

Appendix A: Learning Motivation Questionnaire

Adapted from the Intrinsic Motivation Inventory (Ryan, 1982)

Instructions: Please rate each statement based on your experience with the VR learning activity using the following scale:

1 = Strongly Disagree

2 = Disagree

3 = Neutral

4 = Agree

5 = Strongly Agree

Perceived Competence Subscale

1. I can successfully solve light and shadow problems in VR activities.
2. I believe I can understand the principles of how light forms shadows.
3. When I do experiments in VR, I feel very capable.
4. I can clearly explain the light and shadow phenomena I observed in VR.
5. I think I performed well in VR science activities.

Autonomy/Choice Subscale

6. In VR learning activities, I can decide how to explore light and shadow myself.
7. I can learn at my own pace in the VR environment.
8. I can choose different ways to test light and shadow concepts.
9. I can freely control the experimental process in VR.
10. During the learning process, my decisions affect how I learn in VR.

Relatedness Subscale

11. I enjoy discussing VR light and shadow experiments with classmates.
12. In VR activities, I feel a good connection with teachers and classmates.
13. Even in the VR headset, I don't feel lonely because I know others are participating too.
14. I feel comfortable sharing my observations and discoveries in VR with others.
15. VR activities make me feel like I'm part of this class.

Interest/Enjoyment Subscale

16. Learning about light and shadow concepts in VR is interesting.
17. I look forward to the next VR science class.
18. Using VR for learning makes me feel more pleasant than traditional classrooms.
19. VR activities make me more engaged in learning science.
20. Doing experiments in VR is an enjoyable way of learning.

Appendix B: VR System Usability Questionnaire

Adapted from the System Usability Scale (Brooke, 1996)

Instructions: Please rate each statement about the VR system using the following scale:

1 = Strongly Disagree

2 = Disagree

3 = Neutral

4 = Agree

5 = Strongly Agree

1. VR is simple to operate.
2. I can easily complete tasks in VR.
3. The VR interface is easy to understand.
4. I can quickly learn how to use the VR system.
5. I rarely get stuck when using VR.
6. Finding things (buttons) in VR is easy.
7. I think the VR operation steps are clear.
8. I can use VR by myself without help from others.
9. I can move and interact smoothly in the VR environment.
10. I think VR is convenient to use.

Appendix C: Conceptual Understanding Test

Developed based on Taiwan's elementary science curriculum standards for fourth-grade students

Instructions: Please select the best answer for each question based on what you learned about light and shadow.

Multiple Choice Questions

1. When light rays are parallel to the light box, what happens when a convex lens is inserted?

- a) No change
- b) Light disappears
- c) Light bends and focuses to a bright point

2. When light enters the cube vertically, what happens to the light spot?

- a) Shifts
- b) Disappears
- c) Appears on the straight line on the opposite side of the cube

3. A magnifying glass has no effect on light rays in the light box.

- a) True, b) False

4. If red light shines on blue text, what color will we see?

- a) Red, b) Black or dark color, c) Blue

5. When will we see the original color of the text on the table?

- a) When the light source and text color are the same
- b) When the light source and sticker color are different
- c) In darkness

6. In this activity, what do students mainly use to observe color changes?

- a) Natural light
- b) Colored lights
- c) Fluorescent lights

7. During the color guessing activity, how many colors of text are on the table?

- a) One
- b) Two
- c) Three

8. Why should the classroom lights be turned off during experiments?

- a) Save electricity
- b) Reduce light interference
- c) Increase challenge

9. Light travels in curved lines inside the light box.

- a) True, b) False

10. In the teaching activity, why should students draw and record the observed phenomena?

- a) To decorate the classroom
- b) To record and share observation results
- c) For drawing competitions

11. At what angle will light rays bend when entering?

- a) 45 degrees
- b) 90 degrees
- c) Non-90 degrees

12. Light rays passing through the center of a convex lens will bend.

- a) False, b) True

13. What was the main teaching material used in this teaching activity?

- a) Small whiteboard
- b) Laser pointer and plastic small cubes
- c) Whiteboard markers

14. When light passes through a convex lens, it bends and focuses at a point.

a) True, b) False

15. What did the teaching activity hope students would observe?

a) Changes when light enters plastic blocks

b) The color of plastic blocks

c) The intensity of the laser pointer

Scoring Rubric

Each question: 1 point

Total possible score: 15 points

Content Areas Assessed

Light propagation: Questions 1, 2, 9, 11, 12

Light and color interaction: Questions 4, 5, 6, 7

Experimental procedures: Questions 8, 10, 13, 15

Optical instruments: Questions 3, 14

Cognitive Levels

Knowledge/Recall: Questions 6, 7, 8, 13

Comprehension: Questions 1, 2, 4, 5, 10, 15

Application: Questions 3, 9, 11, 12, 14