PHOTOSYNTHESIS

Project for Foundations of Cognitive Science

Prepared By:

Heena Gulati,
Christine Lee,
Katalina Park

Lesson Plan to teach Photosynthesis

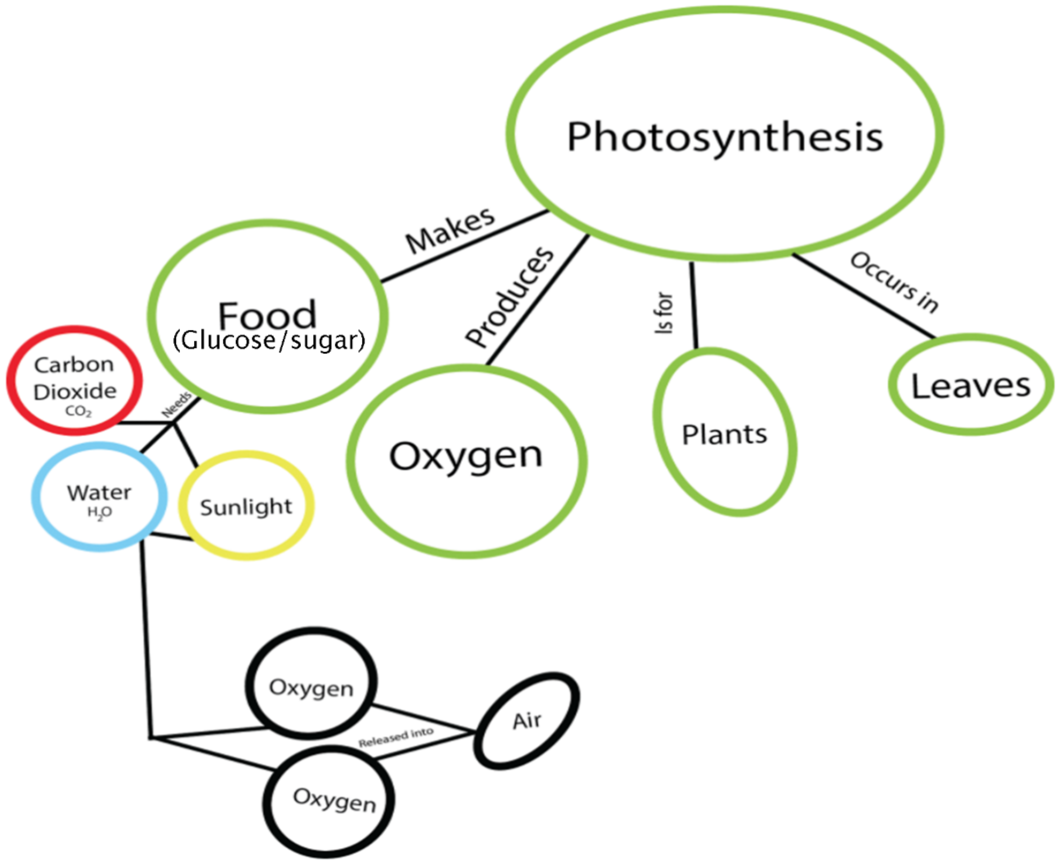
Outline of Lesson Sequence

This lesson is aimed for ninth grade AP Biology, Chemistry or Earth Science class students.

1. *Gain attention of students*: Present on the projector screen/board the word photosynthesis separated to make two smaller words "photo" and "synthesis". Ask students to define what each of the smaller words mean. (*Photo means light, Synthesis means putting together*).
    a. *Make Connection:* Ask students if they have plants or if they know how to feed their plants. Make the connection between the words "photo" and "synthesis" and their knowledge on how plants obtain food.
    b. Prepare students for question and activate prior knowledge: "What do you think photosynthesis means?"

2. *Advance Organizer*: Based on the students' responses to the previous question, "what do you think photosynthesis means?", we will create a relatively general and abstract concept map with the students in order to recall any potential prior knowledge about the process of photosynthesis. Following Mayer's suggestions, the instructors should not include any new information on the advance organizer concept maps (Driscoll, 2005, p. 138).

a.



Preliminary Concept Map of Students' Prior Knowledge (Fig. 1.1):

b. Tell students the process in which plant organisms capture light energy from the sunlight and change it into chemical energy= photosynthesis.

