An Evolving Model for Seeing Colored Objects: A Case Study Progression

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Abstract. We document the experience of a single participant in a course for secondary teacher professional development in order to track the changes in her thinking about how light interacts with colored objects. Our two main interests in conducting this analysis are first, to better understand learners' ideas about light and color, and second, to observe changes in learners' thinking as they occur in real-time classroom events.

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INTRODUCTION

Scientific reasoning is a process that unfolds as people learn together. We document the experience of a single participant in a course for secondary teacher professional development in order to track the changes in her thinking about how light interacts with colored objects. One of our interests in conducting this analysis is to better understand learners' ideas about light and color, about which there is little existing research [1-3]. In this example, the focal participant initially uses a model in which we see colors by means of reflected light (a model that is appropriate for opaque objects, but not transparent objects). Our other primary interest is in observing changes in learners' thinking as they occur in real-time classroom events. In this case, we see the focal participant's model for seeing colored objects evolve in the course of a class period as part of an effort to create a consensus model for the interaction of light with colored objects.

CONTEXT

The participants discussed in this paper are secondary teachers taking a professional development class about energy [4] at Seattle Pacific University. They took part in an activity called Energy Theater [5] in which participants act out what happens to energy in various situations. Each participant plays the part of a single unit of light energy traveling through the given situation. For example, the first situation given to the participants was "Sunlight travels through a red acetate." The red acetate was marked by tape on the floor. The participants assigned themselves to either red, blue, or green light, and chose whether to move through the acetate or be absorbed by it [6]. Each participant is forced to make a clear decision about how his or her color of light will act because he or she must make a distinct movement with his or her body. Through this process participants must work together to come to a common agreement about what will happen in the given scenarios.

DATA AND METHODOLOGY

The data for this study consists of audio-video recordings of naturally occurring classroom events. For the current analysis, we made close observations of one full classroom session (one hour). From this hour, we selected two episodes of a few minutes each that were relatively dense with information about a single participant's learning experience. This case-study approach supports our goal of understanding the details of what individuals do to learn in collaborative science learning activities. The primary focus of our analysis is the participants' talk along with the body positions that are part of acting out Energy Theater. In addition, our understanding is greatly supplemented by our observations of gesture, gaze, prosody, and so on [7].

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FINDINGS

We found that one particular participant, Lisa, appears to alter her idea of how light and color work in the course of the session. She seems to come to class with a certain set of ideas about light and color to which she had been exposed in previous experiences and observations. She realizes almost immediately that her ideas do not match up with the ideas of other participants in the class, and she begins the challenging process of changing how she thinks about light. By the end of the class she has developed a new understanding of light and color, and she openly recognizes that she has learned something new.

The intent of the lesson was not to change any of the participants' ideas about (visible) light and color. The lesson incorrectly assumed that participants already knew how light interacted with opaque and transparent objects. In fact, the goal of the lesson was to further develop an understanding of some of the invisible components of the spectrum. Lisa's struggle with her own understanding reveals a shortcoming in the assumptions of the lesson. However, the general format of Energy Theater, with its emphasis on highly exposed learner thinking and learner-directed discourse, provided the opportunity to flexibly accommodate Lisa's learning needs.

Opaque Model

Lisa comes to class with a basic understanding of light and color: at some point in her life she has either been taught or has reasoned on her own that if an object appears to be a certain color, that object is reflecting that color of light and absorbing all others [see Fig. 1]. This model of light and color is functional when considering opaque objects. However, this session of Energy Theater forces Lisa to think about how light interacts with transparent objects (in this case, acetates) rather than opaque objects. Lisa's understanding of the opaque model of light becomes evident when the participants begin to act out the chunks of light in an Energy Theater scene.

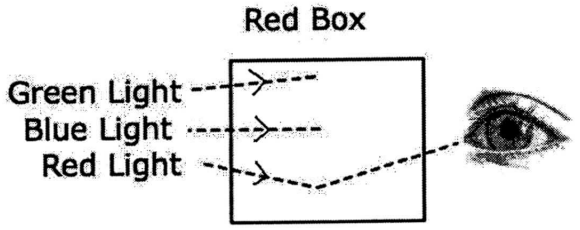

FIGURE 1. Opaque model. Green light and blue light are absorbed by a red colored box. Red light is reflected off the red box and seen by the eye.

