Learning Sequence for Pinhole Projection Activity

Discovery Learning – Students create a pinhole projection apparatus using an index card, another index card with a pinhole in the middle, and a clear light bulb with a large filament. The first index card with the pinhole is held closer to the lamp; the second index card is held in the shadow of the first. Students see the image of the lamp's filament projected onto the second index card, allowing them to observe inversion. Students distinguish the difference between image and object, note the object height (h_o), and determine that the distance of the object (d_o) and the distance of the image (d_i) (both measured from the pinhole) affect the image height (h_i).	**Interactive Demonstration** – The instructor explains to students the use of a pinhole camera, which consists of an open-ended cardboard box or tube, one of which has been inserted into the other at their open ends. Holes have been cut into their outer ends and covered on one side with aluminum foil (to allow the creation of one or more pinholes of various sizes and shapes), and the other covered with wax paper (to allow for translucent projects to be seen). The teacher asks the students to predict what would happen to h_i if they were to vary *di* and d_o. The teacher then asks students to explain what would happen if the size of the pinhole and the number of pinholes were increased.	**Inquiry Lesson** – Students conduct controlled activities with the assistance of the instructor to find a simple qualitative relationship between d_i and h_i when d_o and h_o are fixed. Students conduct another controlled activity to derive a qualitative relationship between d_o and h_i when d_i and h_o are held constant. Students write conceptual relationships such as: "When d_i increases, h_i increases if all else is held constant." The teacher asks the students how they might conduct a controlled experiment to determine the mathematical relationship(s) between the associated variables.
Inquiry Lab – Students are engaged in conducting controlled experiments using a meter stick and ruler, a means for quantifying data. The lab activity is "jigsawed" so that students can evaluate several simple relationships from the inquiry lesson. For instance, one group might determine the relationship between do and hi when di is held constant. Another group might find the relationship between di and hi when do is held constant. The first group will find an inverse relationship; the second group will find a proportional relationship. Drawing these relationships together, and looking at the system parameter of ho, with the assistance of the teacher, students find that magnification equals $h_i/h_o = d_i/d_o$. The teacher can introduce the role of the negative sign in the relationship if the distances are considered vector quantities.	**Read-world Applications** – The teacher helps students to generalize the principles of pinhole projection to the use of lenses. Lenses are like pinholes but for the fact that lenses have focal lengths, and pinholes do not. Given this background, students explain the workings of optical devices such as telescopes, binoculars, and microscopes.	**Hypothetical Inquiry** – Students use their knowledge of geometry (similar triangles) to derive the relationship $h_i/h_o = d_i/d_o$, noting that magnification is merely a definition. Students use trigonometry ($tan\, a = tan\, b$) to show the source of the relationship $$\frac{h_o}{d_o} = \frac{h_i}{d_i}$$