3. *Present Instructional Content*

   a. Present the following question(s): What is the **definition of photosynthesis**?

      i. Present the responses to these question(s) through a collaborative, preliminary concept map (advance organizer Fig 1.1) of the students' responses and factual information.

ii. Ask students to copy down the collaborative concept map in their notes as they will be required to update their concept maps after exposure to more details.

1. "*Plants need food but they do not have to wait on people or animals to provide for them. Most plants are able to make their own food whenever they need it. This is done using light and the process is called photosynthesis. Therefore,* ***photosynthesis*** *is the process by which plants make their own food. We will add more details to this definition and concept map after understanding the process of photosynthesis."* (Photosynthesis for Kids, 2016)

b. Present the following question(s): What involves the process of photosynthesis? What parts or elements are needed?

i. Present the responses to these questions with visuals and conceptual information in the form of a video of photosynthesis: https://www.youtube.com/watch?v=sQK3Yr4Sc_k (Stop video at 9:12)

ii. Ask students to individually make an updated concept map after watching the video for their notes and submit through online assignment on class sites page. See secondary concept map below (Fig. 1.2) for an example of students' updated concept map. **(Falls under learning objective #1: recall definition of photosynthesis).**

iii. Ask students to answer knowledge questions about the video **(Falls under learning objective #1: recall definition of photosynthesis)**.

c. Present the following question(s): Are there multiple stages in the process of photosynthesis? If so, what are they?

   i. Ask students to engage in a simulation to understand two stages of photosynthesis commonly known as the Light Dependent Reactions and the Calvin Cycle. Before starting the actual simulation, we will have a brief pre-training diagram that will prepare students for learning new information by exposing and introducing students to new terms (Fig. 1.6).

   ii. Students will explain the two stages of the process by answering knowledge questions about the simulation.

      1. *<u>Light dependent reactions</u> occur in the thylakoid membrane of the chloroplasts and take place only when light is available. During these reactions light energy is converted to chemical energy. Chlorophyll and other pigments absorb energy from sunlight. This energy is transferred to the photosystems responsible for photosynthesis. Water is used to provide electrons and hydrogen ions but also produces oxygen. Do you remember what happens to the oxygen? The electrons and hydrogen ions are used to create ATP and NADPH.* (Photosynthesis for Kids, 2016)

      2. *<u>The Calvin Cycle</u> reactions occur in the stroma of the chloroplasts. Although these reactions can take place without light, the process requires ATP and NADPH which were created using light in the first stage. Carbon dioxide and energy from ATP along with NADPH are used to form glucose.* (Photosynthesis for Kids, 2016)

d. Present the following question(s): Why is photosynthesis important? Does it affect us directly? How does it affect us and our environment? What would our environment look like without the existence of this process?

i. *Final Assessment*: Ask students to collaborate in groups to develop a 3 page write-up on the implications of photosynthesis and its relationship to our environment. Students must address the processes of photosynthesis (including the chemical makeup), its positive impact to our environment, and the possible detriments without it. Assignment may be submitted by next class.

4. *More Practice:* In addition to the final assessment, students will engage in more practice through multiple module sets on the terms and concepts of photosynthesis on the tutoring system, Cerego. https://cerego.com/sets/728693
5. *Feedback:* Students will be provided immediate feedback on Cerego (tutoring system).

Design Implications

Learning Objectives

1. Students will be able to **recall** the definition of photosynthesis.
2. Students will be able to **explain** the process of photosynthesis, including the Light Dependent Reactions and the Calvin Cycle.
3. Students will be able to **apply** their knowledge about photosynthesis through the use of simulations.
4. Students will be able to **formulate** a projection of what our environment would look like without photosynthesis.

