International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION
New Perspectives in Science Education
3rd Edition

Conceptual Change Activities of Light Rays by the Learning Cycle Model Approach

Yun-Ju Chiu, Feng-Yi Chen
Chang Gung University, (Taiwan)
yjchiu@mail.cgu.edu.tw, jocelyn@mail.cgu.edu.tw

Abstract
This study integrated multiple activities into a theme focused on the concept of shadow formation according to the learning cycle model which consists of three sequential phases: Exploration, Concept Introduction and Concept Application.
In this study, a number of innovative activities including taking a walk under the lampposts, noticing the darkness and color of shadows, the shadow of a hole, and the shadow remaining on the fluorescent paper are designed to bring cognitive conflict forth. Based on the learning cycle model, some innovating strategies including drawing many rays, noticing the area to see whether the light rays reached or not on the screen, drawing lines by yellow pencil and so on, are introduced into these activities for conceptual change.

1. Introduction
The light rays are used as a basic tool to illustrate the formation of shadows and images in geometrical optics. By using only two special rays, teachers and textbooks can interpret the position and size of the images clearly. However, many researches have indicated that the representation of light rays is very abstract for students, and they have many difficulties in drawing and interpreting ray diagrams. Goldberg and McDermott (1987) advised that instructors should help students understand that the special rays are not necessary for image formation, but merely sufficient to locate its position. Grayson (1995) stated that the two-ray strategy is highly abstract and therefore can mislead students to interpret the image formation too literally. Many rays are better than two.
Furthermore, plenty of studies even have found that many students, including high school and college students, fail to explain the phenomena of shadow through the approach of light rays. Most of the students use an 'emanating' model to explain it. That is, they figure that an image is formed near the object when light irradiates it; and thus, the image is projected onto the screen and then the shadow is seen (Chiu, 2011). Feher and Rice (1988) placed pinholes and opaque objects (a bead and a ball) in front of a cross-shaped light source to elicit children's conceptions of shadows. They also study children's ideas about colored objects and colored shadows to understand children's conceptions of shadows (Feher and Rice, 1992).
In this study, I carry out a series of thematic learning activities about the concept of shadow formation according to the learning cycle model. By using the many-rays model, we lead students to explain why some area is luminous while others are dark on the screen.

2. Karplus's Learning Cycle
The Learning Cycle Model, originally conceived by Robert Karplus in the 1960s, consists of sequentially three phases: Exploration, Concept Introduction and Concept Application (Karplus, 1977).The model is derived from constructivist ideas of the nature of science, and the developmental theory of Jean Piaget. It is an inquiry-based teaching model useful to teachers in designing curriculum materials and instructional strategies in science.

3. Activities
Based on the learning cycle model, I integrated multiple activities into a theme focused on the concept of shadow formation (Fig.1). The subject includes 36 fourth-graders under 6-week instruction. Each week lasts for 45 minutes. The instructional strategy is not to give or show answers directly but to lead students to have thoughts and questions from hands-on activities and demonstrations. The design of the modulus is based on a constructivist view of learning. It provides a planned sequence of instruction that places students at the centre of their learning experience, encouraging them to

explore, construct their own understanding of scientific concepts, and relate those understandings to other concepts.

