Reflection and Refraction

In this instructional segment, students will investigate the behavior of light. Students will investigate the ways in which light interacts with mirrors and lenses. Students will also make connections between wave characteristics and wave behavior. This is part 2 of 3 instructional segments on waves.

Student Science Performance	
Grade or course: Physics	**Title:** Optics
Topic: Waves	

Performance Expectation for GSE:

SP4. Obtain, evaluate, and communicate information about the properties and applications of waves.

a. Develop and use mathematical models to explain mechanical and electromagnetic waves as a propagating disturbance that transfers energy.
(*Clarification statement:* Mathematically describe how the velocity, frequency, and wavelength of a propagating wave are related.)

d. Plan and carry out investigations to characterize the properties and behavior of electromagnetic waves.
(*Clarification statement:* Properties of waves include, but not limited to, amplitude, frequency, wavelength, and the relationship between frequency or wavelength and the energy of the wave.)

e. Plan and carry out investigations to describe common features of light in terms of color, polarization, spectral composition, and wave speed in transparent media.
- Analyze experimentally and mathematically aspects of reflection and refraction of light waves and describe the results using optical ray diagrams.
- Perform calculations related to reflections from plane surfaces and focusing using thin lenses.

f. Plan and carry out investigations to identify the behavior of light using lenses.
(*Clarification statement:* Investigations concerning Snell's Law, optical ray diagrams, and thin lens equation should be conducted.)

Performance Expectations for Instruction:

Students will
- develop and use models to explain the characteristics and behavior of electromagnetic waves.
- calculate the speed of electromagnetic waves in a vacuum and media.
- use models to describe and evaluate color, spectral composition, and polarization.
- design investigations to analyze the path of light waves as they reflect off of plane and curved mirrors both ray diagrams and mathematical representations (Law of Reflection and Curved Mirror Equations).
- design investigations to analyze the path of light waves as they refract through prisms and thin lenses using ray diagrams and mathematical representations (Snell's Law and Thin Lens Equations).

Additional notes on student supports

Materials:

Teacher Demos (Phenomenon) – Projected Student
- Plane Mirror, Laser, Baby Powder
- Convex Lens, Outdoor area with plenty of sunlight, white paper, wall

Student Investigation
- Computer and Internet Access

Students will continuously obtain, evaluate, and communicate information. This is not a linear process. Students will communicate through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.

Engaging Learners	**Phenomenon: Teacher will give students plane mirrors, lasers, and baby powder or corn syrup (if you have a tank)**
	Obtaining Students will use the mirror, laser, and baby powder to find and trace the path of a laser as it hits the plane mirror and reflects.
	Evaluating Students will state a claim about the path and behavior of light.
	Communicating Students will share their claims on chart paper or the whiteboard as a point of reference. The teacher will not comment but simply post their claims by themes (i.e. If students have the same or similar claims the teacher will group their claims together on the chart paper)
Exploring	*Obtaining* Students will use curved mirror ray diagrams and mirror equations to compare and contrast the differences they discover between their mathematical reasoning (i.e. mirror equations) and model representations (i.e. ray diagrams) *Provide student with a sample ray diagram and the formula for the Curved Mirror Equation* $(\frac{1}{d_0}+\frac{1}{d_i}=\frac{1}{f})$*. The sample ray diagram should include the focal point, radius of curvature, distance of the object, distance of the image, and the principal axis.*
	Communicating Students will communicate their findings with their peers in a class discussion. *Teacher Notes: keep the students on topic. The focus of the discussion should be around their mathematical findings and their ray diagrams. Students should be engaged in academic discourse around the behavior of light and the use of models to represent their findings.*
	Evaluating Students will modify their claims using their evidence from the models (ray diagrams, mathematical formulas) and their discussion with their peers. The products should include their reasoning which will tie their modified claims to their evidence. *Teacher Notes: you want students to notice the discrepancies between what they find mathematically and what they were able to predict from their ray diagrams.*
	Formative Assessment of Student Learning
Explaining Finalizing Model	*Obtaining* Students will use the following simulation to gather information around refraction. PhET simulation-- Bending Light (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu)