According to Bloom's Taxonomy, the following dimensions can be traced for the above-mentioned learning objectives (Bloom et al., 1956):

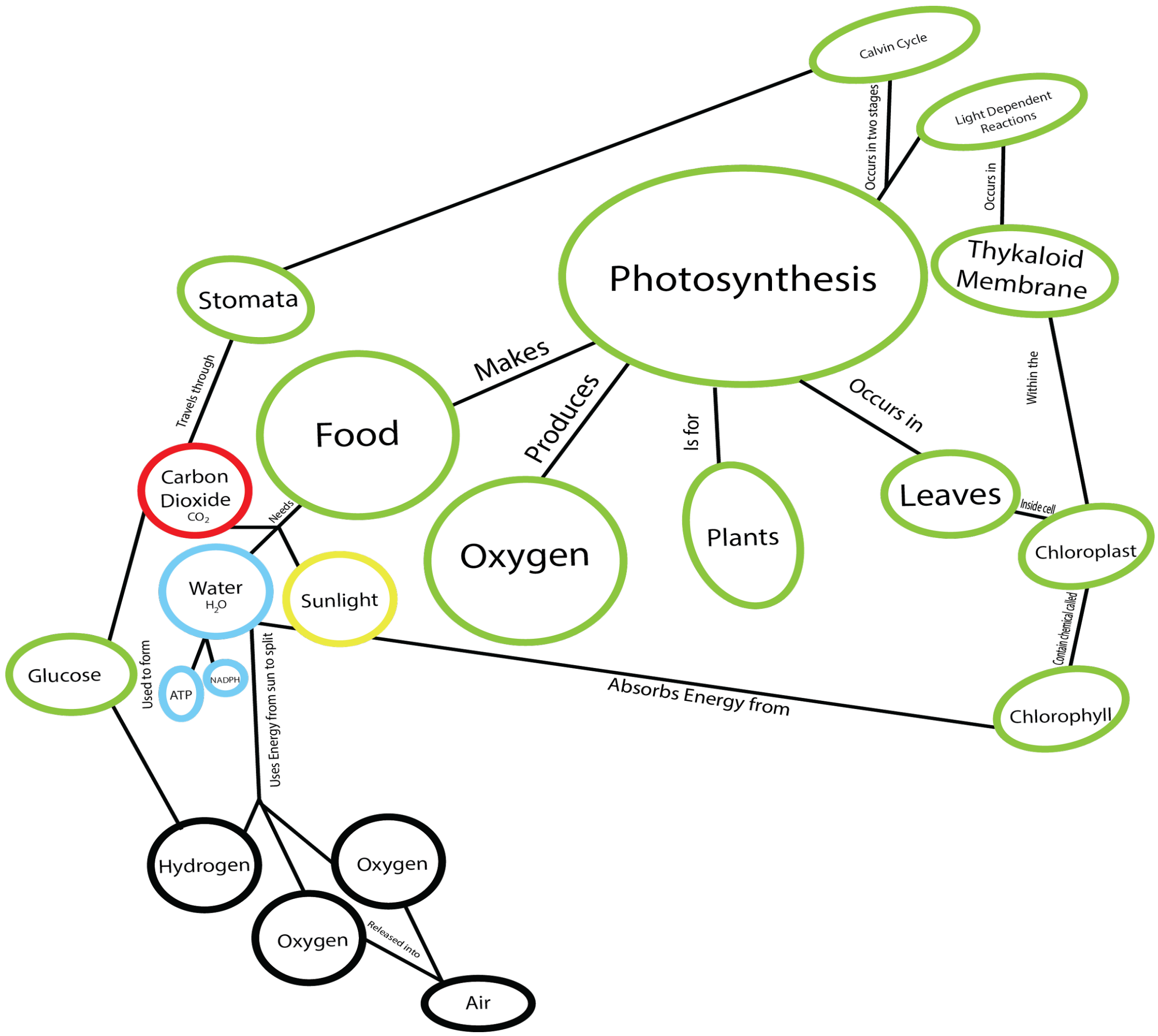
- Evaluating (Objective 4)
- Analyzing (Objective 2)
- Applying (Objective 3)
- Understanding (Objective 1)
- Remembering (Objective 1)

Types of Knowledge

Content	**Type of Knowledge**	**Strategies Used**
Definition of Photosynthesis	Fact, Concept	Preliminary Concept Map (Fig. 1.1), Pre-training diagram (Fig. 1.6)
How Plants make Food	Fact, Process	Preliminary Concept Map (Fig. 1.1), Watching a Video
Process of Photosynthesis ● Light Dependent Reaction ● Calvin Cycle	Procedure (Process)	Video, Updated Concept Map (Fig. 1.2) Supplementary resource/tool - simulation (Fig. 1.8)
Chemical Reaction	Fact, Principle	Discussion
Importance of Photosynthesis	Principle/Rule	Final assessment: Collaborative writing piece
Summary of the Concept	Fact	Cerego (continuous practice)

