“Understanding the Quantum Orders, Patterns, and Superpositioning in Effect on the Process of Photosynthesis and Plant’s Growth”

Maydafe Cherryl A. Clark

Teacher Leadership Shilgozhoo Institute (TLSI)

2024

Author Note:

Maydafe Cherryl A. Clark, is a 7th Grade STEM teacher? STEAM Coordinator of San Carlos Middle School, San Carlos Arizona. Correspondence about this curriculum unit can be addressed to Maydafe Cherryl A. Clark, 255 Holly Road Globe AZ 85501. Email contact: mcherrylclark@gmail.com

Acknowledgement:

I would like to acknowledge the people behind the success of my curriculum writing - Ms. Korinne Bullock, my principal who'd been so supportive to my journey, to my colleagues who never cease in inspiring and motivating me to finish my curriculum unit until it gets done and of course to my husband - Kenneth Clark who'd been a wonderful best friend and partner in life who'd supported me morally and spiritually to be successful in whatever journey I have been into.

Introduction

My unit titled, "Understanding the Quantum Orders, Patterns, and Superpositioning in Effect to the Process of Photosynthesis and Plant's Growth" represents the second phase of my TLSI fellowship, which is an innovative model for curriculum development aimed at fostering an inclusive learning environment for a diverse student body. The initiative emphasizes the creation of educational materials that cater to a wide range of cultural backgrounds of Apache and learning styles, ensuring that all students have the opportunity to succeed and thrive in their academic pursuits. Through this fellowship, I will help my learners be equipped with the tools and strategies necessary to design and implement a curriculum that not only meets the varied needs of their students but also prepares them to become global citizens in an increasingly interconnected world. Environmental education enhances critical thinking, problem solving, and effective decision-making skills and teaches individuals to weigh various sides of an environmental issue to make informed and responsible decisions.

Our students have little or no background about quantum technology and photosynthesis; however, there are some misconceptions that need to be addressed involving the superpositioning and patterns of the changing climate around San Carlos, Arizona, especially.
Quantum effects are a difficult topic to teach with the students, especially when they don't have a background in them from their prior grade level. The process that powers much of life on Earth, photosynthesis, is so finely tuned that just one photon is enough to kick it off. Scientists have long suspected that photosynthesis must be sensitive to individual photons, or particles of light, because despite the way it dominates our days, the sun's light is surprisingly sparse at the level of individual plant cells. Learners today should learn about quantum computers as part of their middle school education. Quantum computing technology is rapidly maturing, and we are on the brink of a technological revolution. Quantum computers work with qubits instead of the much more familiar binary digits, or bits, and while the bits in our current electronics can only have the value of either a 0 or a 1, a qubit can be both at once. Thanks to this property, among others, quantum computers can perform faster and more precise computations than classical computers. This means they should be particularly well-suited to tasks relying on probabilities and optimization, such as creating a new complex molecule to develop a material with specific properties.
On the other hand, photosynthesis, the process by which plants and other organisms convert light energy into chemical energy, involves intricate biochemical steps. One recent study confirmed that this reaction can be initiated by the absorption of a single photon, bridging the realms of quantum physics and biology (CITATION of current study).

I will be using an extensive multi-layered curriculum development process to guide the creation of the materials and assessment, to ensure quantum is integrated in curriculum development. This process includes using quantum technology research, experiments, gamification techniques, project-making through investigatory projects and reviews, which will help me integrate STEM and place-based learning in my curriculum to connect to the San Carlos Apache culture.

Some activities will reflect several methods of teaching environmental literacy and values. Each activity attempts to guide the learner through the process of awareness, understanding challenge, motivation, and action using active involvement and hands-on experiences. I will combine the nanotechnology and computing techniques activities with academic standards for the 7th grade

science class and assess the subject areas that correlate with the Next Generation Science Standards. Teaching through place-based techniques will help my students learn about the concepts, understanding the breadth and the more in depth about the probability of growing various plants in San Carlos, AZ, through quantum phenomena including superpositioning, orders, and patterns. Place - based techniques, often referred to as place-based education or learning, are instructional approaches that use the local community and environment as a starting point to teach concepts with key aspects on local context like culture of Apache, history and involving community education to make learning more relevant and engaging for the students. The place-based programs emphasize sustainability and environmental awareness. I am teaching my students to appreciate and care for their local ecosystems.

A conceptual framework through project learning techniques will cover the activity guide and other curriculum materials under the five major themes in my class:

A. Quantum Coherences: Ultrafast spectroscopy studies reveal evidence of quantum coherences (superpositions of quantum states) in photosynthetic light-harvesting complexes.
B. Quantum Superposition: In photosynthesis, light-gathering macromolecules exploit molecular vibrations with no classical equivalents. These vibrations exist in a superposition of states, allowing efficient energy transfer
C. Place-Based Approach and Project-Based Approach: Consider how the specific environment (place) affects quantum coherence and superposition within plant cells during photosynthesis. Factors like temperature, humidity, and local interactions play a role.
D. Quantum Sensors: Develop sensors based on quantum principles to monitor plant health, optimize light exposure, and enhance photosynthesis efficiency.
E. Gamification Techniques: Allowing the kids to understand can make learning quantum entanglement engaging, interactive, and accessible for my students.

In this unit, I encourage discussions through debates in my class to explore different configurations and record observations that illustrate the principles of quantum entanglement through real-world applications. While I am eager to introduce the involvement of quantum mechanics in plant growth, I would like to recommend to my students to observe the effects of measurements on the entangled state. I will guide my students to use a quantum simulation platform, which will allow me to explain the basics of quantum mechanics.

To make the learning process engaging, I will introduce interactive activities such as the tic-tac-toe game, the Plinko quantum board, and the use of polarizing filters. These activities will help students understand how a single photon reaches different parts of the plant necessary for its growth. By combining debates, hands-on experiments, and simulations, students will gain a deeper understanding of both quantum mechanics and its applications in biology.

Context

School Demographic

San Carlos Community is a place where about 4,000 people live in Gila County, Arizona. It is part of the San Carlos Apache Indian Reservation, a vast area of over 1.8 million acres in the southeast of Arizona. San Carlos Community is the main hub and administrative center for the reservation.

San Carlos Community is a census-designated place in Arizona that is located within the San Carlos Apache Indian Reservation. Despite the oppression and violence, they faced, the Apache people resisted and fought for their freedom and rights. They also preserved and developed their culture and identity through various forms of expression and organization.

Today, the San Carlos Apache Tribe is a sovereign and progressive nation that provides for its members and honors its heritage. The San Carlos Community is a place of pride and hope for the Apache people.

School Demographic

San Carlos Middle School aims to provide a quality education for its students that respects their cultural heritage and prepares them for future success. The school's mission states: "San Carlos Middle School will provide an environment that fosters academic excellence, cultural awareness, and social responsibility for all students." The school's vision statement states: "San Carlos Middle School will empower students to become lifelong learners who are respectful, responsible, and productive citizens."

I serve as a Science/STEM teacher at San Carlos Middle School, a public school in San Carlos, Arizona. The school belongs to the San Carlos Unified School District, which educates the students of the San Carlos Apache Indian Reservation. The school serves about 378 students from grades 6 to 8 and provides a curriculum that covers language arts, math, science, social studies, physical education, and electives. The school also features a library, a cafeteria, a gymnasium, and a computer lab. The Brave is the school's mascot, and its colors are red and white.

San Carlos Middle School offers various programs and activities for its students, such as athletics, clubs, field trips, dances, and ceremonies. The school organizes field trips to places such as Point of Pines Lake, Phoenix Zoo, Arizona Science Center, and Grand Canyon University.

San Carlos Community is a place in Arizona that is located within the San Carlos Apache Indian Reservation. The community and the reservation have a history of living of interconnectedness like many Indigenous cultures emphasizes the idea that everything in the universe is related. This is similar to the concept of entanglement in quantum physics where particles remain connected over vast distances.

The knowledge of ecosystems among the San Carlos Community may vary depending on their education, experience, and interests. However, some sources of knowledge that they may have are:

The School

The students at San Carlos Middle School, which serves the San Carlos Apache Indian Reservation, may learn about fire and carbon cycling in their science curriculum. The school also offers various STEM activities that enhance their learning and skills, such as building a solar oven,

a pollution detector, or a balloon car. San Carlos Middle School participated in the Regional Science Fair and Arizona State Science Fair competitions. These activities enhance the student's ability to hone the scientific processes and inquiry-based learning among our students.