	Students should sketch some sort of representation of the bending light simulation. There are handouts on the site that you may use. Students will then research examples of light bending. *Use prisms, lenses, and light moving from one medium into another (e.g. air to water).* Students will analyze color and spectral composition. The PhET simulation [Color Vision](#) explores how color is observed (multiple activities are found in the teacher section). (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu)
	Evaluating The diagrams that students construct should include the following: ● For prisms or moving from one medium to another – normal, angle of incidence, angle of refraction, incident ray, refracted ray, and barrier between media ● For lenses - The incident ray, refracted ray, focal point, principal axis The thin lens equation can be used to draw parallels between the curved mirror math and the lens math. *Provide students with the formula* ($\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f}$).
	Communicating Students will finalize their models using ray diagrams for prisms, light movement between media, and thin lenses. Students may also use the thin lens equation to support their ray diagrams.
Elaborating Applying Model to Solve a Problems	**Phenomenon: A converging lens produces an image on wall when the object is on the opposite side of the lens from the wall.** Teacher will take students outside. Tape or hold paper against the wall and have a student stand away from you. Have the other students near the paper so that they can see the paper. Hold the convex lens up near the paper and an image of the student that is far away is projected.
	Obtaining **Exploratory Investigation:** Teacher informs the students that they go outside for a demonstration to investigate the behavior of light using lenses. Students will take paper outside to document observations. **Student Investigation:** The students in groups of 2-3. The students will use the simulation: [PhET simulation: Geometric Optics.](#) The students will develop a data table that allows them to record the data from the investigations that they design.
	Evaluating Students will use their observations to formulate a claim about the path the light traveled and what happened outside. Students will share their claims with the class and the teacher will document these claims

	Students will use the simulation to plan and carry out an investigation to explore the behavior light using lenses. They will use this evidence to compare with their initial claims.
	Communicating Students will finalize their claim, evidence, and reasoning using the demonstration, the simulation, and the peer communication.
Evaluation	***Assessment of Student Learning***
	Students will complete ray diagrams for both curved mirrors and thin lenses. Students will also explain the nature of light using color, spectral composition, and polarization. Teachers will grade the claim, evidence, reasoning portion of the investigations as a summative assessment.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	● Developing and using models ● Using mathematics and computational thinking ● Planning and carrying out investigations
Crosscutting Concepts	● Patterns ● Cause and Effect
Disciplinary Core Ideas	From *A Framework for K-12 Science Education:* ● PS4A: Wave Behavior ● PS4B: Electromagnetic Radiation

Additional Supports for struggling learners: **The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.**		
General supports for the following categories:		
Reading: 1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	Writing: 1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	Math: 1. Provide calculators as needed. 2. Provide graph paper as needed.
Supports for this specific lesson if needed:		
Performance expectations for instruction: 1. The teacher should provide information to students in various formats to reach as many students as possible. 2. The students should be given adequate time to complete each part of the lesson. 3. The students should be allowed to express their knowledge in various formats. 4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.		
Engage: 1. The teacher should be prepared to repeat directions as needed. 2. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student groupings. 3. The teacher should consider giving students a template to record their claims.		
Exploring: 1. The teacher should consider explicitly teaching students to use the equations and ray diagrams. The teacher should consider using them as a model to students and then practice using them together prior to having students practice individually. 2. The teacher should use guiding questions to assist students in using the ray diagrams and equations. 3. The teacher should have clear and consistent discussion guidelines in place to help students feel more comfortable and be more likely to participate.		

4. Students may need additional time to complete their assignment.
5. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include drawing, diagramming, writing or verbally explaining.

Explaining:

1. The teacher should consider providing students with an organizer for research, data and sketches of observations.
2. The teacher should consider providing sources for students to use in their research.
3. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include drawing, diagramming, writing or verbally explaining.
4. Students may need additional time to complete their assignment.
5. The teacher should provide practice for students to use the equations and read/construct the diagrams.
6. The teacher should consider providing students with a rubric to evaluate their work. This should increase student ownership of their work.

Elaborating:

1. The teacher should consider doing the demo more than once.
2. The teachers should be prepared to repeat directions as needed.
3. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student groupings.
4. The teacher should consider providing students with an organizer for planning and carrying out the investigation.
5. The teacher may need to consider guiding questions to assist students in the planning process.
6. The teacher should consider providing students with multiple formats to share their work. These formats could include using technology, gallery walks or presenting.

Evaluating:

1. The teacher should consider giving students multiple formats to communicate their knowledge. This could be drawing, writing or designing a presentation.
2. Students may need additional time to complete their assignments.