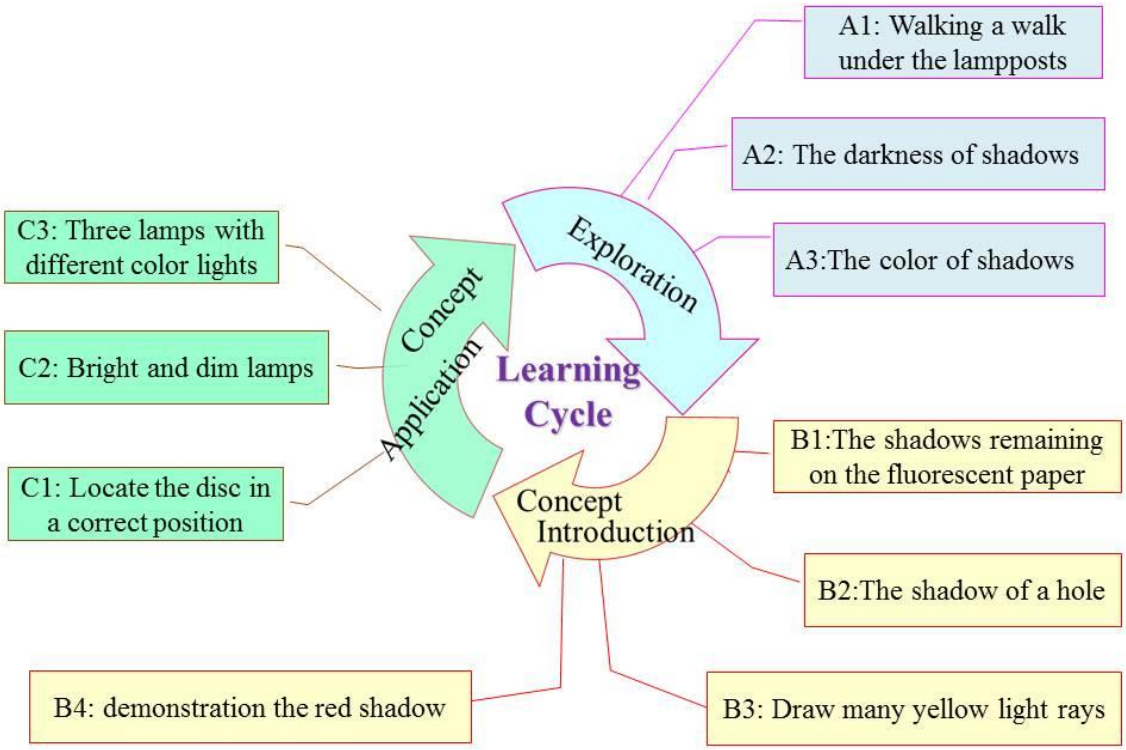

Fig.1.The series of thematic activities according to the Learning Cycle

3.1 Exploration

In this phase, the activities about the size, color and darkness of the shadows give rise to some cognitive conflicts. The adopted instructional strategy, according to the constructivist perspective, intends to make students aware of their conflicts and inconsistencies in thinking so as to clarify their misconceptions.

3.1.1 Activity A1: Taking a walk under the lampposts

Instead of the traditional shadow game under the sunshine, we design a special homework: have students take a walk under the lampposts with their family. They must observe and record the variations of the shadows which are ever-changing in number, size, position, and tint when taking a walk under the lampposts at night.

3.1.2 Activity A2: The darkness of shadows

After the discussion on the findings in the lampposts homework, a hands-on experiment is designed to explore the relationship between size and darkness of shadows. With a flashlight, a disc (4cm in diameter) and a screen (A4-sized flat paper) for each group, students can move each of them forth and back to observe and record the variations.

In this hands-on experiment, most students colour the shadow black, and only 1 student draw the shadow's size correctly (Fig.2).The common misconception about the darkness of the shadows is "the bigger the size the shadow is, the dimmer shadow they may see". Some students think the shadows' darkness is diluted as their sizes getting bigger, but some students persist that darkness could not change as the size of the shadows vary. We make use of such cognitive conflicts to encourage students' free exchange of views.

3.1.3 Activity A3: The colour of shadows

Why are the shadows black? Can we create a red or green shadow? In the process of discussion, students are encouraged to express their own ideas and assigned the after-class experiment as a way to prove their hypothesis. And in the following week, they should raise related questions in class.

3.2 Concept Introduction

In this phase, we introduce the graphical representation of many rays into these activities and lead students to notice the area the light rays reached in the screen (Fig.3). Two new concepts are introduced. First, the so-called shadow is the area where no light rays reached. That is why it looks black. Secondly, the density of the shadow's darkness results from the brightness and contrast on the screen.

3.2.1 Activity B1: The shadows remaining on the fluorescent paper

We ask students to put their hands on a fluorescent paper, and then, turn on the light for several seconds. Students will find the shadows of their hands remained on the fluorescent paper after turning the light off and moving their hands away. This activity clarifies the definition of shadow: "shadow is the area where no light rays reached."

3.2.2 Activity B2: The shadow of a hole

In this hands-on experiment, a white board with a hole replaces the disc of the previous activity A2. We ask students to draw many rays (at least 10 lines) from the flashlight using a yellow pencil and indicate the area of shadow on their worksheets (Fig.4). Some students mistake the yellow round area as the shadow at first. Then, we remind them that the so-called shadow is the area where no light ray reached. This is a good question of cognitive conflict.

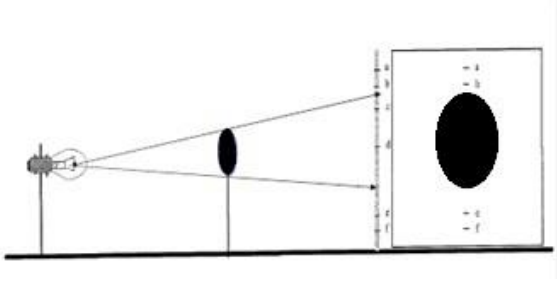

Fig.2. using the two-special rays and colouring the shadow black.

