Session 8: Designing a Lesson

Contents

Session Overview

In this session of the course, participants focus on applying some of the insights and understandings they've gained as they plan lessons for students. The lessons they design are focused on addressing a common alternative conception regarding photosynthesis. During the first part of the session, participants observe a video that shows students grappling with the concept of photosynthesis in individual interviews and classroom activities. They look at a few common alternative conceptions, and discuss the possible origins of these ideas. Then participants are given a handout to guide their development of a lesson to address a specific photosynthesis-related alternative conception while keeping the framework of the learning cycle in mind.

Designing instructional materials is challenging and requires different skills than teaching. The goal of this session is not to create curriculum developers or even great lessons, but to engage participants in considering the important elements that good instructional materials embody. While few educators will engage in full-scale materials design in their careers, most educators will need to adapt and modify their instruction according to feedback about students' level of understanding, and experiences like these can help to inform this process.

That leads to the final message of the session—a reminder that one experience, no matter how compelling and memorable, is not necessarily sufficient to enable students to transform deep-seated alternative conceptions. As they witness in the video, students often come up with quite ingenious and clever ways to retain their older ideas at the same time as they adapt some aspects of more accurate conceptions. Monitoring students' changing ideas and engagement through repeated experience, over time, are part of the path to building more accurate understanding.

It should be noted that in designing the "Communicating Science" course as a whole—we have tried to "practice what we preach." The course seeks to exemplify a flexible model of how people learn. In that sense, this session can be seen as the *application* phase for the entire course, as students apply what they have learned about learning and teaching to the task of designing a lesson.

Background Information for the Presenter

Importance of Accessing Students' Ideas in Science
As discussed in previous sessions, taking students' prior ideas into account is very important for teaching science effectively. By incorporating a constructivist approach to teaching, we acknowledge that students have already assembled their own personal schemas for understanding the natural world. We also recognize that to help students learn science in a lasting and meaningful way, we must create situations so they confront their inaccurate or incomplete ideas and have the opportunity to adjust their thinking to a more scientific view. For this reason, having students' alternative conceptions firmly in mind when designing lessons can help teachers achieve their goals for student learning in science.

Why do we develop and hold onto inaccurate ideas?
The tenacious structures of thought that students create about science are quite unique to the individuals who produce them, however, they also share some common features. Research studies have shown that children (and adults) all over the world may share the same alternative conceptions in science, even though their school experiences can be very different. This may be because alternative conceptions and naïve ideas have as their source a characteristically human approach to trying to understand the world.

We primarily use our physical perception of events to make sense of the phenomena we encounter. What we see, hear, taste and feel counts for a lot in the ways that we understand the world around us. In science however, we must rely on constructing mental models for things that can't be perceived directly. Often these models contradict what can be directly observed – i.e., the Earth does seem flat from our viewpoint, and we usually can't see gases or feel their mass. This is one reason that scientific ways of understanding may not seem to "make sense" to learners and why they sometimes have a difficult time believing the more accurate explanations.

It can also be a struggle to understand the world from a systems perspective. We tend to explain what we see by attributing particular properties to specific objects, rather than thinking of the interactions between groups of objects. For example, we may think that a metal container will help to keep ice cold, because metals generally feel cold to the touch. We don't necessarily think about the way the air surrounding the container will interact with the metal by rapidly transferring heat and the metal will efficiently transfer this heat to the ice, thus causing it to melt. Obviously, this argues for providing students with ample experiences in analyzing how systems work and how small changes to system components can result in large overall effects.

Another common pattern found in young children's thinking (and in many adults!) is to focus on explaining *changes* rather than on things that occur in a steady state. Changes are what seem to require an explanation, and things that don't change seem to merely exist without necessarily having a cause. This kind of thinking makes it hard to recognize, for example, that all particles in matter are constantly moving, even when the substance is in a solid state and not only when it is changing phase. Similarly, the prominent alternative conception that a force can only be present when objects are in motion, is likely as a result of this kind of error in causal reasoning. Again, we have a tendency to reduce complex causes or systems of interactions into being the result of a single action or event that occurs in a linear fashion to produce whatever is observed.

