
<tr>
<th>Instructional Materials</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>None required</td>
<td>Unit Graphic Organizer</td>
</tr>
<tr>
<td></td>
<td>Case Study Focus Questions</td>
</tr>
<tr>
<td></td>
<td>Student Support Guide for CCCs</td>
</tr>
<tr>
<td></td>
<td>Infrared Discovery Matrix</td>
</tr>
</tbody>
</table>

Teacher Role

• Collect student final assignment.
• Facilitate curriculum unit review.
• Administer optional final assessment.

Student Role

• Reflect on the activities, practices, and concepts presented over the past 9 days.
Steps to follow:

1. Congratulate the students on their hard work over the past 9 days.
2. Collect the final assignment.
3. Facilitate optional student discussions reviewing the curriculum unit; may include looking back to the Unit Graphic Organizer (Day 2), Case Study Focus Questions (Day 2), Student Support Guide for Crosscutting Concepts, (Day 8) and Infrared Discovery Matrix (Day 9).
Fancy Cameras

A friend was surfing the internet and came across these images of the same galaxy. They were labeled as radio, microwave, infrared, optical, UV, and X-ray. She pointed it out to her group of friends. They all thought it was really cool but wondered how the same object could look so different in photos. They had a lot of different ideas about the image. Here is what they said:

**Wei:** “I don’t think cameras can photograph different wavelengths of light. It's just like one of those Instagram filters that changes colors around after you take the photo.”

**Latoya:** “These can’t be real photos. Galaxies don't produce microwaves, radio waves can only be heard and not seen, and the Sun is the only thing that produces UV light.”

**Juan:** “I think they used filters, so that the camera only recorded certain colors of visible light coming from the galaxy. When you combine them together, it makes a photo just like what you would ordinarily see with your own eyes.”

**Sofia:** “I think each image is recording a different wavelength of light coming from the object. So, the camera must have a sensor that can detect those wavelengths, and then it shows that as different colors.

**Jared:** “Each image looks different because of the speed of the waves. Like, the radio images looks different because that light travels much slower than visible light, and the infrared light travels the fastest.”

Which student(s) do you agree with the most? ________________

Explain why you agree.
Resolving Power ($\lambda / \Delta \lambda$)

Wavelength ($\mu$m)

IRTF, SOFIA, and JWST Instruments

SpeX (IRTF)
iShell (IRTF)

NIRCam (JWST)

EXES (SOFIA)

MIRI (JWST)

GREAT (SOFIA)

FIFI-LS (SOFIA)

FPI+ (SOFIA)

NIRSpec (JWST)

FORCAST with grisms (SOFIA)

FORCAST (SOFIA)

HAWC+ (SOFIA)

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NASA SMD SciAct AAA
IRTF, SOFIA, and JWST Instruments

"footprints" = spectral resolution vs. wavelength
<table>
<thead>
<tr>
<th>Wavelength range</th>
<th>Objects / systems</th>
<th>Prominent spectral features</th>
<th>Interesting to astronomers because ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual to Near-IR</td>
<td>HII (ionized hydrogen) regions</td>
<td>Atomic and molecular emission lines</td>
<td>Raw material for new stars, excited by UV emission from nearby young stars</td>
</tr>
<tr>
<td>Visual to Near-IR</td>
<td>Cool stars: M dwarfs, red giants, and red supergiants</td>
<td>Molecular absorption lines and bands</td>
<td>Stellar evolution archetypes; chemical evolution of the Galaxy</td>
</tr>
<tr>
<td>Visual to Near-IR</td>
<td>Brown dwarfs</td>
<td>Molecular absorption lines and bands</td>
<td>Star and planet formation processes</td>
</tr>
<tr>
<td>Visual to Mid-IR</td>
<td>Planetary nebulae</td>
<td>Atomic and molecular emission lines</td>
<td>Late stage of solar-mass stellar evolution; recycling of chemical elements to the ISM</td>
</tr>
<tr>
<td>Near-IR to Mid-IR</td>
<td>Exoplanets</td>
<td>Atomic and molecular absorption lines during stellar transit</td>
<td>Composition and temperatures in exoplanet atmospheres</td>
</tr>
<tr>
<td>Near-IR to Mid-IR</td>
<td>Protostars</td>
<td>Atomic and molecular emission lines</td>
<td>Longest-lasting stage of star formation</td>
</tr>
<tr>
<td>Near-IR to Mid-IR</td>
<td>Protoplanetary disks</td>
<td>Atomic and molecular emission lines (and absorption lines, if seen edge-on)</td>
<td>Compositions, chemistry, and gas motions In forming planetary systems</td>
</tr>
<tr>
<td>Near-IR to Mid-IR</td>
<td>Planetary surfaces</td>
<td>Silicate and ice reflection absorption bands</td>
<td>Composition of planetary surfaces</td>
</tr>
<tr>
<td>Near-IR to Far-IR</td>
<td>Asymptotic Giant Branch (AGB) red giant stars and carbon stars</td>
<td>Molecular absorption lines &amp; bands; maser emission lines</td>
<td>Late stages of stellar evolution; recycling of chemical elements to the ISM</td>
</tr>
<tr>
<td>Mid-IR to Far-IR</td>
<td>Planetary atmospheres</td>
<td>Atomic and molecular emission and absorption lines</td>
<td>Composition and gas motions in planetary atmospheres</td>
</tr>
<tr>
<td>Mid-IR to Far-IR</td>
<td>ISM dust</td>
<td>Near-IR ice and organic absorption and emission bands; Mid-IR silicate bands (usually absorption)</td>
<td>Composition of raw material for new stars and planets</td>
</tr>
<tr>
<td>Mid-IR to Far-IR</td>
<td>Debris disks</td>
<td>Atomic and molecular emission and absorption lines</td>
<td>Nearly-mature planetary system</td>
</tr>
<tr>
<td>Far-IR</td>
<td>Molecular cloud cores</td>
<td>Atomic and molecular emission lines</td>
<td>Earliest star formation processes, before protostar stage</td>
</tr>
</tbody>
</table>
Final Assignment

1. Plan an astronomy investigation that would yield infrared spectra. What astronomical object would you like to investigate? What telescope and instrument would you use? Why?

2. Explain how scientists know and understand a science research finding from data collected by a scientific instrument using a model; show your reasoning in your response. Include the following labels, words, and/or items in your explanation:

   - Infrared
   - Emit
   - Reflect
   - Data
   - Telescope
   - Instrument

   Optional terms/labels:

   - Transmit
   - Speed of light
   - Other items or ideas you wish to add