Science Fair

The school also participates in the Regional and State Science Fair, which is open to all students in grades 5-8. The science fair allows students to conduct experiments, investigations, or demonstrations on topics of their interest and present their findings to judges and peers. This encourages students to apply the scientific method, use critical thinking, and communicate effectively.

Traditional ecological knowledge and Interconnectedness of Apache culture

The San Carlos Apache tribe may have traditional ecological knowledge that has been passed down from generation to generation through oral stories, ceremonies, arts, and crafts. This knowledge may include information about photosynthesis, such as how plants grow and survive through vital necessities like soil, water, and climate and sunlight. This knowledge may also include information about carbon cycling matter, such as how plants use carbon cycling, such as how plants use carbon dioxide for photosynthesis; how animals use carbon for respiration, how organic matter decomposes and releases carbon, and how charcoal can store carbon.

In Apache culture, the belief that all things are connected mirrors the quantum idea of entanglement. This interconnectedness is seen in their respect for nature and the environment, recognizing that actions in one part of the ecosystem affect the whole.

Scientific Research about Photosynthesis and Quantum Technology

The San Carlos Apache Tribe may also have access to scientific research that has been conducted on photosynthesis and its relationship in their ecosystems by external researchers or by their own tribal members. For example, some studies have examined how fire frequency and type regulate the response of soil carbon cycling and storage to fire across soil depths and ecosystems using a meta-analysis. Other studies have investigated how fire affects soil respiration, soil carbon content, soil microbial communities, soil enzyme activities, and soil physicochemical properties using field experiments. These studies may provide more detailed and quantitative data on fire and carbon cycling in their ecosystems and lead to plant’s growth in the vast land of San Carlos, AZ.

Science Curriculum

Our school offers a curriculum that includes science, technology, engineering, and math (STEM) subjects for its students in grades 6-8 aligned to the Arizona State Standards. The school also provides various opportunities for its students to engage in STEM activities that enhance their learning and skills. Among the many STEM activities in which the students in San Carlos Middle School participate are

Science Fair

The school participated and won various categories at the Regional and State Science Fair, which is open to all students in grades 5-8.

The school conducts a STEM activity that involves building a solar oven using a pizza box and other common materials. The solar oven uses the sun's energy to heat up food items, such as marshmallows or hot dogs. Pollution detector: The school participates in a STEM activity that involves building a pollution detector using a circuit board, an LED light, and a carbon monoxide sensor. The pollution detector measures the amount of carbon monoxide in the air and displays it using different colors of light.

Robotics Club

The school has a robotics club that meets after school and teaches students how to design, build, program, and operate robots using LEGO Mindstorms kits. The robotic club also competes in local and regional robotics competitions, such as FIRST LEGO League and VEX Robotics.

Science Projects and competitions

The school conducts a STEM activity that involves building a solar oven using a pizza box and other common materials. This solar oven uses the sun's energy to heat up food items, such as marshmallows or hot dogs. The school participates in a STEM activity that involves building a pollution detector using a circuit board, an LED light, and a carbon monoxide sensor. The pollution detector measures the amount of carbon monoxide in the air and displays it using different colors of light. Another STEM project is the balloon Car. The school conducts a STEM activity that involves building a balloon-powered car using recycled materials, such as cardboard, plastic bottles, straws, and rubber bands. The balloon car uses the air pressure from the balloon to move forward. These examples of the science activities performed by the students in San Carlos Middle School in terms of participation in STEM help the students learn about various STEM concepts and skills while having fun and being creative and join the competition in Regional and State for the Science Fair. For the first time, I mentored and coach my students for the school year of 2023 and won several categories in Science Fair competitions like, environmental science *Utilizing the Agave roots into "Tus" (jar)*, Chemistry category, *"Feasibility Study of Banana Peels into a Organic Banana Fertilizer",* Physical Science*, " Investigating the Food Safety and Reliability Using Various Common Can Openers*, Engineering category, *""Exploring Gas Density Effects on Two Different types of Flying Orbs Performance - A Simulation Approach", and* behavior Science, *Analyzing the Impact of Note Taking and Research - Based Methods on Student's Engagement in Learning 7th Grade Science in SCMS.*

International Competition

This year San Carlos Middle School won an International honorable mention for Girls Who Game Minecraft Education Competition, participated by 133 countries around the world. I helped these students with varying academic abilities and individualized learning plans. Some of my students are academically challenged, while others are highly academically accomplished. This year, I have noticed that some of my students are more socially inclined and participative than in previous years. Although I don't assume that my students will be able to grasp an understanding of the context of the lesson, I am always prepared to give instructions suited to their needs according to their learning styles.

Rationale

Teaching photosynthesis to my students can be a fun and interactive experience. I want to start with the basics before delving into the intricacies of photosynthesis. Establish some foundational knowledge essential for students' learning by explaining the process of photosynthesis in simple terms and discussing its importance in the ecosystem. I will also incorporate the use of interactive tools in my classroom by using educational resources such as videos, colorful diagrams, and virtual labs, in order to help my students visualize the process of photosynthesis and better understand its various components. I will include that conducting experiments through hands-on experiments can be a great way to reinforce the concepts learned in photosynthesis lessons, like actual project making through planting under different conditions to see how they respond to changes in light, water, and nutrients. Lastly, use the topic in real-life examples through gamification activities and project-based learning through creating models of maze and tic-tac-toe.

Photosynthesis occurs all around us, so it's easy to find real-life examples to illustrate the concepts learned in class. We can have a nature walk and point out different plants and trees that are undergoing photosynthesis, connect it with games so it will become interactive, and all students will have the opportunity to enjoy and get involved.

Through continuous review, students can surely find the importance of understanding the concepts learned in class and being able to complete quizzes or worksheets in application of quantum mechanics to the process of photosynthesis. I also aimed to help my students understand deeply how superposition, patterns, and order of lights affect the growth of the plant in the process of photosynthesis.

Some STEM projects that I am looking forward to coming up in the middle of our topics are creating a project related to quantum mechanics, such as using Minecraft education in building landscapes, understanding qubits and showing plants growing in certain coordinates, plinko - quantum board and growing plants using polarage or polarizing filters.

Since my students in the classroom are diverse. Some may work incredibly hard but still struggle every day to perform on their assignments. I have also seen some students who typically get labeled as "difficult" light up the minute they walk into the room and basically just get bored during the science class. In order to support these students, I will provide flexibility to my lesson to help them achieve their own capacity to do STEM projects where my students can finish one project in a quarter related to photosynthesis, cycling matter and quantum technology.

I always believed project-based learning approach integration into STEM is critical because this approach provides an opportunity to bring back creativity and increase student achievement at the same time. As a Science and STEAM coordinator in San Carlos Middle School, I can say that I am brave enough to look beyond traditional approaches (yield very little result) because I want to say that students become active participants in their learning when the arts are intentionally integrated and provides an opportunity for students to own learning and have some vested interest in their own success.

The students will use an interactive model to further understand the patterns and superposition of the light energy absorbed by plants essential for their growth. Thus, this will also allow them to venture further on the possibility of forming patterns through games and make some projects

related to quantum mechanics involving how light passes through the process of photosynthesis. The variables are displayed with graphic representations, making it accessible to students who are better visual learners.

Background information as well as questions for pre-activity, during, and post-activity are included. I include supplemental links to improve their personal understanding or to enrich the lesson for students who have the ability to go further through journal writing and make a reflection of what they have learned from my class in relation to quantum technology and understanding plant growth.

This unit focuses on understanding patterns, superposition of the photons to the plant, showing them the flow of energy into and out of various ecosystems, and defining the process of photosynthesis in my science subject. It would further lead them on the ways to understand the concept of quantum mechanics.

My curriculum is organized into six sections, that includes ecological knowledge, an introduction to quantum mechanics and its principles, quantum coherence through experimental evidence, application of knowledge to the real-world (plant growing), interactive and hands-on activities (gamification techniques and simulations using Phbet apps) and Assessment and evaluation through projects, presentations and lab reports.