Concept Map (Fig. 1.2)

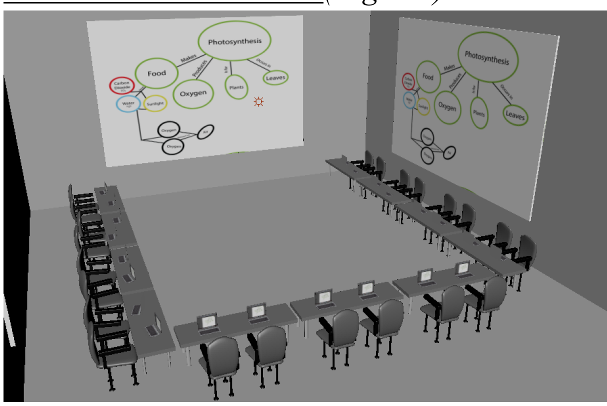
This is the expected concept map of the students' updated learning of the topic. As you can see, this differs from the preliminary concept map. This is to be submitted through the online class site.



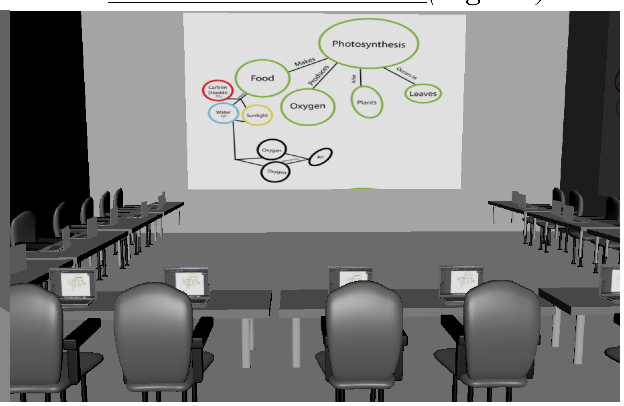
Narrative of Environment

The setting of the lesson takes place in a 9th grade high school science classroom. The arrangement of the classroom is very important to take into consideration. As you can see in Figure 1.3, the students' tables are arranged in the shape of a horseshoe, or the letter "U". This particular arrangement supports both the student-to-student interaction as well as the teacher-to-student interaction. It provides easier access for the students to face the instructional area, for the instructor to interact with and monitor the entire class, encourages discussion and active engagement among students, and promotes relationships between the learners and the instructor. A large screen is at the front of the classroom, allowing the instructor to display the collaborative concept map (Fig. 1.1), the informational video, and the various external sources that the students a required to use (simulation, class site, Cerego). Figure 1.5 illustrates an example of what the student's screen may look like. In this example, a student is following along by creating his or her own representation of a concept map, using *Adobe Illustrator* software.

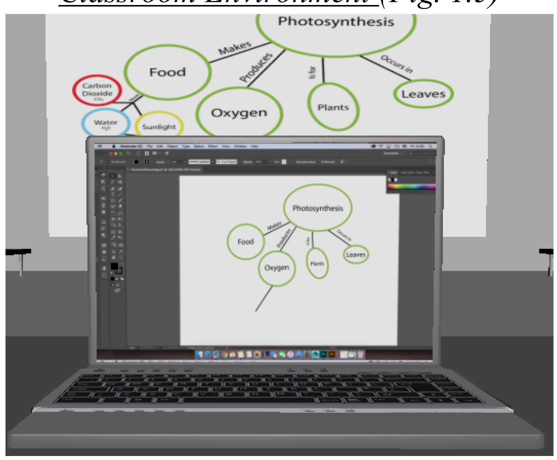
Classroom Environment (Fig. 1.3)



Classroom Environment (Fig. 1.4)



Classroom Environment (Fig. 1.5)



Theories: **Cognitive Load Theory, Multimedia Theory/Principles, Meaningful Learning Theory**

According to the *Cognitive Load Theory* (Driscoll, 2005, p. 71-110), learners can absorb and retain information effectively only if it is provided in such a way that it does not "overload" their mental capacity. This is because our short term (working) memory can only process a certain amount of information (7 ± 2 units) simultaneously (Miller, 1956). It is also proven that the more information and content delivered at once, the more likely that the students will not actually learn what is being taught (Sweller, 2010). Therefore, in our planned lesson and design, we have minimized extraneous load by omitting any unnecessary and distracting information to lessen the difficulty of the learning processes. We have instead put in an effort to maximize students' germane load through the utilization of proper techniques and multimedia tools to facilitate an effective learning process. We have also chunked or segmented the learning material into smaller pieces with clear associations among each other through multiple meaningful activities to help the learners comprehend and retain information more effectively.