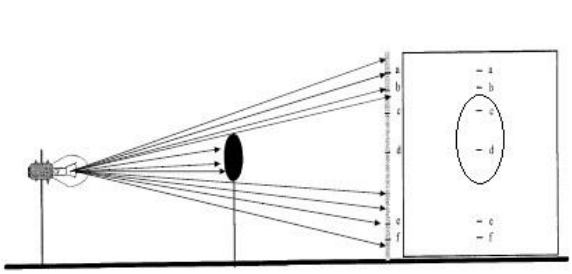

Fig.3. many rays are better than two.

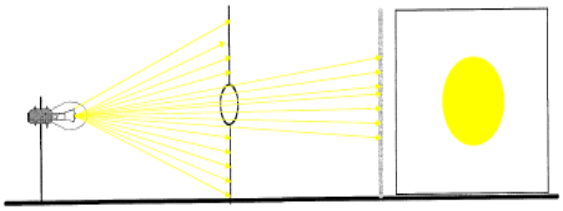

Fig.4. drawing many rays with a yellow pencil and filling yellow colour in the area where light rays reach.

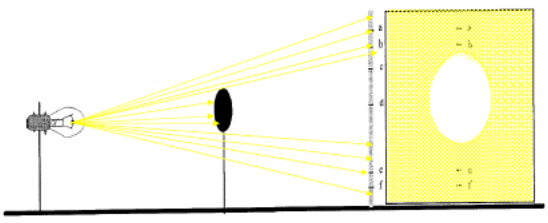

Fig.5. drawing many rays with a yellow pencil and leaving the area of the shadow blank.

3.2.3 Activity B3: Draw many yellow light rays

In this hands-on experiment, a disc between a flashlight and a screen made by a white board are used like Activity A2. We ask students to draw many rays (at least 10 lines) from the flashlight with a yellow pencil and indicate the area of shadow (Fig.5). The yellow area on the screen turns into another cognitive conflict: Some students wonder why the colour of the shadow becomes white?

3.2.4 Activity B4: Demonstration of the red shadow

In this demonstration, we create a red shadow by two lamps with coloured transparent paper: one is red and the other is green. We lead students to notice the screen where just only the red rays reach

and explain why. We ask students to pay attention to the parts where only red rays reach and explain why.

3.3 Concept Application

The concept application phase provides the students with an opportunity to explore the usefulness and application of the concept learned in the previous phase. The instructor can also evaluate the learning effect in this phase.

3.3.1 Activity C1: Locate the disc in a correct position

This is a dynamic paper-pencil test. Each student has a worksheet and a moveable paper-disc with an adhesive tape on its back. Students must move the paper-disc forth and back to locate the suitable position in order to match the size of the shadow drawn on the screen of the worksheet, and then, peel off the tape and paste the paper-disc on the worksheet.

3.3.2 Activity C2: Bright and dim lamps

We vary the brightness of a lamp by demonstration. Student can see the brighter the lamp, the darker the shadow. Then, we ask students to predict that if two lamps, one bright one dim, are turned on at the same time, what will they see on the screen? Which shadow is bigger and which is darker? Which shadow will shake if I shake the bright lamp?

3.3.3 Activity C3: Three lamps with different colour lights

We demo three lamps—red, green and blue—and ask students to predict what they will see on the screen. A worksheet and three colour pencils are provided.

3.3.4 Evaluation

Most students do these jobs well in the activities C1-C3. Activity C3 is easier than C2 for students.

4. Conclusion

In terms of the constructivist perspective, as a director and a planner, the instructor must bring out the students' preconceptions before instruction, and according to these misconceptions, adopt instructional strategies to make students aware of conflicts and inconsistencies in their thinking. Cognitive conflict is an important concept in the constructivist theory of learning. It arises when students observe an event which is at odds with their current understanding.

In this study, the innovative activities including taking a walk under the lampposts, noticing the darkness and color of shadows, the shadow of a hole, and the shadow remaining on the fluorescent paper are designed to bring cognitive conflict forth. Through the process of cognitive conflict, self-regulation will be initiated and concept-change will be possible. These activities can be applied to students aged from 9 to 15.

In this series of thematic learning activities, we bring in some innovating strategies including introducing the graphical representation of many rays, noticing the area whether the light rays reached or not on the screen, drawing lines by yellow pencil, and so on. These activities in three phases follow the learning cycle model.

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