Another impediment to understanding science is that learning is often very context dependent. We may experience a scientific phenomenon or process in one context and not be able to make generalizations or extend it to another. For example when performing investigations, students may be unaware of the transferable aspects of the activity, and only relate their understanding to the particular situation they have witnessed first hand. In order to learn how to transfer or generalize scientific understanding, students need to be explicitly asked to think about concepts and explanations as applied to a variety of settings.

Some Common Alternative Conceptions Explained

Concentration in Solutions

When a solid is completely dissolved in a liquid, the resulting solution has the same concentration from top to bottom. We call the dissolved substance the solute and the liquid into which the solid dissolved the solvent. Once a solute is completely dissolved, the solute particles can freely move around between the solvent particles and therefore spread out evenly. As a result, the amount of solute per volume of solvent is the same at any location within a solution. Of course this is only true when the solution has not gone beyond the saturation point, i.e., the amount of solute added can be completely dissolved.

Temperature and Heat Transfer

When you expose any two materials – whether metallic material or non-metallic – to the same conditions, both will reach the same temperature. For example, after being in a in a car on a hot summer day for a while, the metal buckle and the seatbelt strap will both be at the same temperature as they come in contact with the hot air. As the air in the car heats up from the sun, the heat transfers to all the objects in the car until they reach the same temperature. In other words, the temperature of all the objects is equilibrated. While the metal buckle may "feel" hotter when we touch it, our experience is caused by the metal transferring heat more quickly to our finger than the seatbelt strap, not by a difference in temperature.

Insulation Properties of Materials

If you want to keep something either hot **or** cold, you must insulate it. Insulation is achieved by materials that slow down the rate of heat transfer. Therefore, insulation is any barrier that slows down the rate at which heat is transferred between an object and its surroundings. Metals transfer heat quickly, non-metallic materials like wool or Styrofoam transfer heat more slowly. So tightly packed wool can keep a can of soda cold, but aluminum foil will actually cause the can of soda to warm up more quickly as the heat from surrounding air transfers to the can.

Phase Change and Mass
When you freeze any liquid, including water, a change in physical state occurs. The liquid neither gains nor loses particles upon freezing, so the mass of the solid formed must be the same as the mass of the original liquid. While the number of particles does not change, the solid formed contains stronger forces holding the particles together than the original liquid. This explains why solids hold their shape while liquids can be poured.

Size and Density
Density is a property of substances related to the amount of mass in a fixed volume. Solid objects will float or sink in a liquid depending on their density and the density of the liquid. When the average density of the object is less than the density of the liquid, the object will float. When the average density of the object is greater than the density of the liquid, the object will sink. While big objects can weigh more than little objects, it is the density (mass per unit volume), not the mass alone, which determines whether the object floats or sinks. Objects with low density have more "empty space" within their structure (i.e., the particles are more spread out). So a big piece of plastic can float (low density) while a small piece of stone will sink (high density).

Gases and Mass
Because gases are made of matter and all matter has mass, gases therefore have mass. Like liquids and solids, gases are composed of particles that have mass. While it is true that gases are much less dense than liquids and solids, this is because the particles in the gas are spaced very far apart. A helium balloon floats in air because the helium gas is less dense than the air surrounding it. While the helium gas has less mass per volume than air (which is composed of mostly nitrogen, oxygen and carbon dioxide gases), nonetheless, it still has mass.

Materials and Preparation

Materials Needed

For the class:

- ❑ Part one of the video *Lessons From Thin Air*
- ❑ DVD player & projector (or VCR and monitor)
- ❑ Slides or overhead transparencies of the following pages:
  —Learning Cycle
  —Common Alternative Conceptions Slides (6)
  —Designing a Lesson
  – Addressing a Specific Alternative Conception

For each participant:

- ❑ 1 copy of each of the *Common Alternative Conceptions Explained* handout
- ❑ 1 copy of *Designing a Lesson to Address an Alternative Conception* handout
- ❑ 1 copy of the *Photosynthesis* handout