Sections are divided into topic areas that correspond directly to the conceptual framework, and the major purpose of having students study ecology related to photosynthesis and relates to the exploration and understanding of quantum mechanics will help them access qualitative data regarding the optimal conditions of the plant receiving sunlight from various angles using polarage or polarization filters, understanding the conditions for the cycling matter, specifically the soil of surrounding the area of San Carlos Middle School,

I would like to help this curriculum realize through thorough research about the implications of quantum mechanics in biological systems and describe the flow of energy matter among living things in the ecosystem through classroom debates and discussions involving quantum mechanics and technology aligning through the Science standards.

Additionally, I would like to help my students develop analyzing the data and visualize the process of photosynthesis that provides experience to help students understand the intricate relationship between quantum mechanics and photosynthesis and finally help them put these into practice of analyzing and interpreting data in application of Engineering and Science processes.

Why did I choose this topic?

Providing a clear connection and promoting deeper connections to content, as it is an inquiry approach that requires time for students to make connections between the problems they are facing, to think about what they already know, and to develop lines of inquiry for new content they “need to know,” especially connecting quantum mechanics to the content about photosynthesis.

According to the Buck Institute for Education (BIE.org) they often refer to project-based learning as a “deep dive” into content. Its focus on depth over breadth helps students develop deep understanding of content both in specific disciplines and fosters the inquiry skills necessary for

success in STEM. Through the project-based approach, it fosters the development of both the analytical and creative thinking necessary for innovation. For example, a project-based approach to learning might ask the students to consider How can we create a project showing patterns on how lights travel to the parts of the plants? The project-based learning approach supports the questioning skills with graphic organizers, KWL charts, and 5 Whys organizers.

As a result of the questioning, students' work may focus on finding ways to make existing options in developing the ways to use the creative project that includes the study of the plant locally grown in the area of San Carlos and use a project-based approach to draw patterns on how a single photon gets into the plants. Thus, the real-world problems and challenges using a project-based approach required analytical thinking and creative problem solving needed for success in STEM.

Furthermore, project-based Learning fosters reflection and metacognition, as it said, “we don’t learn from experience; we learn from reflecting on experience. (John Dewey). It is recursive and requires extensive reflection for successful solution development. The student would likely develop ideas and implement them as they constantly ask the questions like, *what do we know? what do we need to know? what do we think will happen and why? what do we think will happen and why? And what really happened? Where did our thinking go wrong?*

The reflective nature of the project-based approach in my topic helps students make the connections between content they are learning and how it impacts their thinking and problem solving. Such as utilizing the knowledge helps them understand not only what they are learning, but how they learn quantum. This allows them to use the nature-journaling activity, gamification, and project-based learning activity in every project they finish in this curriculum. These would enhance their deeper connections to photosynthesis content, connect ideas across disciplines, and build the questioning, thinking, and metacognitive skills necessary for success of the topic about probability of various patterns formed using dice, plinko board, or tic-tac-toe board they created to deeply understand quantum mechanics. I am also considering gamification like random walk or “follow the light activity game.”. In addition, understanding and enhancing scientific literacy in teaching STEM helps my students understand the fundamental principles of quantum mechanics that govern the behavior of matter and energy at the smallest scales.

As part of the Apache community, students will be informed citizens on the basic understanding of quantum mechanics who can engage with and understand scientific advancement and their implications for society. This will relate to the future career opportunities through the early exposure to quantum mechanics that truly inspire students to pursue careers in the STEM field, particularly in emerging areas like quantum information science and engineering.

While I am considering a diverse workforce, I believe that introducing quantum mechanics in the middle school can help create a more diverse and inclusive pool of future scientists and engineers, addressing the current lack of diversity in quantum-based related fields.

In this curriculum, I will make an effort to make quantum mechanics an interesting, fascinating counterintuitive concept like superposition, entanglement, and wave-particle duality that captivates the student’s curiosity and interest, through gamification techniques and interactive simulation, students can make learning quantum mechanics fun and engaging to explore complex topics.

One of the many approaches that I am proposing to implement in my project-based learning curriculum in relation to photosynthesis and quantum mechanics is to implement minecraft education focusing on presenting the process of photosynthesis through the flow of the photons to the process of the photosynthesis, nature-journaling, and data collection through notetaking.

II. Content Objectives

The content objectives in my unit curriculum help bridge the gap between biology and quantum physics, offering a deeper insight into one of nature's most efficient processes. These include the following aspects in teaching:

a. Basic Principles of Photosynthesis Comprehend the fundamental chemical process water + carbon dioxide + light = glucose + oxygen recognize the role of chlorophyll and other pigments in capturing light energy.
b. Quantum coherence

   Learn how quantum coherence allows excitons (energy packets) to travel efficiency through photosynthetic apparatus using polarized film in growing plants.

   Understand that excitons can traverse multiple paths simultaneously optimizing energy transfer

c. Role of Photons and Excitions

   Explore how photons (light particles) are absorbed by chlorophyll molecules creating excitons.

d. Energy transfer mechanism

   Investigate the mechanisms by which energy is transferred within the photosynthetic system, including the role of quantum coherence in preventing energy loss.

   Using the Plinko - Quantum board students can examine the energy from excitons used to convert carbon dioxide and water into glucose and oxygen.

e. Experimental evidence

   Through review of experimental studies, students can provide evidence for quantum coherence in photosynthesis, such as persistence of quantum beating signals at physiological temperatures and rays of the sun and understanding that a single photon is all that matters to show its relationship to the process of the photosynthesis.

Applications and implications

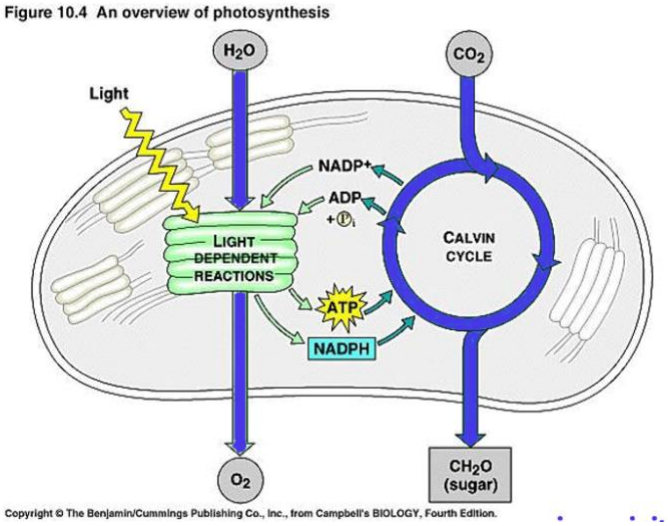
As a Science teacher I would like to begin with the potential applications of understanding photosynthesis at the quantum level, such as understanding plant growth during the biochemical processes of the photosynthesis application of quantum technology like polarage or polarization filters.

Understanding Photosynthesis

It is the process by which green plants and certain other organisms transform light energy into chemical energy. During photosynthesis in green plants, light energy is captured and used to convert water, carbon dioxide, and minerals into oxygen and energy-rich organic compounds.

Plants are called autotrophs because they can use energy from light to synthesize, or make, their own food source. Many people believe they are "feeding" a plant when they put it in soil, water it, or place it outside in the Sun, but none of these things are considered food. Rather, plants use sunlight, water, and the gasses in the air to make glucose, which is a form of sugar that plants need to survive. This process is called photosynthesis and is performed by all plants, algae, and even some microorganisms. To perform photosynthesis, plants need three things: carbon dioxide, water, and sunlight.

Figure 1



Apache culture and relatable concepts

Like many Indigenous cultures, interconnectedness and the idea that the universe is related, which is the similar concept of entanglement in quantum physics. In Apache culture, the belief that all things are connected mirrors the quantum idea of entanglement with respect for nature and the environment recognizing that one part of the ecosystem affects the whole.

Additionally, non-linear thinking, wherein quantum physics challenges cause-and-effect thinking like Apache storytelling and worldview, which often embrace a more holistic and cyclical understanding of time and events matter. So as the sunlight, its appearance early in the morning and receiving its rays direct to the ground and to plants matter delves into a more in-depth understanding of how plants grow through the various angles of sunlight to the different parts of the plants.