According to the *Cognitive Theory of Multimedia Learning* (Mayer, 2009), there are two separate channels (auditory and visual) for processing information and each channel has a limited (finite) capacity. Even though there are separate channels in the working memory for processing visual and verbal material, research has demonstrated that working-memory overload can be debilitating for the learner (Antonenko & Niederhauser, 2010; Barrouillet, & Camos, 2007). Learning is an active process of selecting, organizing and integrating information from these dual channels which is possible if the instructional plan is designed in a way that it incorporates various textual and graphical elements in a balanced form so as not to overload the learner.

As aforementioned, before going in depth about the process of photosynthesis, we will have a brief *pre-training* diagram in order to familiarize learners with new terms and characteristics about photosynthesis (Fig. 1.6). The learners will be able to click on the terms and the terms will initiate a pop-up box that will give brief informative descriptions of what their relation is to the photosynthesis process. The pop-up boxes will disappear if the cursor is no longer hovering over a term in order to reduce clutter and allow the learner to focus on one term at a time. Pre-training should address potential essential overload in order to avoid overwhelming the students (Mayer, 2014, p. 322). Essential overload occurs when the material is too complicated for the learner's cognitive capacity (Mayer, 2014, p. 62). While pre-training is often used for narrated animations, we believe that this technique would prove helpful for our simulation lesson, because it will reaffirm students' prior knowledge or provide students with sufficient prior knowledge in order to move forward in the topic (Mayer, 2014, p. 323). The interface of pre-training is basically a way to provide an opportunity for learners to engage in guided discovery. Directive support steers students in a certain direction, whereas non-directive support helps them perform certain actions but not tell them how and what to do in it (De Jong and Njoo, 1992). It has also been shown that it is important to provide directive support to students and guide their learning process so that they can use their mental resources effectively (Eysink et al., 2009).

Similarly, in order to ensure that learners' loads are reduced, we have implemented *spatial contiguity principle* in our design for the pre-training diagram. Following the spatial contiguity principle, we have placed the text near the corresponding graphics. Hence, learners won't have to search the entirety of the page in order to make connections between the text and the graphics. By looking at our diagram, learners should be able to note that sunlight is the source of a plant's energy or that the process of photosynthesis occurs in the leaf of a plant."The theoretical rationale for the spatial contiguity principle is that it reduces the effort required to scan back and forth between the text and the graphic" (Mayer, 2014, p. 283).

In order to optimize information acquisition, our simulation uses the *personalization principle* discussed in Mayer's CTML model (Fig. 1.7). Students will have the option of working with an agent, speaking in the form of informal conversation. This technique will allow students to feel as though they are working with someone, "In a personalized version of the game, the agent speaks in an informal, conversational style, addressing you as if you were both sharing the learning experience" (Mayer, 2010, p. 158). By speaking directly to the learner and using personal pronouns like 'you', the personalization principle finds that personalized agents are likely to generate more motivation in learners than non-personalized agents as they foster environments where learners feel like participants, rather than just observers (Mayer, 2010, p.160). In our particular simulation, the agent will explain how different lighting situations will affect plant growth. For example, if the learner simulates photosynthesis under green lighting, but doesn't quite understand why green lighting is less effective than other types of lighting, the learner can call on the agent, who will give an informal explanation of how green wavelengths are reflected, rather than absorbed by the plant. The agent may also ask questions to prompt learners to reflect on what they've learned, like "Why do you think that green lighting is reflected off plants?". Mayer notes that, in comparison to non-personalized learning conditions, personalization often results in more meaningful learning and better comprehension (Mayer, 2010, p. 159).

In addition, our simulation also aims to create deeper learning by implementing the *redundancy principle.* While the simulation is not an animation, we are presenting learners with graphics and optional narration (through the agent) rather than including on-screen text about photosynthesis. Thus, we are "eliminating the redundant on-screen text" (Mayer, 2014, p. 282). By doing so, we can attempt to reduce extraneous processing that might otherwise be caused by additional on-screen text that the user would have to process in both the visual and auditory channel (Mayer, 2014, p. 283).