The participants are presented with the scenario of sunlight passing through a red acetate. Two parallel lines of tape are laid out on the floor to signify the front and back of the red acetate. The seven participants in this group assign themselves arbitrarily to different colors of light (either red, green, or blue, with each participant being a single color), and Lisa chooses to be green light perhaps because of the color of her shirt. The participants representing blue light start off the scene by traveling from the sun toward the acetate and then stopping (being absorbed) within the acetate. The red light participants go second, traveling all the way through the acetate to the other side. Lisa leads the green light participants and travels straight through the acetate, just as the reds had a moment earlier [see Fig. 2]. The instructor stops the scene to discuss what their representation has said about light and color.

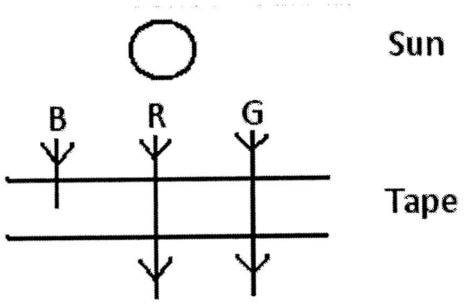

FIGURE 2. Two parallel lines of tape across the floor symbolize the edges of the red acetate, and participants approach the tape from the side of the sun. Participants representing blue light stop in between the taped lines to signify absorption. Participants representing red light walk past the taped lines to signify transmission. Lisa leads the green participants in walking past the taped lines just as the red participants had.

Most participants think that green light should have stopped and been absorbed by the red acetate; however, Lisa appears confused. She asks, "Shouldn't they [red light] be reflected off? And shouldn't... the rest of us [blue and green light] go in?" These questions lead us to believe that Lisa is attempting to apply the opaque model of light to an acetate, which is a transparent object. Although she appears not to realize it at the time, her established model of light cannot be successfully applied to transparent objects. Lisa's confusion drives her to develop a new model of light and color.

Compromise Model

The underlying stimulus of Lisa's confusion appears to be the failure of her opaque model of light to explain how light interacts with transparent objects. After a few minutes of group discussion Lisa seems to understand the shortcoming of her model. She realizes that light can travel through transparent objects whereas light is either absorbed by or reflected back from opaque objects. However, her original model does not account for light traveling through objects. Having made this differentiation between opaque and transparent objects, Lisa begins to develop an altered version of her original model that can account for light traveling through transparent objects.

The details of her new model become apparent when she asks, "Wouldn't some [green and blue light] be absorbed [by the red acetate] and some go through just like the red [light]?" Lisa appears to have reasoned that if red light can go through a red acetate, then green and blue light must be able to as well. From this reasoning Lisa seems to have created a new model that combines her previous notion of light with her new idea that light travels through transparent objects [see Fig. 3]: The incident light behaves as in the opaque model (red light is reflected and green and blue light is absorbed), and in addition, some of all colors is transmitted.

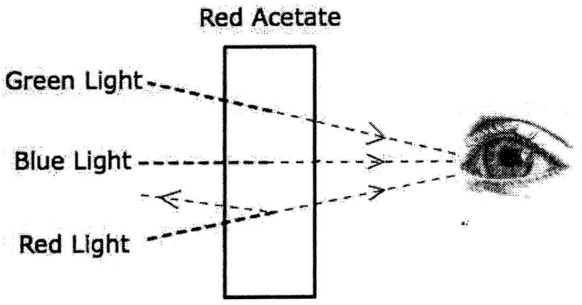

FIGURE 3. Compromise model. Some of the green and blue light is absorbed and some is transmitted through. Some red light is reflected back and some is transmitted through. The left side of the model appears to mimic the opaque (red light is reflected and green and blue light is absorbed), while the right side alters the original model by letting light through.

Despite Lisa's effort to change her model to match up with the model of other participants, this new compromise model does not completely resolve all of the opaque model's conflicts, described in the next section. Lisa is forced to develop yet another model in an attempt to get rid of all conflicts.

Transmission Model

In developing the compromise model Lisa incorporates the idea that light can travel through transparent objects. However, she does not appear to consider light that goes through a transparent object to have an effect on the color of that object. Rather, Lisa seems to continue to account for the color of an object by what color of light is reflected by that object, whether the object is opaque or transparent.