Preparation of Materials

Before the day of the activity

Obtain a copy of the video, *Lessons From Thin Air*, part of the Annenberg Foundation video series, *Minds of Their Own*. Video Series: Minds of Our Own, 1997 Producer: Annenberg Corporation for Public Broadcasting, 1-800-965-7373, http://www.learner.org

On the day of the activity

1. Make one copy for each participant of the following pages:
   – *Common Alternative Conceptions Explained* handout
   – *Designing a Lesson to Address an Alternative Conception* handout
   – *Photosynthesis* handout

2. Make slides or overhead transparencies of the pages:
   —Learning Cycle
   —Common Alternative conceptions slides
   —An impediment to fully understanding photosynthesis
   —Designing a Lesson

3. Set up a DVD player or VCR and monitor in the classroom. Cue the video to the beginning.

Instructor's Guide

Session Objectives

In this session, participants:
— learn that alternative conceptions in science are common and can be hard to change;
— gain an understanding of effective strategies for uncovering and addressing students' alternative conceptions in science;
— apply what they've learned in the course thus far, to the task of designing a lesson to address a specific alternative conception; and
— reflect on their own understanding of designing lessons.

Session Activities at a Glance

Strategies for Uncovering and Addressing Students' Ideas
Participants are shown the first part of the video, *Lessons From Thin Air*, which is about photosynthesis. In the video, Harvard graduates and middle school students display a commonly-held alternative conception that the mass of a plant comes primarily from water and minerals, rather than from CO_2 gas in the air. The interviewer in the video asks questions to find out why the student holds these ideas, and provides some clues to encourage them to re-examine their thinking. During the video the participants are challenged to note strategies used both to uncover alternative conceptions, and to challenge them.

Discussing Alternative Conceptions in Science
After a class discussion on the strategies used in the video, the class is presented with a number of other widely-held alternative conceptions. Small groups are assigned one of these alternative conceptions and told to discuss what they think might be the source of this idea.

Designing a Lesson to Address an Alternative Conception
The whole class then focuses on an alternative conception related to the understanding photosynthesis. In small groups, they are challenged to come up with an activity designed to encourage students to question this alternative conception. Each group is assigned to outline an activity that is designed specifically to address problems with understanding photosynthesis. The large group then discusses the challenges involved in meeting this lesson design task.

Reflecting on Designing Lessons
The session ends with a reflection prompt about what they've learned about designing lessons in science. They begin by brainstorming and writing down how their ideas about designing lessons have changed through the experiences in the session. They share these with a partner, then discuss in the large group.

Time Frame

Total Workshop: 2 hours
Strategies for Uncovering and Addressing Students' Ideas (30 minutes)
Discussing Alternative Conceptions in Science (20 minutes)
Designing a Lesson to Address an Alternative Conception (60 minutes)
Reflecting on Designing Lessons (10 minutes)

Strategies for Uncovering and Addressing Students' Ideas (30 minutes)

1. Project the "Learning Cycle" slide. Reflect on how there have been learning cycles used throughout the course to structure individual sessions and in the overall design of the course.

2. Explain Use of Learning Cycle in the course. Tell participants that in the *overall* learning cycle design of the course, the beginning sessions of the course provided opportunities for Invitation, Exploration, and Concept Invention. Tell them that today's session is part of the overall Application stage of the course—as they begin trying to put some of ideas and strategies they've gained from the course into practice.

3. Explain that they will incorporate strategies to design lessons that address alternative conceptions. In this session they'll be practicing designing lessons in small groups and seeking to incorporate the strategies taught in the course into their lesson design. In their lessons they'll be focusing on addressing a specific set of student alternative conceptions.

4. Introduce *Lessons from Thin Air* video. Tell them that first you're going to show them a short video dealing with alternative conceptions. The video is part of a series called *Minds of their Own* that was made by the same group that made the *Private Universe* video they saw in the *Constructing Knowledge* session.

5. Focus on alternative conception strategies as they watch video. Tell participants that, as they watch the video, they should try to identify strategies the interviewer uses:

- to uncover alternative conceptions
- to address alternative conceptions

6. Show Part 1 of *Lessons from Thin Air.* Participants watch the segment of the video that relates to photosynthesis (the first ~17 minutes). Stop the tape right after you hear: "Parents have to be asking their child all the time, 'Are you really learning to understand or are you just learning to pass the test?'"