Additionally, our designed hypothetical simulation is geared towards focusing the learner solely on the light-dependent process of photosynthesis. We use the *coherence principle* in an effort to reduce any extraneous or irrelevant material (Mayer, 2014, p. 280). In the example provided below, the simulation only allows the learner to experiment with different lighting conditions in order to see how different lighting affects photosynthesis. Our design is minimal, as we only included images and text that we deemed necessary, purposeful, and relevant to the instructional goal. In our example simulation (Fig. 1.8), we wanted to eliminate extraneous text by creating color coded boxes in order to illustrate to learners that these specifically colored boxes indicate what color lighting the plant will receive. We believe that this design decision is more efficient than having arbitrarily colored boxes labeled with text saying 'red', 'green', etc., as it will decrease the probability of extraneous load by eliminating unnecessary text. We have also decided to exclude other factors that might affect the process, such as plant type, because it would be superfluous to this specific example and we want to reduce any potential extraneous processing.

The simulation, Leaflab, also follows Principle 5 of Richard Lowe and Wolfgang Schnotz's *Animation Principles in Multimedia Learning*. According to the fifth principle, people learn better from an animation when interaction opportunities accord with aims and learner expertise (Lowe, Schnotz, 2014). As the simulation allows students to change parameter values and see what happens based on their actions, learners can better focus on the macro and micro-dynamic information. Furthermore, the design of user-controllable animations is purposefully limited so that it tailors to the learner's prior knowledge and information processing capacities. Simulations are proven to be most effective when incorporated in traditional lesson plans, especially with learner control and proper guidance and feedback (Domagk, Schwartz and Plass, 2010). We have used simulations as a supplementary learning tool so that learner can reflect on their learning and apply their understanding of the concept. This ensures that the information is transmitted from one memory system to another and retained for a longer period of time.

Another theory that applies to this lesson is *Ausubel's Meaningful Learning Theory*, where Ausubel suggests that advance organizers may foster meaningful learning by presenting them prior to new instruction. By doing so, this helps learners to make connections with their existing prior knowledge with the lesson's prerequisite knowledge (Driscoll, 2005). Advance organizers also provide the necessary scaffolding for students to either learn new and unfamiliar material or to integrate new ideas into relevant ideas. Hence in this lesson, students are asked to create general/abstract concept maps on photosynthesis. This allows for students to incorporate their prior knowledge with the lesson's prerequisite knowledge, and for the instructor to determine how to scaffold from this point on. New knowledge can be acquired and 'subsumed' through advance organizers and connected to the prior existing schemas (Joyce et al., 2000). According to the Schema Theory, concept maps serve as effective advance organizers for learners as they are able to connect one concept to the other which also facilitates the speedy retrieval of information at later stages (Anderson, Yilmaz, & Wasburn-Moses, 2004; Baxendell, 2003; Bransford, 2004). By stimulating schema, students can link prior knowledge with new concepts and advance organizers provide a kind of "mental scaffolding to learn new information" (Hassard, 2005, p. 1). Both Bransford (2004) and Anderson (2004) agree with Ausubel that advance organizers are an excellent way to activate and build schema prior to the actual learning of new material by students. This lends support to our decision of including a concept map to teach the important conceptual indicators of photosynthesis.