Teaching Strategies

I believe that STEM isn't meant to replace traditional teaching; it is not meant to be done all the time. San Carlos Middle School, needs to teach math facts and science concepts, but there are ways to bring other disciplines in and incorporate STEAM, a project-based approach, integrating the nature-based learning project activities into quantum mechanics.

In this curriculum, I am introducing photosynthesis and local plant growth in the San Carlos Reservation Area. My students will have opportunities to build and create a Plinko board, use polarage or polarization filters in the application of STEM integration in my lesson, foster the engineering design process while growing plants and understanding the process of the photosynthesis, and do a daily nature-journaling activity with my students that includes the symmetry or a civic act about plant growth, delving into the concepts of the process of the photosynthesis, and deeply understanding the concepts on how the flow of photon reaches the plant for its growth during the process.

STEM (Project-based approach)

In Science Ecosystems lessons, which will begin in the month of September, we will focus on studying the physical behavior of the plant's growth in the process of photosynthesis in the application of Polarage or understanding the superpositioning and coherence through analyzing the quantum effects in the growth of the plant.

a. Students investigate the biotic structure of the local plant, use software to design, create a project like the plinko board, and show several probabilities on how the patterns of the photons get into the various parts of the plant.
b. Students will learn to collect data through spectroscopy to measure the absorptions and emission spectra of the photosynthesis samples under polarized light.
c. Students will investigate how quantum coherence affects energy transfer in photosynthesis. This can be done by analyzing the changes in polarization as light passes through the photosynthetic samples.
d. Students will understand the polarization of light. They will learn how light waves can oscillate in different directions and how polarized light has waves oscillating in a single direction.
e. Students will use polarizing filters to understand how they can block or transmit light based on its polarization.
f. Students can interpret results through energy transfer efficiency by determining how efficiently energy is transferred within the photosynthesis system under different polarization conditions.
g. Students will understand quantum behavior, such as changes in polarization that indicate coherent energy transfer through the tic-tac-toe game.
h. Students will use insights from quantum mechanics to enhance solar energy technologies.

Nature-journaling focused on the content and personal reflection

In my class, I followed a whole week's routines:
Monday: note-taking activities (frontloading scientific terms and researching Scientific terms online),
Tuesday: Nature-Journaling activities (outdoor) and Quantum Mechanics Game
Wednesday: STEM project-based activities (Plink Board)
Thursday: Gamification (Tic-Tac- Toe)
Friday: Assessment.

There's a lot of incredible nature for us to explore, especially around the vicinity of San Carlos Middle School. Nature-journaling is a STEM activity that allows us to mindfully appreciate all of the diverse life around us. Not only is nature journaling a great way to get outside and have fun, but it can also teach us and our learners important science and engineering process skills. The best part of engaging learners in journaling activities is having them express their feelings and being able to write something about their observations, predictions, and making inferences with a bit of curiosity.

Journal writing activities are strategies that hone and improve the writing skills of my students. It is regularly recording observations, feelings, and perceptions of the natural world. It offers a way to slow down and notice more of the world around us. It also gives the chance for my students to regularly practice and deepen their observation skills, creativity, and scientific thinking. Nature journals can also serve as long-term records of the environment. Scientists and naturalists use journals to observe and track changes in the natural world and how their ideas have evolved over time.

Nature-journaling

Getting Started: Select a format for your journal. For example, you may draw, write, or both. You can use a physical journal or make your observations on a digital platform.

Select a prompt to begin with the nature journal entry about photosynthesis and quantum mechanics. Use the simple prompt on this page or explore the resources on the next page for other ideas. Record the date, time, location, temperature, and weather. Then, focus your attention on something natural that sparks the interest, like a game such as tic-tac-toe or plinko board... Focus all your attention on it. *What do you notice about it?* Record as many general and specific observations about the game. Ask the students, *what do you wonder about it? What does it remind you of?* Record this information as well through various readings and research.

Research-Based Approach

Research-based learning involves the investigation of concepts and theories and allows my students to become solution seekers through an exploratory approach. Compared to a rigid textbook-based style that encourages rote-learning, this puts the student at the center of knowledge acquisition. *John Dewey's project-based approach, Jean Piaget's constructivist theory, Maria Montessori's play-way approach, and Jiddu Krishnamurti's questioning mind approach are early examples of 21st century versions of research-based learning.*

I will incorporate the five stages of research-based learning that are related to STEM and engineering Design processes.

a. Identify and clarify issues, questions, challenges, and puzzles. A key component of research-based learning is the identification and clarification of issues, problems, challenges, and questions for discussion and exploration. The learner is able to seek relevancy in the work they are doing and to become deeply involved in the learning process.
b. Find and process information. Students are tasked with searching for, finding, closely reading, processing, and using information related to the identified issue and question from one or more sources. As they seek out resources and read information, and then organize, classify, categorize, define, and conceptualize data. In the process, they become better readers.
c. Think critically and creatively. Students are provided with the opportunity to use their researched information to compare and contrast, interpret, apply, infer, analyze, synthesize, and think creatively.
d. Apply knowledge and ideas and draw conclusions. Students use what they have learned to draw conclusions, complete an authentic task, summarize results, solve problems, make decisions, or answer key questions.
e. Communicate results. Students communicate results of their research activities in a number of possible ways, such as through a written research report, a persuasive essay, a book designed to teach younger students, a math problem solution, a plan of action, or a slide presentation to members of the community.

Research schedule (Monday) 15 minutes frontloading vocabulary words related to photosynthesis and quantum mechanics.

Understanding quantum mechanics requires grasping the physical significance of the science involved. Concepts such as normalization, superposition, interference, probability amplitude, and entanglement can be challenging for beginners. To introduce these topics in my 7th Grade Science quantum mechanics curriculum, I use several class activities involving a nonclassical version of tic-tac-toe. Quantum tic-tac-toe (QTTT), a quantum analogue of classical tic-tac-toe (CTTT), demonstrates superposition in movement, qualitative (and later quantitative) displays of entanglement, and state collapse due to observation. With proper discussion, QTTT can also help students understand various other topics.

Quantum Tic-tac-toe Mechanics

Here are the basic rules of Quantum Tic-Tac-Toe (QTTT):

1. Superposition: Each move involves placing two marks in separate squares, representing a superposition. For example, if it's X's turn, they place X1 in two different squares.
2. Entanglement: When a player places their marks, they can entangle them by dragging from one square to another. This means the marks are linked, and their final positions depend on each other.
3. Measurement and Collapse: At any point, a player can choose to measure a square, causing the superposition to collapse into a definite state. This means one of the two marks will be chosen randomly to stay, and the other will disappear.
4. Winning: The game is won by forming a line of three marks (like in classical tic-tac-toe), but only after all superpositions have collapsed. The player with the most complete lines wins.
5. Classical Moves: If a square turns red, it can no longer be used for quantum moves and behaves like a classical tic-tac-toe square.

Tic-Tac-toe Board

The tic-tac-toe board is square and is divided into nine square subspaces. These subspaces will be referred to as principal squares and will each carry a number to denote the particular square being referenced. The numbering pattern of the principal squares on the board is shown in Figure 1. Prior to discussing the game play, some vocabulary and concepts are introduced. The following four elements are underlying physical concepts that are necessary for game play and thus their use is weaved within the description of the game.

Figure 1. The layout of the game board for either classical or quantum tic-tac-toe. This figure also displays the enumeration scheme that is used throughout this paper.

Spooky Marker

Named after Einstein's reference to entanglement and hidden variable interactions as "spooky action at a distance", is a direct consequence to the system being completely described through a finite number of basis functions of an observable. A coupled pair of electrons exist within a 0-spin state; that is to say that the wave function of the pair is of the form: $\psi = 1/\sqrt{2}(|\uparrow\downarrow\rangle + |\uparrow\downarrow\rangle)$. If one observes the state of a single electron within the pair, say it is in the up-state, that observer incidentally knows the state of the other spin within the pair. Like CTTT markers, the spooky marker represents a single move of a single player during one turn, yet a spooky marker exists within two separate principal squares simultaneously.