7. Discuss strategies for uncovering alternative conceptions. Ask the participants what strategies they identified that the interviewer used to *uncover* alternative conceptions. If your participants don't raise them, consider mentioning the following examples:

Asked questions to find out what the student already knew before instruction.
• How much do you think that (log) weighs?
• What did it need to grow?

Asked questions to find out what the student remembered after instruction, one month later.
• Can you remember what you said about air?
• What is it (the plant) using from the air?
• What do you remember about the photosynthesis equation you drew a month ago?
• What would you say now about the percentages?

Asked questions to find out what the student was thinking.
• What would you say about air not weighing anything?
• Why would you say that sometimes that statement is right, and sometimes wrong?

8. Discuss strategies for addressing alternative conceptions. Ask what strategies the interviewer used to *address* the alternative conceptions, and again, consider mentioning the following examples, if they don't come up:

• **Identified a foundational idea that the student did not understand** (that gas has mass) which may be a stumbling block for the student to be able to comprehend that the mass of the wood came primarily from CO_2.

• "**Adapted the curriculum**," and presented new materials to address the specific needs of the student.

• **Asked questions to prod the student into thinking more deeply about the subject matter.**
"You mentioned carbon dioxide and you mentioned oxygen. Any idea what these things are?"
"Do they have any kind of weight, do you think?"

• **Brought in information and evidence that conflicted with the student's ideas,** through the use of more focused questions, forcing the student to rethink ideas.
"Ready, OK, I want you to hold that." (piece of dry ice)
"Do you know what dry ice is? Does it have weight?"
"What if I told you this is carbon dioxide? It's frozen carbon dioxide."
"What do you think is happening to it? What do you think will be left?"
"It's not made of water, it's made of CO_2. Any clues about what might be left when it's gone?"

Discussing Alternative Conceptions in Science (20 minutes)

1. Introduce additional alternative conceptions. Tell paticipants that you're now going to introduce some commonly held alternative conceptions in science.

2. Display and briefly explain the first slide. Show the *Concentration in Solutions* slide and briefly explain the ideas students sometimes express about this concept and why it is generally considered incorrect. Be careful not to mention the possible sources of this erroneous idea.

(1) Concentration in Solutions
Some students think that the concentration is greater at the bottom of the container in a solution.

3. Briefly introduce other alternative conception slides. Do the same with the other slides: *Phase Change and Mass, Temperature and Heat Transfer, Insulation Properties of Materials, Size and Density,* and *Gases and Mass.* Again, be careful not to discuss the possible reasons for these ideas.

(2) Temperature and Heat Transfer
Some students think the fabric and metal buckle of a seat belt in a hot car are at different temperatures, because one feels hotter than the other.

(3) Insulation Properties of Materials
Some students think that wool generates heat and/or that aluminum foil can be used to insulate heat and cold.

(4) Phase Change and Mass
Some students think that when you freeze water, the ice will be either heavier or lighter than the original sample of liquid water.

(5) Size and Density
Some students think that only big things sink and little things float.

(6) Gases and Mass
Some students think the reason gases float and are invisible is because they have no mass.

> ***Note:*** *There are many other common alternative conceptions that could serve well in this activity other than the above list. Feel free to substitute others if they seem more appropriate for your participants' needs.*

4. Explain that small groups will discuss possible sources of one alternative conception. Each small group will now discuss what they think are some possible sources for one of these alternative conceptions—what observations of real world phenomena or other factors might foster such a widely held misunderstanding.

5. Groups discuss possible sources of alternative conceptions. Assign one alternative conception per group, and distribute the *Alternative Conceptions Explained* handout. They can refer to the handout for a simple scientific explanation of each of the ideas.

6. Class discusses possible sources of conceptions. After about 10 minutes, regain the full groups' attention, and lead a discussion of what they think might be sources of each of the alternative conceptions. Point out that understanding the possible sources of these ideas can be the first step in designing instruction that can help students achieve more accurate scientific understandings.

