Modeling Plant-Based Movements Using Principles of Soft Robotics

(Performance-based Assessment PBL/ADI)

RESET AN AEOP EFFORT aeop

Engage | Explore | Explain | Elaborate | Evaluate| | References | Appendix

Authors

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SUBJECT/GRADE LEVEL

Subject Area(s)

Physical Science

Life Science

Horticulture/Agriculture

Grade Level(s)

3-5 & 6 -8

Materials

- TinkerCAD or similar 3D Modeling Software
- Various Household items to create a Makerspace

STANDARDS

Next Generation Science Standards

(Grades 3-5)

- **3-5-ETS1-1** Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- **3-5-ETS1-2** Engineering Design: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **3-PS2-2** Motion and Stability: Forces and Interactions: Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.
- **3-LS4-2** Biological Evolution: Unity and Diversity: Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.

- **4-PS3-2** Energy: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- **4-PS3-4** Energy: Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

(Middle School)

- **MS-LS1-4**. Use arguments based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- **MS-LS1-5**. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- **MS-ETS1-1**. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **MS-ETS1-2**. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Mathematics Standards | Common Core State Standards

(Grades 3-5)

- **MP.2** Reason abstractly and quantitatively. (3-LS4-4)
- **MP.4** Model with mathematics. (3-LS4-4)
- **CCSS.MATH.CONTENT.K.G.B.5** Model shapes in the world by building shapes from components (e.g., sticks and clay balls) and drawing shapes.

(Middle School)

- **MP.2** Reason abstractly and quantitatively.
- **CCSS.MATH.CONTENT.7.EE.3** Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

English Language Arts Standards | Common Core State

(Grades 3-5)

- **RI.3.3** Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect. (3-LS4-4)
- **W.3.1** Write opinion pieces on topics or texts, supporting a point of view with reasons. (3-LS4-4)
- **W.3.2** Write informative/explanatory texts to examine a topic and convey ideas and information clearly. (3-LS4-4)
- **CCSS.ELA-LITERACY.CCRA.SL.2** Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

- **CCSS.ELA-LITERACY.CCRA.SL.4** Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

(Middle School)

- **RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts.
- **RST.6-8.2** Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
- **WHST.6-8.2** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
- **WHST.6-8.8** Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
- **WHST.6-8.9** Draw evidence from informational texts to support analysis, reflection, and research.
- **SL.8.5** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

LESSON OBJECTIVE(S)

Students will use qualitative and quantitative math skills to design and build a physical or virtual model to mimic the structural biology of at least one of the 3-dimensional movements of plants, culminating in a verbal and written presentation.

CAREER CONNECTION(S)

Mentor Background: Dr. Brendan Hanrahan - received his B.S. degree in Ceramic and Materials Engineering from Clemson University in 2006, and his M.S. and Ph.D. degrees in Materials Science and Engineering from the University of Maryland in 2009 and 2013, respectively. For his Ph.D., Brendan determined the fundamental materials properties dictating the performance of micro ball-bearing platforms, which could serve as enabling technologies for future microsystems.

STEM Careers: Mechanical Engineering, Materials Science, Botany

ENGAGEMENT

Brief Description: This stage aims for students to appreciate plants for more than their aesthetic or nutritional value. Plants typically take a backseat when it comes to interest in biology. “To counteract this relative lack of interest in plants, Strgar (2007) suggested that teachers need to take a more active role in terms of their knowledge, enthusiasm, and interest toward plants”.

Procedures:

Phenomenon:

Bring a healthy plant to class. Have the students prepare their lab notebooks. Discuss the requirement that students must take detailed recordings of their qualitative and quantitative observations. Set the plant in front of the class and then have them make observations regarding the plant's movement. It is obvious that the plant will not visually move in the time frame given to the students. However, lead them to the discussion as to what factor must we account for to observe a plant moving. That factor would be time. Plants move very slowly as a function of time. We are not conscious because we are looking for an immediate visual clue, but if we scale our time on plant time, we can see how plants move.

Discuss the very basic principles of the following paper on Plant Awareness Disparity with students and how it relates to your particular lesson of the unit. The idea is that we humans do not appreciate their importance to the biosphere. As an example, for a physics-focused unit, discuss how we do not appreciate the ability for plants to physically move either through growth mechanisms or responses to environmental stimuli. Reveal the plant to the class and then have them write their observations. The students will likely count the number of stems, leaves, or height for the quantitative observations. For the qualitative observations, students will describe the color or shape of the plant. Allow the students to record ANY qualitative and quantitative observations that they feel are important. The goal here is to coach students that observations should be recorded.

The goal is to steer students towards observing plant movement. The plant will not be moving in the concise time frame of the observation activity. Ask the students to consider watching this plant over a more extended time (days or months). Ask the students to predict what we may expect to see over that more prolonged period. Lead students to realize that plants are not stationary and exhibit efficient natural movement in response to environmental stimuli.

OPTIONAL (Homework or Classroom Activity):

Students can plant lima beans and/or sweet peas with some soil and paper cups. This can be done individually or in student groups depending on class size and access to materials and a space in the classroom that can receive ample sunlight. In addition, put a straw pointing vertically upwards in the middle of the soil. As the vine begins to grow. Have students take a photograph once a day for the next several days. Have the students either print the photographs or record them sequentially into a slideshow. This will show a time lapse growth of the plant and when viewed as a function of time, will demonstrate the movement pattern of the growing vines.