Superposition

As players have placed a pair of spooky markers that represents their move for that turn, this move can be said to exist as a superposition of the states (board positions) in which it may be realized. If player one, referred to as Alice, places spooky markers for her first move into squares

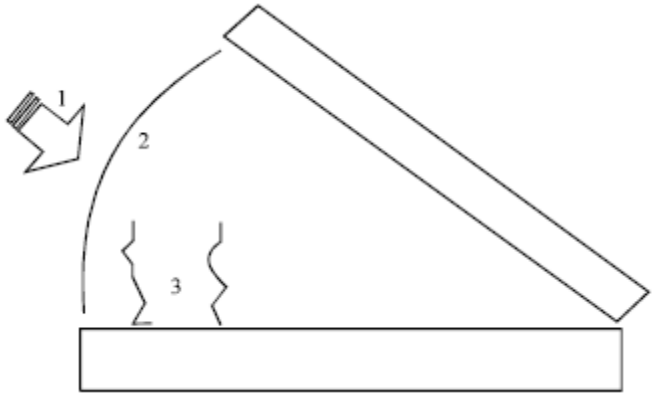
Growing plants using the polarization effect

Growing plants using the polarization effect involves using polarized light to influence plant growth and development. Research has shown that different types of polarized light can have varying effects on plants:

Circularly Polarized Light: Studies have found that plants like lentils and peas grow faster under left-handed circularly polarized light compared to right-handed. This effect is due to the absorption of polarized light in the interior of the leaves or stems.
Based on the research, the growth of lentil and pea under left-handed and right-handed Circularly Polarized (CP) light was studied. It was found that the shoots of both plants grow faster under left-

handed CP light. The state of polarization of light penetrating the outer layer of stem and leaf was analyzed by means of polarizing optical microscopy and polarimetry that allows to quantify the changes in the state of light polarization. The birefringence of the outer layer of the leaf (epidermis) and stem was found to have a negligible effect on polarization state of light. In both plants, lentils and pea, circular polarization of light does not change significantly when light penetrates the outer layer (epidermis) of stem or leaf. The birefringence of the outer layer of leaf and stem is small; therefore, the accelerated growth of shoots under left-handed CP light results from its absorption in the interior of the leaves or stems. The observed effect can be used to promote the growth of plants.

Linearly Polarized Light: Linearly polarized light has also been shown to affect plant growth.

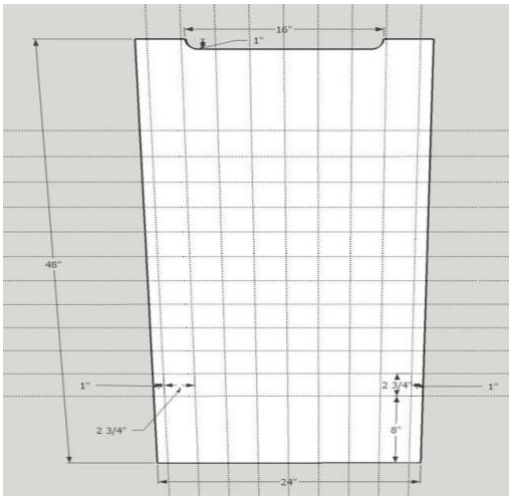


Project - Based Learning Activities:

Plinko - Quantum board project:

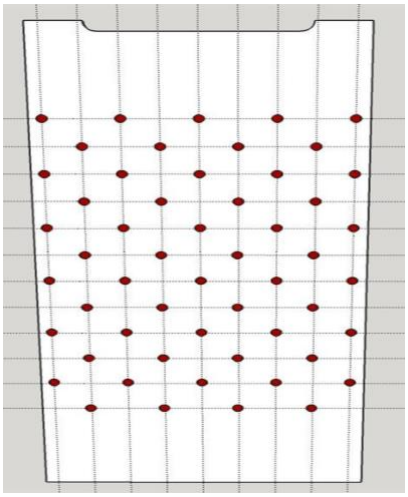
a. Layout Grid and Router Top

Measure 8" from the bottom of the board (the 24" edge). Draw a line across the entire board. From that line, draw a line every 2 3/4" until you have drawn 11 more lines (12 total). Then measure 1" from the left side and draw a line from the top to the bottom of the board (the 48" edge). From that line, draw a line every 2 3/4" until you have drawn 9 lines total. Once you get to the right side, there should be 1" remaining just like the 1" on the left side. Optional step, you can cut out an area at the top of the board for some extra detail. Use your jigsaw to do this, and finish by using a round-over bit on a router, or use your sander.



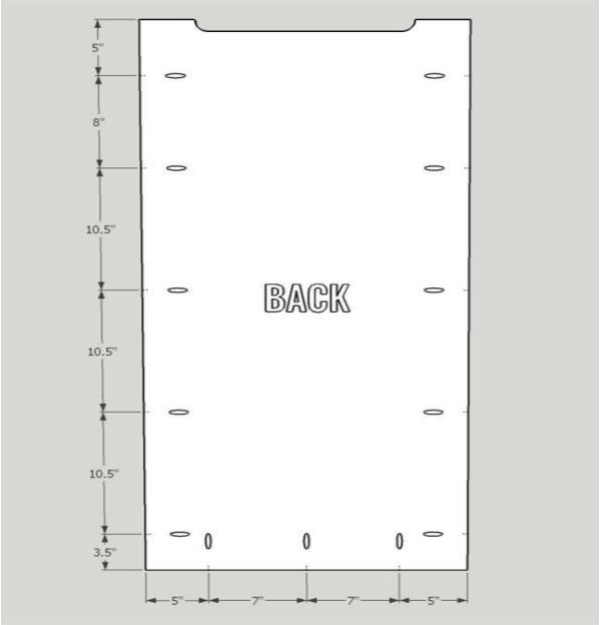
b. Drill Holes for Dowels

Using a 3/8" drill bit, drill holes in the locations shown on the diagram. Try to drill as straight as possible and only go 1/2" deep. A collar stop on your bit at 1/2" would be very handy, if available.



c. **Drill pocket holes**

Drill pocket holes on the back of the board in the locations shown on the diagram.



Photosynthesis Activities:

Diagram to illustrate photosynthesis

Students will create a visual representation of the photosynthesis process, including elements like carbon dioxide, water, sunlight, and chlorophyll. The students will draw a diagram representing the photosynthesis process and carbon-cycling.

Photosynthesis relay game

In photosynthesis relay games they can use tic-tac-toe and plinko - quantum board to represent a single photon that gets into the plant for the process of the photosynthesis. In this game, you will select 9 students in each team to participate. Then give them two pieces of color like red or yellow cloth. The mechanic of the game is to ensure they have at least one straight or diagonal one color to win a game! Once they are able to form it, they will shout “photons”! Then they win the game.

Leaf Chromatography

Separate pigments in leaves using chromatography to understand the role of chlorophyll and other pigments in photosynthesis.

Measuring photosynthesis rate

Students will conduct experiments using spinach leaves, baking soda, and light sources to measure the rate of photosynthesis.

Stomata lab

Students will use clear nail polish and microscopes to observe stomata on leaves, helping students understand gas exchange in photosynthesis.

Quantum mechanics activities:

Polarization of light

Use polarizing filters to explore how light polarization affects the absorption and emission of light in photosynthetic samples.

Quantum coherence experiment

Investigate how quantum coherence allows efficient energy transfer in photosynthesis by analyzing changes in light polarization.

Exciton Dynamics

Study the behavior of excitons (energy packets) in photosynthetic systems using spectrometers and polarized light.

Fluorescence Measurement

Measure the fluorescence of chlorophyll under polarized light to understand energy transfer processes.

Integrated Activities

Photosynthesis and Quantum Mechanics Presentation:
Have students create presentations that explain how quantum mechanics enhances our understanding of photosynthesis.

Simulation Software

Use simulation software to model the quantum mechanical processes in photosynthesis, allowing students to visualize energy transfer at the molecular level.

Research projects/investigatory projects

Assign research projects where students investigate recent studies on quantum effects in photosynthesis and present their findings.

Interactive Labs

Set up lab stations where students can perform experiments related to both photosynthesis and quantum mechanics, such as measuring the effect of polarized light on photosynthetic efficiency.

These activities not only make learning about photosynthesis and quantum mechanics fun and interactive but also help students grasp complex concepts through hands-on experience.