Designing a Lesson to Address an Alternative Conception (60 minutes)

1. Introduce photosynthesis focus for lesson. Display the slide, "An impediment to fully understanding Photosynthesis." The entire class will now focus on addressing the alternative conception that the student (and others) in the video expressed regarding where trees get their mass:

> Many people think that the mass of a tree primarily comes from soil, water, and nutrients.

2. Describe design task. Explain that, working in the same small groups, they will now design a lesson aimed at helping students recognize their alternative conceptions related to photosynthesis and help them build a more scientifically accurate understanding. This lesson should be appropriate for the age of the students they are working with. Say that participants will plan the activity for the lesson on paper, but they can include the use of hands-on materials in their description.

3. Introduce planning sheet and goals. Display the *Designing a Lesson* slide. Distribute the handout with the same title to each participant and say that they will first begin by deciding on a specific goal for the lesson and then proceed with planning the other parts of the lesson. Point out that it can be helpful to have assessment in mind as they design their lesson—how they will know whether students have achieved this goal .

4. Photosynthesis is a complex topic—they will focus on one aspect. Distribute the handout on photosynthesis and point out that fully understanding the entire process is far beyond what can be realistically accomplished in one lesson. They will need to focus in on an age-appropriate aspect of the concept that they think students must confront in order to reach a more accurate (if not complete) understanding of the concept.

5. Participants design lessons. Let participants know they will have about 30 minutes to work on their lesson and fill out their planning sheet. Circulate among the groups, answering any questions and providing assistance as needed.

6. Each small group shares lessons with another small group. After ~30 minutes, tell participants that they will now present their ideas for a lesson to another small group, who will give feedback. Display the Lesson Feedback slide. Encourage them to be frank when providing feedback, including the pros and cons and whether they think the lesson is feasible for the students they are teaching. They will have about 10 minutes for one group to present their ideas and the other group to respond, then 10 more minutes to switch roles, and do the same.

7. Discuss grade level expectations for understanding photosynthesis. After both groups have had a chance to hear and respond to lesson ideas, focus their attention. Explain that even very young students in elementary school can become aware that photosynthesis is the process by which plants use water, carbon dioxide, and energy from the Sun to produce food. It is also important for everyone to understand that the Sun is the ultimate source of energy for all living things. However, because we can't actually experience the chemical processes involved in photosynthesis directly, fully understanding the complex system of carbon cycling and energy transformations that occur as a result of photosynthesis requires thinking in rather abstract terms that are quite difficult for young children, as well as for many adults.

Reflecting on Designing a Lesson (10 minutes)

1. Introduce topic for reflection. As a conclusion to the session tell participants that you would like to have them reflect on the process of designing a lesson. They will do this using the structure known as "**Think, Pair, Share.**"

2. Participants think and write about prompts. Ask participants to first "**Think**" about the following questions, and write down their own ideas on a piece of paper.

- What was challenging about this assignment?
- What caused you to think?
- What did you need more information about?
- How will this experience help you to prepare a science activity specifically to address an alternative conception?

3. Partners discuss prompts. After a few minutes tell each student to "**Pair**" up with another student, to discuss and compare ideas.

4. Large group discussion. Lead a class discussion allowing a few partners to share some highlights of their discussion.

5. Explain that it takes more than one experience to address deep-seated ideas. Remind participants that one experience, no matter how compelling and memorable, is not necessarily sufficient to enable students to transform deep-seated alternative conceptions. As they saw in the videos, students often come up with quite ingenious and clever ways to retain their older ideas at the same time as they adapt some aspects of more accurate conceptions. Monitoring students' changing ideas through repeated experience, over time, are part of the path to building more accurate understanding.

Session Handouts

— Common Alternative Conceptions Explained

— Designing a Lesson to Address an Alternative Conception

— Photosynthesis

Common Alternative Conceptions Explained…

(1) Concentration in Solutions

Some students think that the concentration is greater at the bottom of the container in a solution.