This dependence on the reflection rather than the transmission of light to determine the color of an object is made clear when Lisa says, "Why is it when you look at a green shirt, [green light is] what's being reflected? Why isn't it when you look at this [green acetate], isn't [green light] being reflected also?" Although Lisa has accepted the fact that light travels through a green acetate and not through a green shirt, she appears to think that they both look green to her eyes because they are reflecting green light. In Lisa's thinking the concepts of seeing the color green and green light being reflected are very closely associated, and she has not yet separated them.

At this point in the episode, Lisa conducts an impromptu experiment to determine whether a green acetate appears green because it reflects green light back to her eye or because it transmits green light through to her eye. Lisa places a green acetate over a dark surface to eliminate any light coming through from the other side. If the acetate appears green the observation will confirm her model that color is determined by reflected light. Alternatively, if the acetate appears black the experiment will show that the acetate must have green light transmitting through it in order to appear green. Placing the acetate on a black wall, Lisa sees that the acetate no longer appears green and accepts a new model [see Fig. 4]. She now appears to believe that the color of transparent objects is determined by what color of light is transmitted through the object rather than what color is reflected.

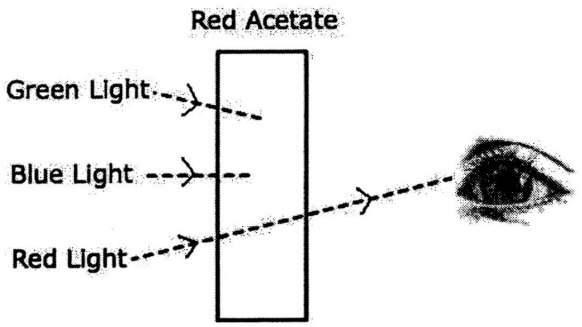

FIGURE 4. Transmission model. Green and blue light is absorbed by the red acetate and red light is transmitted through to the eye.

Learning Something New

Perhaps the most significant part of Lisa's progression of thought throughout the episode occurs at the very end when she states that she has learned something new. After struggling with her model of light and color for almost an hour, Lisa recognizes that her model no longer conflicts with the models of the other participants. She realizes that she finally understands light and color in a similar way to those around her in the context of the shared exercise. She signifies this realization and shows that she accepts this new model of light and color by saying, "This kind of stuff I never really learned." Lisa understands that she now has a more comprehensive model of light. Whereas before the class Lisa only understood light in terms of opaque objects, she now recognizes the differences between opaque and transparent objects and how those differences affect light and color.

DISCUSSION

Lisa's progression of thought throughout the course of the class period suggests that she came to class with a certain understanding of light and color and left class with an enhanced and more complex understanding. Lisa did not come to class as a blank slate ready to learn how light interacts with acetates. She came with a set of ideas about how light and color work and proceeded to develop her ideas until they no longer conflicted with the ideas of the other participants.

This idea of students coming to the table with certain raw resources that must be used to construct new understanding is described at length by Hammer [8]. Hammer emphasizes the difference between flawed resources and flawed uses of effective resources. In this case, Lisa's original resource, the opaque model, was a reasonable expression of how light interacts with opaque objects. However, Lisa's application of this model was flawed because she applied it to transparent objects. Lisa did not have a flawed prior understanding but simply applied her understanding to a scenario that was beyond its scope.

While the ultimate goal of a class such as the one in which Lisa participated is to guide the participants to a deeper understanding of the phenomena being studied, this deeper understanding cannot always be reached easily. Redish [9] explains that altering a mental model previously accepted by a student can be extremely difficult. An instructor cannot simply propose a new model and hope that a student will embrace it. Instead, students must have a clear understanding of both the conflicts caused by their original models and the advantages of a potential new model.

Lisa provides an excellent example of a learner having (productive) difficulty changing a pre-established mental model. During the first half of the class period she persists in her previous way of thinking about light and color. Through past experiences and observations she has become comfortable with the idea that an object appears a certain color because it reflects that color and absorbs all others. Through persistent application of this more comfortable mental model to situations she had not previously considered, Lisa begins to recognize the shortcomings of her model. Only when she realizes that her model does not satisfactorily describe light as it interacts with transparent objects does she begin to prefer working with a new model.

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