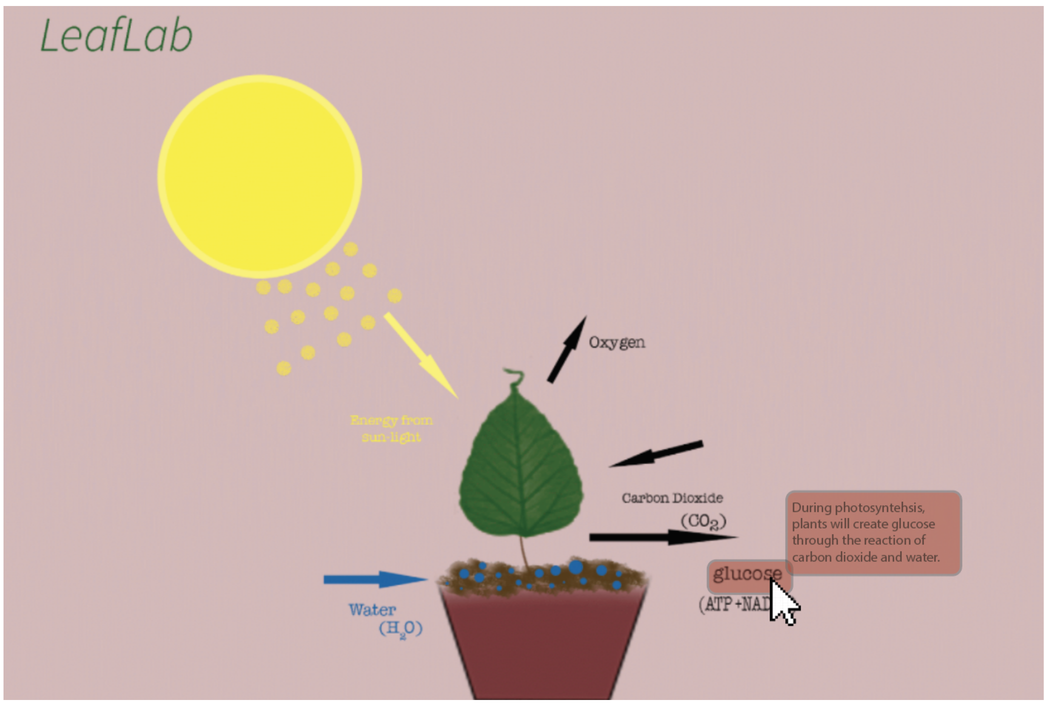
According to the *Cognitive Information Processing Model* by Schunk (1996), there is a memory system comprising of three basic components - sensory memory, short-term memory and long-term memory. Working memory and short-term memory are temporary storage systems, whereas long-term memory is for permanent storage of information (Atkinson and Shiffrin Model, 195. The processes that help the transfer of information from one stage to the next are attention, rehearsal, chunking, encoding and retrieval. Our lesson plan has been designed in a way that all the techniques used in can be mapped to these processes which have been explained in the following paragraphs.

As explained in the first step of the lesson, the questions are presented to students in order to gain their attention. The questions will arouse students' curiosity so that they are able to focus their attention on the topic being presented. The advance organizer and the concept map will help in the encoding process.

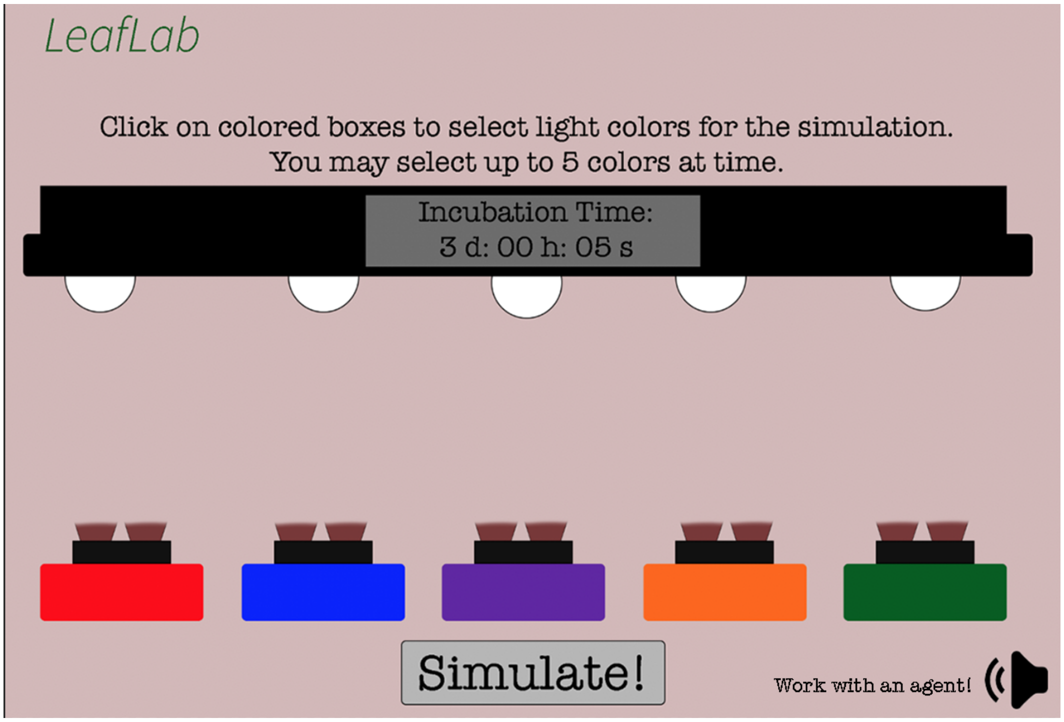
According to the Miller's formula, short-term memory can only process 7 ± 2 units of information at a time (Miller, 1956), thus, our lesson will present information in small chunks. It has also been our endeavor to provide conceptual information in different visual formats such as a text-based concept map supplemented with videos to explain processes of photosynthesis so that students can rehearse the information learnt and retain it in long-term memory. In order to ensure the information is retrieved, several strategies such as Cerego and collaborative writing piece have been included in our lesson plan so that the knowledge is deeply encoded and learners will be able to apply it to different contexts.