Explanation: When a solid is completely dissolved in a liquid, the solution you get has the same concentration from top to bottom. We call the dissolved substance the *solute* and the liquid into which the solid dissolved the *solvent*. Once a solute is completely dissolved, the solute particles can move around freely between the solvent particles and therefore spread out evenly. As a result, the amount of solute per volume of solvent is the same at any location within a solution. Of course, this is only true when the solution has not gone beyond the saturation point, i.e., when the amount of solute added can be completely dissolved.

(2) Temperature and Heat Transfer

Some students think the fabric and metal buckle of a seat belt in a hot car are at different temperatures, because one feels hotter than the other.

Explanation: When you have a metallic material and a non-metallic material under the same conditions, both will reach the same temperature. For example, in a car on a hot summer day, the metal buckle and the seatbelt strap will both be at the same temperature as they equilibrate in the car. While the metal buckle may "feel" hotter when we touch it, our experience is caused by the metal transferring heat more quickly to our finger than the seatbelt strap, not by a difference in temperature.

(3) Insulation Properties of Materials

Some students think that wool generates heat and/or that aluminum foil can be used to insulate heat and cold.

Explanation: If you want to keep something either hot **or** cold, you must insulate it. Insulation is achieved by materials that slow down the rate of heat transfer. Therefore, insulation is any barrier that slows down the rate at which heat is transferred between an object and its surroundings. Metals transfer heat quickly, non-metallic materials like wool or Styrofoam transfer heat more slowly. So tightly packed wool can keep a can of soda cold, but aluminum foil will actually cause the can of soda to warm up more quickly as the heat from surrounding air transfers to the can.

(4) Phase Change and Mass

Some students think that when you freeze water, the ice will be either heavier or lighter than the original sample of liquid water.

Explanation: When you freeze any liquid, including water, only a change in physical state occurs. The liquid neither gains nor loses particles upon freezing so the mass of the solid formed must be the same as the mass of the original liquid. While the number of particles does not change, the solid formed contains stronger forces holding the particles together than the original liquid. This explains why solids hold their shape while liquids can be poured.

(5) Size and Density

Some students think that only big things sink and little things float.

Explanation: Density is a property related to the amount of mass in a fixed volume. Solid objects will float or sink in a liquid depending on their density. When the average density of the object is less than the density of the liquid, the object will float. When the density of the object is greater than the density of the liquid, the object will sink. While big objects can weigh more than little objects, it is the density (mass per unit volume), not the mass alone, which determines whether the object floats or sinks. Objects with low density have more empty space within their structure (i.e., the particles are more spread out). So a big piece of plastic can float (low density) while a small piece of stone can sink (high density).

(6) Gases and Mass

Some students think the reason gases float and are invisible is because they have no mass.

Explanation: Because gases are made of matter and all matter has mass, gases therefore have mass. Like liquids and solids, gases are composed of particles that have mass. While it is true that gases are much less dense than liquids and solids, this is because the particles in the gas are spaced very far apart and the gas is mostly empty space. A helium balloon floats in air because the helium gas is less dense than the air surrounding it. While the helium gas has less mass per volume, nonetheless, it still has mass.

Designing a Lesson to Address an Alternative Conception

Goal: What is the main learning goal of the lesson?

(1) Invitation: What would you do or ask to get students interested?

(2) Discussion of initial ideas: What questions would you ask to draw out their ideas?

(3) Exploration: How would you use materials to get students to explore and think further?

(4) Discussion of concepts: How would you guide students to making sense of their explorations and new ideas?

(5) Application: What challenge or application would you use to give another opportunity to apply their new ideas?

(6) Assessment: How will you know if students have adopted new ideas or understandings as their own? How will they demonstrate their understanding?

Photosynthesis

Photosynthesis is a challenging concept for children to learn. A strong understanding of photosynthesis requires having mental models for understanding energy and how it can be transformed. It also requires an understanding of how organisms transform matter into different molecules through chemical processes, in order to store and use energy. This level of understanding is beyond most elementary school students. But there are simpler aspects of photosynthesis that are accessible for younger children.