Student Assessment Plan

In the student assessment plan, student will be evaluated on their understanding of photosynthesis and quantum mechanics

Photosynthesis Assessments

a. Quizzes and tests:
b. Multiple-choice questions on the steps of photosynthesis.
c. Short answer questions explaining the role of chlorophyll.
d. Diagram labeling of the photosynthesis process.

Sample quiz questions

Photosynthesis Quiz

Multiple Choice

- What are the main products of photosynthesis?
  a) Oxygen and glucose
  b) Carbon dioxide and water
  c) Oxygen and carbon dioxide
  d) Glucose and water

True or False

The light-dependent reactions of photosynthesis occur in the thylakoid membranes. (True/False)

Short Answer

Explain the role of chlorophyll in photosynthesis

Matching type test

Match the following terms with their definitions:

a) Stomata
b) Chloroplast
c) Calvin Cycle
d) Light-dependent reactions

Diagram Labeling

Label the parts of a chloroplast and indicate where the light-dependent and light-independent reactions occur.

Quantum Mechanics Quiz

Multiple Choice

What is the principle of wave-particle duality?

a) Particles can only behave as waves.
b) Waves can only behave as particles.
c) Particles can exhibit both wave-like and particle-like properties.
d) Waves and particles are completely separate phenomena.

True or False

Quantum coherence is essential for efficient energy transfer in photosynthesis. (True/False)

Short Answer

Describe the concept of quantum superposition

Matching

Match the following quantum mechanics terms with their definitions:

a) Photon
b) Exciton
c) Quantum coherence
d) Polarization

Lab Reports

a. Detailed reports on experiments measuring the rate of photosynthesis.
b. Analysis of leaf chromatography results to identify pigments.

Alignment to Arizona Standard (Science)

1.L2U2.7 Develop and use models about how living things use resources to grow and survive; design and evaluate habitats for organisms using earth materials.

7.L2U1.12 Construct an explanation for how some plant cells convert light energy into food energy.

7.E1U1.1 The composition of the earth and its atmosphere and the natural and human processes occurring within them shape the earth's surface and its climate

7.E1U1.5 Construct a model that shows the cycling matter and flow of energy in the atmosphere, hydrosphere, and geosphere.

MS-LS1-6: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

MS-LS1-7: Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

L4U1.11: Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

P2U1.1: Develop and use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun.

LS2-1 - Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem

These alignments allow the students to explore how cause and effect take place within the context. The core idea in this unit explains phenomena using evidence based obtained from observation and/or scientific investigations. Evidence may lead to developing models and/or theories to make sense of phenomena in Science subjects.

On the other hand, knowledge produced by science is used for engineering and technologies to solve problems and or create products, while applications of science often have both positive and negative ethical and social implications to the outcomes of the students' experiments and activities involving quantum mechanics.

Bibliography

DOE/Lawrence Berkeley National Laboratory. (2023). Photosynthesis, key to life on Earth, starts with a single photon. ScienceDaily. https://www.sciencedaily.com/releases/2023/06/230614220632.htm

Exploring Nature. (n.d.). Photosynthesis poster building. Retrieved from https://www.exploringnature.org/photosynthesis_poster_building_6-8.pdf

How plants use quantum physics to boost photosynthesis. (2018). NBC News. https://www.nbcnews.com/science/science-news/how-plants-use-quantum-physics-boost-photosynthesis-flna6C10477922

Lawrence Berkeley National Laboratory. (2023). Nature's quantum code: Unraveling the secrets of photosynthesis. SciTechDaily. https://scitechdaily.com/natures-quantum-code-unraveling-the-secrets-of-photosynthesis/

Practical Biology. (n.d.). Investigating factors affecting the rate of photosynthesis. *Practical Biology*. Retrieved from https://www.practicalbiology.org/investigating-factors-affecting-the-rate-of-photosynthesis

Save My Exams. (2017). Practical: Investigating factors affecting the rate of photosynthesis. *OCR A Level Biology Revision Notes*. Retrieved from https://www.savemyexams.com/ocr-a-level-biology-revision-notes

Science and Nonduality. (n.d.). Quantum biology: Photosynthesis - An interview with Chris Fields. Retrieved from https://scienceandnonduality.com/article/quantum-biology-photosynthesis/

ScienceDaily. (2018). Quantum effects observed in photosynthesis. https://www.sciencedaily.com/releases/2018/05/180521131756.htm

University College London. (2014). Quantum mechanics explains the efficiency of photosynthesis. *UCL News*. Retrieved from https://www.ucl.ac.uk/news/2014/jan/quantum-mechanics-explains-efficiency-photosynthesis

Appendices

Sample Lab reports / Investigation on the experiments measuring the rate of photosynthesis:

Title: Investigating the Effect of Light Intensity on the Rate of Photosynthesis

Introduction

Photosynthesis is the process by which green plants convert light energy into chemical energy, producing glucose and oxygen from carbon dioxide and water. This experiment aims to investigate how varying light intensity affects the rate of photosynthesis in lentil plants.

Hypothesis:

Increasing light intensity will increase the rate of photosynthesis up to a certain point, beyond which the rate will plateau.

Materials and Methods
Materials:

- Lentil seeds
- Beaker (600 mL)
- Boiling tube
- Clamp stand
- Light source (lamp)
- Ruler
- Stopwatch
- Sodium bicarbonate solution (1%)
- Thermometer
- Scissors
- Forceps
- Polarizing filters (for quantum technology application)

Procedure
Preparation

Cut a 10 cm length of Elodea and place it in a boiling tube filled with water.
Add a small amount of sodium bicarbonate to the water to ensure a constant supply of carbon dioxide.
Attach a paper clip to the end of the Elodea to keep it submerged.

Setup

Place the boiling tube in a beaker filled with water to act as a heat sink.
Position the light source at a fixed distance from the Elodea.
Use a clamp stand to hold the boiling tube in place.

Experiment

Turn on the light source and allow the Elodea to acclimate for 2 minutes.
Count the number of oxygen bubbles produced by the Elodea in 1 minute. Repeat this count three times and calculate the average.
Move the light source to a new distance (e.g., 10 cm, 20 cm, 30 cm) and repeat the measurements.
Record the temperature of the water to ensure it remains constant.
Advanced Study (quantum mechanics):
Use polarizing filters to study the effect of polarized light on the rate of photosynthesis.
Repeat the experiment with polarized light and compare the results with non-polarized light.

Discussion

The results indicate that the rate of photosynthesis, as measured by the number of oxygen bubbles produced, decreases with increasing distance from the light source. This supports the hypothesis that light intensity positively affects the rate of photosynthesis up to a certain point. The decrease in bubble count at greater distances suggests that light intensity becomes a limiting factor.

In the advanced study, the use of polarized light showed a slight increase in the rate of photosynthesis compared to non-polarized light, suggesting that light polarization may enhance energy transfer efficiency in photosynthesis.

Conclusion

The experiment demonstrates that light intensity significantly impacts the rate of photosynthesis in Elodea. Further studies could explore other factors such as carbon dioxide concentration and temperature. The optional use of polarized light provides an interesting avenue for investigating quantum effects in photosynthesis.

Projects

Create a model or poster explaining the photosynthesis process.
Research and present on the impact of environmental factors on photosynthesis.

Project Title: The Magic of Photosynthesis

Objective:
To create a detailed model or poster that explains the process of photosynthesis, highlighting the key components and stages involved.
Materials Needed:

- Poster board or large sheet of paper
- Colored markers, pencils, or crayons
- Scissors
- Glue or tape
- Construction paper
- Printed images of plants, chloroplasts, and other relevant components
- Labels and arrows (pre-printed or hand-drawn)

- Optional: 3D materials like clay, pipe cleaners, or foam for a model

Instructions:

Title and Introduction:

Start with a clear and engaging title at the top of your poster.
Write a brief introduction explaining what photosynthesis is and why it is important.

Diagram of a Plant:

a. Draw or paste an image of a plant on the poster.
b. Label the main parts involved in photosynthesis: leaves, stem, roots.

Chloroplasts and Chlorophyll:

a. Include a detailed diagram of a chloroplast.
b. Highlight the role of chlorophyll in capturing light energy.

Photosynthesis Equation:

a. Write the chemical equation for photosynthesis: [6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2]
b. Explain each component of the equation (carbon dioxide, water, light energy, glucose, and oxygen).

