Key Ideas for Session on Learning Cycles

I. Nature of Scientific reasoning
   A. Understanding as connected experiences, patterns, and explanations
      
      Inquiry (Constructing explanations from patterns in experience)
      Arguments from evidence

      Experiences
      (data, phenomena, systems, objects, events)

      Patterns
      (generalizations, laws)

      Explanations
      (hypotheses, models, theories)

      Application (Using scientific patterns and theories to describe, explain, predict, design)
      Model-based reasoning

   B. Importance of qualitative reasoning as a basis for quantitative reasoning
   C. Rigor as consistent, detailed use of simple models (for example, this lesson does not include Snell’s Law, refraction by lenses, real and virtual images, etc.)

II. Importance of Student Reasoning
   A. Specific misconceptions (for example, that we see out from our eyes)
   B. Sense-making strategies
      • Procedural display: Following procedures that are personally meaningless to get correct answers
      • Narrative reasoning: Learning stories and steps in procedures
      • Practical reasoning: Finding and using patterns
      • Model-based reasoning: Connecting experiences, patterns, and models
   C. Assessment and dialogue as key strategies for engaging students’ personal reasoning

III. Learning Cycles as a Way to Help Students Learn Difficult Content
   A. Transfer of responsibility
   B. Prerequisites for a learning cycle
   C. Specific steps in learning cycles
Transfer of Responsibility in the Learning Cycle

Learning Cycle Requirements
1. An objective focusing on inquiry or application
2. Sets of examples (experiences), patterns, and explanations
3. Clearly defined patterns in student practice (scaffolding for modeling and coaching)
Learning Cycle Requirements for Refraction Learning Cycle

1. Objective
Use the concept of refraction to explain why images of objects viewed through dense media are displaced from the actual location of the objects.

2. Experiences, patterns, and explanations

<table>
<thead>
<tr>
<th>Observations or experiences (examples, phenomena, data)</th>
<th>Patterns (laws, generalizations, graphs, tables, categories)</th>
<th>Explanations (models, theories)</th>
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Application: Model-based Reasoning

Inquiry: Finding and Explaining Patterns in Experience

3. Pattern in Student Practice

Initial Observations

Developing Tentative Explanation or Hypothesis

Explanation Part 1: The Drawing
1. Drawing the situation (viewed from the side), and the key objects in it
   - Light source
   - Object that the viewer sees
   - Media (e.g., air and a denser medium)
   - Eye of the observer
2. Drawing the arrows showing path of the light rays
   - Light bends toward the denser medium
Explanation Part 2: The Written Explanation

3. Explaining the path of the light
4. Explaining what the observer sees
   • Path of light rays “look straight” to an observer even when they are not
## Stages of the Learning Cycle

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<tr>
<th>Stage</th>
<th>Goals for Students</th>
<th>Common Strategies</th>
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| Establishing the problem | • discuss relevant personal experiences and ideas  
• understand learning goals  
• expectancy: believe that they are capable of understanding  
• value: establish interest and relevance of learning goals | • building on questions raised by students or problems that they are curious about  
• eliciting students’ ideas about discrepant events or familiar situations  
• encouraging discussion and debate among students  
• discuss connections to previous units or learning cycles |
| Modeling             | • see and understand how an expert accomplishes the objective  
• understand what they know and what they still have to learn | • “think aloud” problem solving  
• presenting scientific ideas in the context of real world problems  
• explicit contrasts between scientific and naive thinking |
| Coaching             | • practice using scientific ideas to accomplish the objective with support and feedback | • scaffolding (providing support and structure that will gradually be withdrawn)  
• special problems that focus on student misconceptions or learning difficulties  
• systematic feedback and reinforcement  
• cooperative group work  
• working with multiple examples of related meaningful tasks |
| Fading               | • learn to do the task independently                                                | • gradually reduce scaffolding and other forms of assistance  
• evaluation methods that maintain the integrity of the task  
• test questions that focus on key student difficulties |
| Maintenance          | • apply knowledge in other contexts                                                 | • providing opportunities to use the knowledge in other units or courses  
• connecting key ideas and practices for this objective with other important ideas and practices |
Stages in Refraction Learning Cycle

Establishing the Problem: Fish tank discrepant event

Modeling: Teacher’s explanation of the fish tank demonstration

Coaching: Group work

1. The coin in the bowl (using the guide page)
   Put a coin in the bottom of a bowl and get your eyes in a position where the coin is barely hidden by the rim of the bowl. Then slowly add water and watch what happens. Use the worksheet with the heuristic on it to explain what you see. (Hint: Try drawing diagrams with and without water in the bowl. You can think of the problem as explaining how light reflected by the coin reaches your eye even though the rim of the bowl blocks the straight-line path from the coin to your eye.

2. Glass on a printed page (on your own paper, with help)
   Put a piece of glass on top of a printed page. Why does the part of the page under the glass appear to be higher than the rest of the page? (Hint: Try explaining a single letter. Remember to include (a) a ray diagram showing the path of light from the light source to your eye, and (b) a written explanation.

Fading: Working on problems with less support

3. The bent pencil
   Look down the length of a pencil that is partially submerged in water. Explain, using drawings and words, why the pencil appears to be bent. (Hint: You can think of the problem as explaining why the tip of the pencil appears to be shallower in the water than it actually is.)

Extra Credit: The invisible stirring rod
   You can’t see a stirring rod partially submerged in vegetable oil. If you could see the invisible stirring rod beneath the surface, would it appear to be bent? How could you check?

Extra Credit: The timing of sunrise and sunset
   We can see the sun a couple of minutes before it actually clears the edge of the earth in the morning. Similarly, we can see the sun for a couple of minutes in the evening after it should be below the horizon. Use drawings and words to explain how this could happen. (Hint: Think about what happens to the sunlight as it goes from the less dense medium of outer space into the earth’s atmosphere.)

Extra Credit: Looking through a partially submerged tube
   In the “spear fishing” demonstration, the tube that the observer looked through was completely out of the water. What would the observer see if s/he tried to get more accurate by putting the end of the tube under water, then looked through the tube? Make your prediction, then try doing it, and revise your explanation, if necessary. (Hint: Think about how the tube in the water is like the pencil in water.)
Maintenance (not completed in this learning cycle)
Explaining an Example of Refraction

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