Photosynthesis-related concepts taught in elementary school (from simple to more complex)

- Plants need air, water, nutrients, and light.
- The Sun is the major source of energy for the growth of plants.
- Plants use energy from light to make sugars from carbon dioxide and water.
- Plants remove carbon dioxide from the air, and give off oxygen as a waste product.
- The mass of plants is primarily made from carbon dioxide and water.
- Plants transform light energy from sunlight into chemical energy contained in the carbohydrates they produce.
- Plants take inorganic materials from the environment and, utilizing energy from sunlight, transform them into organic matter, which can be used by plants and, ultimately, animals.
- Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment.

Photosynthesis explained at a high school level:

Through photosynthesis, plants convert energy from the light of the sun to energy-storing molecules. These molecules serve as the energy source, not just for plants, but for every other living thing.

Molecules of chlorophyll, found in the chloroplasts of plant cells, absorb photons from the sun. The photons' energy is converted into chemical energy that the plant can use to grow and reproduce. In the course of some rather complicated chemical processes, carbon dioxide and water from the plant cell's surroundings are converted into glucose (or other carbohydrates) plus oxygen. The net effect of photosynthesis is to remove carbon dioxide from the air, produce energy for the plant cell, and give off oxygen as a waste product.

The overall chemical reaction involved in photosynthesis is:

$$6CO_2 + 6H_2O \text{ (+ light energy) } \rightarrow C_6H_{12}O_6 + 6O_2$$

There are two parts to photosynthesis; the light reaction and the dark reaction. In the light reaction, light energy is converted to chemical energy. For this reason the reaction must take place in the light. Chlorophyll and other plant pigments absorb specific colors of light and pass this energy to a chlorophyll molecule where ATP is formed. Cells use ATP to store energy. In the dark reaction, CO_2 is converted to sugar. The dark reaction involves the Calvin cycle where CO_2 and energy from ATP are used to form sugar and subsequently other carbohydrates.

Common Student Ideas About Photosynthesis

Accurate ideas about photosynthesis:

• In their study of 33 eighth and ninth grade students, Stavey et al. (1987) found that 83.3% of the eighth graders and 40% of the ninth graders knew plants absorbed carbon dioxide from the air and over half of all the students identified carbon dioxide as one of the gases included in photosynthesis and respiration of plants.

Inaccurate or incomplete ideas about photosynthesis:

- students think the mass in plants comes from soil nutrients and water.
- students do not associate carbon dioxide with the development of biomass in plants.
- students are not aware that plants respire as they utilize some of the carbohydrates they produce.
- students cannot identify plants as producers or explain what plants produce.
- students think of photosynthesis as a form of breathing in plants.
- students think plants photosynthesize but do not breathe (respire), and only animals breathe.
- students think plants breathe in carbon dioxide and breathe out oxygen during the day and reverse this process at night.

Presentation Slides

— Learning Cycle

— Some Common Alternative Conceptions in Science:

Concentration in Solutions

Temperature and Heat Transfer

Insulation Properties of Materials

Phase Change and Mass

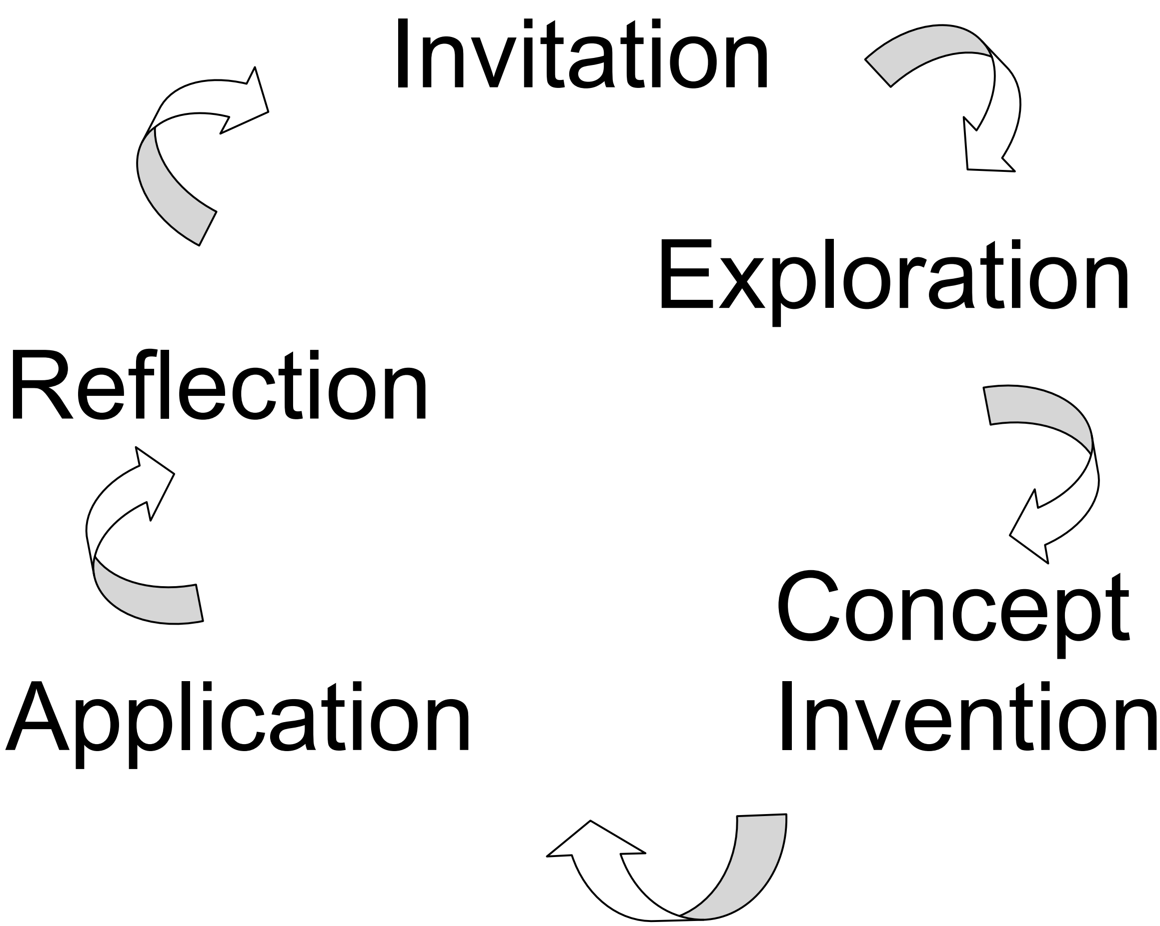
Size and Density

Gases and Mass

— An Impediment to Fully Understanding Photosynthesis

— Designing a Lesson

The Learning Cycle



Some Common Alternative Conceptions in Science…

Concentration in Solutions

If everything is dissolved, is the concentration the same at the top and the bottom?

Some students think that the concentration of a solution is greater at the bottom of the container compared
with the top.

Temperature and Heat Transfer

Are they at the same temperature?

— seatbelt strap vs. metal buckle
— wooden object vs. metal object

Some students think that metals are generally at a higher or lower temperature than other materials in the same location.

Insulation Properties of Materials

Can wool be used to keep things cold? Does aluminum foil insulate?

Some students think that wool generates heat.

Many also think that aluminum foil can be used to keep a soda cold.

Phase Change and Mass

When you freeze a cup of water, does it still have the same mass as when it was a liquid?

Some students think that when you freeze water, the ice will be either heavier or lighter than the original sample of water.

Size and Density

Can little things sink?
Can big things float?

Some students think that the size of an object alone can be used to predict whether it will float or sink.

Gases and Mass

Do gases have mass?

Some students think that gases have no mass.

An Impediment to Fully Understanding Photosynthesis

Many people think that the mass of a tree primarily comes from soil, water, and nutrients.

Designing a Lesson

(1) What is the main goal of the lesson?

(2) How will you address the following aspects of the lesson?

- Invitation
- Discussion of initial ideas
- Exploration
- Discussion of concepts
- Application
- Assessment

Lesson Feedback

- **Share your lesson with another group**
- **Group provides feedback**
- **Switch roles**