All the above explained theories explain the instructional process of our lesson to teach the students about photosynthesis.

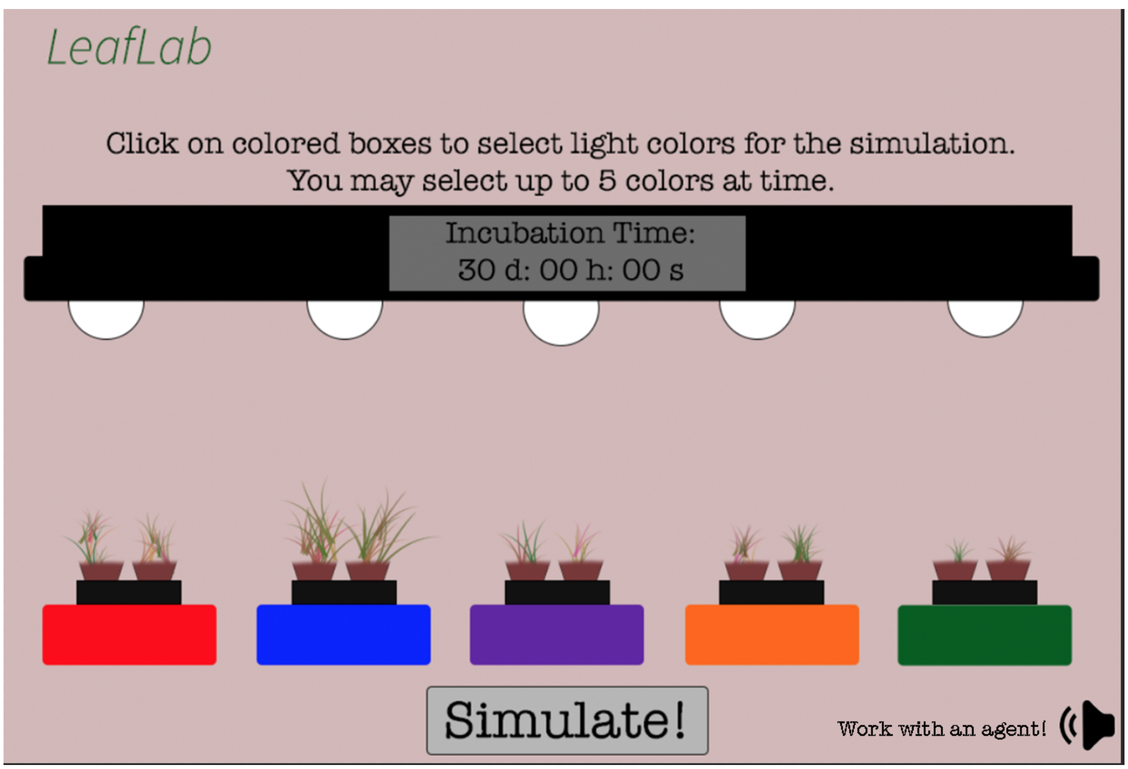
<u>Pre-training interface</u> (*Fig. 1.6)*



Example of photosynthesis simulation interface showing different lighting options_(Fig. 1.7)



Example of simulation interface showing effects of light on photosynthesis after the plants are exposed to light over a significant time period (Fig. 1.8)



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