Stages of Photosynthesis:

a. Light-Dependent Reactions:
b. Illustrate and explain how light energy is absorbed by chlorophyll and converted into chemical energy (ATP and NADPH).
c. Show the splitting of water molecules and the release of oxygen.

Energy Flow

a. Use arrows to show the flow of energy from sunlight to chemical energy in glucose.
b. Label the arrows to indicate the direction of energy transfer.

Additional Information:

a. Include interesting facts about photosynthesis, such as its role in the carbon cycle and its importance for life on Earth.
b. Optional: Add a section on how quantum mechanics enhances our understanding of photosynthesis.

Final touches:

a. Review the poster for accuracy and completeness.
b. Add any decorative elements to make the poster visually appealing.

Example Layout:

Evaluation Criteria:

Accuracy: Correct representation of the photosynthesis process and components.
Clarity: Clear and understandable explanations and labels.
Creativity: Use of colors, images, and 3D elements to enhance the presentation.
Completeness: Inclusion of all required sections and information.

Photosynthesis_Poster_Building_6-8.pdf (exploringnature.org)

Presentations

a. Group presentations on the importance of photosynthesis in ecosystems.
b. Individual presentations on recent scientific discoveries related to photosynthesis

Individual Presentation: Quantum Effects in Photosynthesis

These presentation outlines provide a structured approach to discussing recent scientific discoveries related to photosynthesis and quantum mechanics. They can be adapted based on the specific focus and depth of the presentation.

Title: Photosynthesis and Quantum Mechanics: A Single Photon's Journey

Slide 1: Introduction
a. Title Slide: Include the presentation title, your name, and date.
b. Introduction: Provide a brief overview of the topic, emphasizing the intersection of quantum mechanics and photosynthesis.

Slide 2: Basics of Photosynthesis
a. Diagram: Display a simplified diagram of the photosynthesis process.
b. Explanation: Describe the main stages of photosynthesis and the role of chlorophyll.

Slide 3: Quantum Mechanics Overview
a. Key Concepts: Introduce basic quantum mechanics concepts relevant to photosynthesis, such as wave-particle duality and quantum coherence.

Slide 4: Recent Discovery
a. Single Photon Initiation: Explain the discovery that a single photon can initiate photosynthesis12.
b. Research Details: Provide details about the study conducted by Lawrence Berkeley National Laboratory

Slide 5: Significance of the Discovery
a. Energy Transfer: Discuss how this discovery enhances our understanding of energy transfer in photosynthesis.
b. Practical Applications: Highlight potential applications in improving solar energy technologies and artificial photosynthesis.

Slide 6: Conclusion
a. Summary: Summarize the main points of the presentation.
b. Future Directions: Suggest areas for future research and potential breakthroughs.

Slide 7: Q&A
Questions: Invite questions from the audience to engage in a discussion.

Interactive Activities:
a. Participation in a photosynthesis relay game and ic-tac-toe game

Quantum mechanics Relay Game

Objective: Understand the principles of quantum mechanics through interactive play.

Materials:

a. Cards labeled with key quantum mechanics terms (PHOTON, EXCITON, QUANTUM COHERENCE, POLARIZATION)
b. Flashlights
c. Polarizing filters
d. Markers and tape

Setup:

a. Create cards with terms and definitions related to quantum mechanics.
b. Place the cards at different stations around the classroom or playground.
c. Set up flashlights and polarizing filters at one station.

How to Play:

Divide students into teams. On "GO," the first player runs to the first station, picks up a card, and reads the term aloud. The player then runs to the next station and matches the term with its definition. At the station with the flashlights and polarizing filters, players must demonstrate how light polarization works by shining the flashlight through the filter.The next player repeats the process with a new term.The first team to correctly match all terms with their definitions and complete the demonstrations wins.

Hands-on activities like building a photosynthesis model using craft materials

Activity 1: 3D Photosynthesis Model

Objective: Create a 3D model to illustrate the process of photosynthesis.

Materials:

Green construction paper
Blue and yellow tissue paper
Scissors
Glue or tape
Markers
Small plastic or foam balls (to represent molecules)
String or pipe cleaners
Cardboard or a large poster board

Instructions:

a. Create the Leaf:
   Cut a large leaf shape out of the green construction paper. Draw veins on the leaf with markers to make it look realistic.
b. Sunlight representation:
   Cut strips of yellow tissue paper to represent sunlight. Glue or tape the strips to the top of the leaf, showing how the leaf absorbs sunlight.
c. Water and carbon dioxide:
   Use blue tissue paper to create water droplets and small plastic or foam balls to represent carbon dioxide molecules. Attach these to the leaf using string or pipe cleaners to show how they enter the leaf.

Glucose and oxygen:

Use small plastic or foam balls to represent glucose and oxygen molecules.

Attach these to the leaf, showing how they are produced during photosynthesis.

Assembly:

Glue all the components onto the cardboard or poster board.
Label each part of the model (e.g., sunlight, water, carbon dioxide, glucose, oxygen).

Explanation:

Write a brief explanation of each step of photosynthesis next to the corresponding part of the model.

Activity 2: Photosynthesis Poster with Craft Materials

Objective: Create a detailed poster explaining the photosynthesis process using various craft materials.

Materials:

Poster board
Colored construction paper
Markers and crayons
Glue or tape
Scissors
Cotton balls (to represent clouds)
Small plastic or foam balls (to represent molecules)
Tissue paper (blue and yellow)

Instructions:

Title and Introduction:

a. Write the title "Photosynthesis" at the top of the poster.
b. Include a brief introduction explaining what photosynthesis is.

Draw the Plant:

a. Draw or cut out a plant from green construction paper and glue it to the poster.
b. Label the main parts of the plant (leaves, stem, roots).

Sunlight and Water:

a. Use yellow tissue paper to create rays of sunlight and glue them above the plant.
b. Use blue tissue paper to create water droplets and glue them near the roots.

Carbon Dioxide and Oxygen:

a. Use small plastic or foam balls to represent carbon dioxide entering the leaves and oxygen being released.
b. Attach these with glue or tape and label them.

Glucose Production:

a. Use small plastic or foam balls to represent glucose molecules produced in the leaves.
b. Attach these to the leaves and label them.

Clouds and Atmosphere:

a. Use cotton balls to create clouds and place them above the plant to represent the atmosphere.

Explanation:

Write a brief explanation of each step of photosynthesis next to the corresponding part of the poster.

Activity 3: Interactive Photosynthesis Model

Objective: Build an interactive model to demonstrate the photosynthesis process.
Materials:

- Cardboard box (for the base)
- Green construction paper
- Blue and yellow tissue paper
- Small plastic or foam balls
- String or pipe cleaners
- Markers
- Glue or tape
- Flashlight (to represent sunlight)

Instructions:

Base Setup:

a. Use the cardboard box as the base for your model.
b. Cover the box with green construction paper to represent the ground.

Plant Construction:

a. Create a plant using green construction paper and attach it to the base.
b. Label the parts of the plant (leaves, stem, roots).

Sunlight Simulation:

a. Use a flashlight to represent sunlight.
b. Shine the flashlight on the plant to show how light is absorbed.

Water and Carbon Dioxide:

a. Use blue tissue paper for water droplets and small plastic or foam balls for carbon dioxide.
b. Attach these to the plant using string or pipe cleaners.

Glucose and Oxygen:

a. Use small plastic or foam balls to represent glucose and oxygen.
b. Attach these to the plant to show the products of photosynthesis.

Interactive Elements:

a. Allow students to move the flashlight and simulate the process of photosynthesis.
b. Encourage them to explain each step as they move the components.

Quantum mechanics assessments

a. Quizzes and Tests:
    a. Multiple-choice questions on the principles of quantum mechanics.
    b. Short answer questions explaining wave-particle duality

b. Lab Reports:
    a. Reports on experiments using polarized light to study quantum effects in photosynthesis.
    b.Analysis of data from spectrometry experiments.
c. Projects:
    a. Create a simulation or model demonstrating quantum coherence in photosynthesis.
    b. Research and present on the applications of quantum mechanics in biology.
d. Presentations:
    a. Group presentations on the role of quantum mechanics in photosynthesis.
    b.Individual presentations on the significance of quantum coherence in energy transfer.
e. Interactive Activities:
    a. Participation in experiments using polarizing filters to study light behavior.
    b.Hands-on activities like building models to demonstrate exciton dynamics.

Experiment: Investigating Light Polarization

Objective
To understand how polarizing filters affect the transmission of light and to explore the concept of light polarization.
Materials
Two polarizing filters
Light source (e.g., flashlight or laser pointer)
Protractor
Light sensor or photodetector (optional)
White screen or wall
Notebook and pen for recording observations
Procedure
Setup:
a. Place the light source on a stable surface so that it shines a beam of light towards a white screen or wall.
b. Hold one polarizing filter in front of the light source. This will be your first polarizer.

Initial Observation:
a. Observe the light passing through the first polarizer. Note any changes in the light intensity or appearance.
Adding the Second Polarizer:
a. Hold the second polarizing filter in front of the first one. Rotate the second filter slowly while keeping the first filter stationary.

b. Observe the changes in light intensity as you rotate the second filter. Record the angles at which the light intensity changes significantly.

Quantitative Measurement (Optional):

a. If you have a light sensor or photodetector, place it behind the second polarizer to measure the intensity of transmitted light.
b. Record the light intensity at different angles of the second polarizer (e.g., every 15 degrees).

Analysis:

a. Plot the light intensity against the angle of the second polarizer. You should observe a pattern that corresponds to Malus's Law, which states that the intensity of polarized light passing through a second polarizing filter is proportional to the cosine squared of the angle between the filters.

Observations and Results

a. Qualitative: Describe how the light intensity changes as you rotate the second polarizer. Note any points where the light is completely blocked or maximized.
b. Quantitative: If using a light sensor, present your data in a table and plot a graph of light intensity versus angle.

Conclusion

Summarize your findings. Explain how the experiment demonstrates the principles of light polarization and how polarizing filters can be used to control light transmission.

Discussion

a. Discuss the applications of polarizing filters in everyday life, such as in sunglasses, cameras, and LCD screens.
b. Explore how this experiment relates to the study of quantum mechanics, particularly in understanding the behavior of photons and light waves.

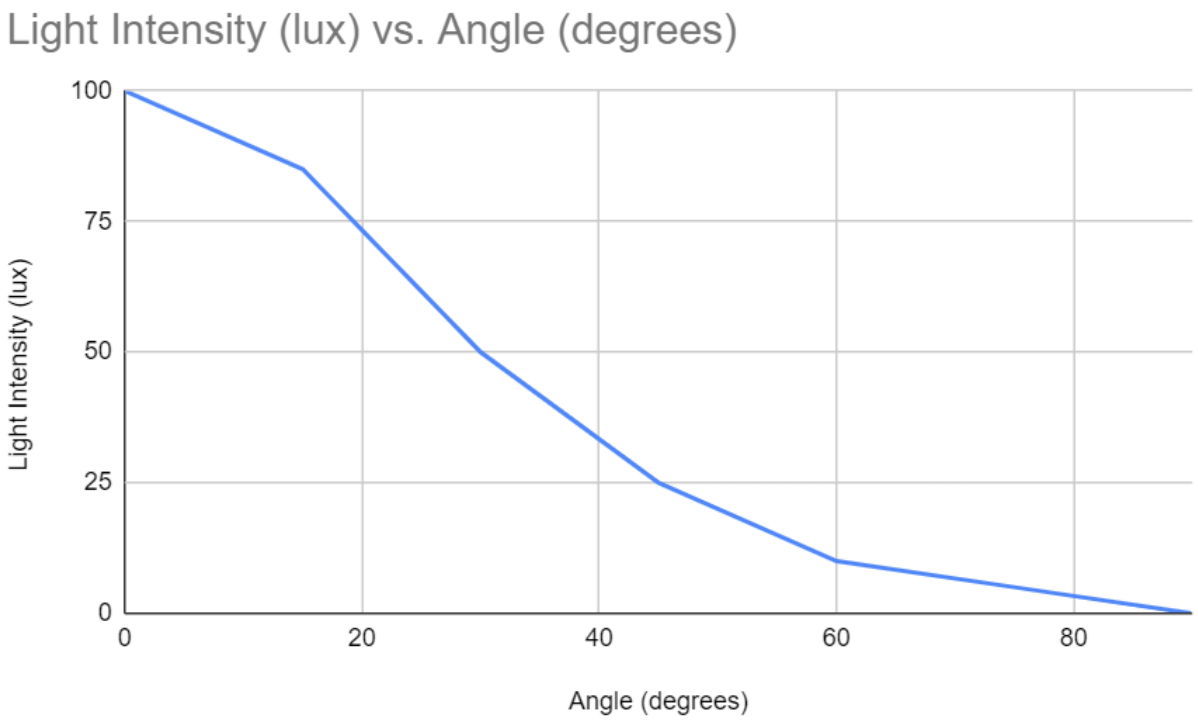
Example Data Table (for Quantitative Measurement)

Table 1

Angle (degrees)	Light Intensity (lux)
0	100
15	85
30	50
45	25
60	10
75	5
90	0

Figure 1. Example Graph

Light Intensity (lux) vs angle (degrees)



Integrated Assessments (photosynthesis and Quantum technology)

Research Papers

a. Write a paper on how quantum mechanics enhances our understanding of photosynthesis.
b. Compare classical and quantum explanations of energy transfer in photosynthesis.

Comparing Classical and Quantum Explanations of Energy Transfer in Photosynthesis

Introduction

Photosynthesis is the process by which plants, algae, and some bacteria convert light energy into chemical energy. Understanding how energy is transferred during photosynthesis is crucial for improving artificial photosynthesis and solar energy technologies. This comparison explores both classical and quantum mechanical explanations of energy transfer in photosynthesis.

Classical Explanation

Energy Transfer Mechanism:

a. In the classical view, energy transfer in photosynthesis is explained through Förster Resonance Energy Transfer (FRET).
b. FRET describes energy transfer between two light-sensitive molecules (chromophores) through dipole-dipole interactions.
c. The efficiency of energy transfer depends on the distance between the donor and acceptor molecules and their relative orientation.

Limitations:

a. Classical models assume that energy transfer occurs through random, incoherent hopping of excitons (energy packets) from one molecule to another.
b. This approach does not account for the high efficiency observed in natural photosynthetic systems, especially under ambient conditions.

Quantum Explanation

Quantum Coherence:

a. Quantum mechanics introduces the concept of quantum coherence, where excitons can exist in a superposition of states, allowing them to explore multiple pathways simultaneously.
b. This coherent behavior enables more efficient energy transfer by reducing the likelihood of energy loss.

Molecular Vibrations:

a. Quantum mechanics also considers the role of molecular vibrations in energy transfer.
b. Specific vibrational modes of chromophores can resonate with electronic transitions, facilitating efficient energy exchange.

Experimental Evidence:

a. Studies have shown that light-gathering macromolecules in plant cells transfer energy by taking advantage of molecular vibrations whose physical descriptions have no equivalents in classical physics.
b. These vibrations assist energy transfer during photosynthesis and enhance efficiency through non-classical behavior.

Advantages:

a. Quantum models explain the high efficiency of energy transfer in photosynthesis, even at ambient temperatures.
b. They provide a more accurate description of the energy transfer process, accounting for phenomena that classical physics cannot explain.

Conclusion

While classical explanations like FRET provide a basic understanding of energy transfer in photosynthesis, they fall short in explaining the high efficiency observed in natural systems. Quantum mechanical models, with their consideration of coherence and molecular vibrations, offer a more comprehensive and accurate explanation. These insights not only deepen our understanding of photosynthesis but also pave the way for advancements in artificial photosynthesis and solar energy technologies.

Debates:

a. Organize debates on the efficiency of photosynthesis from a quantum perspective.
b. Discuss the implications of quantum mechanics in biological systems.

Simulations and Software:

a. Use simulation software to model quantum processes in photosynthesis and analyze the results.

b. Create virtual labs where students can manipulate variables and observe quantum effects.

Field Studies:

a. Conduct field studies to observe photosynthesis in different environments and analyze the data using quantum principles.
b. Collect and analyze samples to study the impact of light polarization on photosynthesis.

These assessments can help gauge students' understanding and application of both photosynthesis and quantum mechanics, providing a comprehensive evaluation of their knowledge and skills.