EXPLORATION

Brief Description: Plants exhibit movement patterns for both growth environmental responses that are very sophisticated yet very slow. If we were to leverage our understanding of the mechanics of the movement patterns we can possibly create soft robotics that use environmental stimuli (external energy) to achieve processes autonomously. Students will explore the website: Plants in Motion by Dr. Roger Hangarter of the University of Indiana. The students will have an opportunity to learn on their own about the different nastic and tropic movements of plants.

Procedures:

Allow students at least 30 minutes to explore the different plant movement videos. The guiding question for their exploration is: How and why do plants move?

After 30 minutes, divide the students into partners and assign them a specific plant movement listed in the essential vocabulary (Tropism, Geotropism, Phototropism, Chemotropism, Hydrotropism, Thigmotropism, Traumatropism, Galvanotropism, Electrotropism). The student team will then create an eye-catching infographic that will teach their peers the fundamentals of that plant movement. Students can also use the Science Hub website to find additional resources to support their infographics. After completion, the students will participate in a peer review activity to explain their infographic and elicit feedback from their peers. An example of this peer review activity is called the: High-Low-Buffalo

Activity:

Poster creation and “Elevator Presentations”:

Objective:

Students will present a 3 minute or less, multimedia (visual, audio, physical) presentation of an assigned trophic or nastic movement to teach fellow peers the characteristics of that movement. Students can decide to

Materials:

- Computer with Internet access
- Chart Paper
- Colored Markers
- Scissors
- Colored construction paper
- Any other common poster making materials

Activity:

Divide students in groups of 2-3 depending on your class size. Provide groups with a single sheet of flip chart paper, access to all poster making materials and a computer with Internet access. Assign student groups a single topic to review (Tropism, Geotropism, Phototropism, Chemotropism, Hydrotropism, Thigmotropism, Traumatropism, Galvanotropism, Electrotropism). Students will then create a poster and then a 2-minute or less presentation to teach each other the characteristics of their assigned plant movement.

Virtual option:

This lesson can be done using breakout rooms and a collaborative tool such as google slides or Google Draw to create the poster. Limit the student groups to a single slide and the same 60s or less presentation time.

Whole Group - Presentation Protocol:

Each group is given the presentation floor to give their presentation.

Peer Review Protocol: After all presentations are finished, In their teams, the students will play one round of High-Low-Buffalo. Each student will come up with one “High, Low, Buffalo” for each other team member.

“High” - A positive comment, something the individual did well.

“Low” - A suggestion of something that could be improved upon.

“Buffalo” - A WOW or Light Bulb moment, something content related that really stood out, can be from any presentation.

Closing Activity (3 - 2 - 1 Exit Ticket):

As an informal assessment students will complete a 3 - 2 - 1 Exit Ticket before they leave. Using this Exit Ticket can help better prepare teachers for the KLEWS Chart activity in the next activity.

3 things I learned today.

2 things I want to learn more about.

1 question I still have about our lesson.

Plants in Motion

https://plantsinmotion.bio.indiana.edu/index.html

Optional or Supplemental Lesson to understand movement on a plant's time scale.

NSTA Plant Movement Lesson Plan

EXPLANATION

** Be sure you have reviewed the Exit Ticket from the previous activity to better prepare yourself for incoming questions. Reviewing the nagwa website to be used during this activity will also be important. **

Brief Description: During this portion of the unit students will complete a KLEWS Chart. A KLEWS chart is a great way for teachers to assess student learning and know what gaps may need to be filled. (A great website talking about KLEWS Charts) Students will also be given a chance to discuss their thoughts with their peers and be given online links to more information.

K – What do we think we know?
L – What are we learning? [claims]
E – What is our evidence?
W – What do we still wonder about?
S – What scientific principles/ vocabulary help explain the phenomena?

Time: 2 x 90 minute classes

Materials: Computer with Internet connection, KLEWS Chart (printed or digital copy)

Procedures: This activity will begin by giving students a KLEWS chart to complete. The top of the KLEWS chart has a place for the students to write the topic or guiding question that is being discussed. For this activity we are asking the students to Explain "Why do plants move in the ways which we have observed?". (Can use the video examples here again if needed.) The first column on the chart is K. For the column K students are asked to write what they know about the topic. This gives us a chance to assess what the students have learned thus far. At his time you may want to ask some probing and follow-up questions to the students. The next column is the L where the students write what they are learning. To complete this column students will make a claim answering the guiding question, "Why do plants move in the ways which we have observed?". Before the students complete this column allow them time to discuss in small groups what they have learned and observed first. After the small group discussion, ask the students to fill in column L with their claim. Second, introduce the student to these new resources; this nagwa website has many great resources to use for plant movement, notably definitions and explanations, a presentation and video (13 minutes). After the students have had a chance to review the material allow them time back in their small groups to discuss the guiding question again before completing the L column. The E column is a space for students to list the evidence they have collected through observations and research. The evidence the students list should connect their claim(L column) to the guiding question. Evidence can be listed in complete sentences or as bullet points. The W column is reserved as a space students can list questions they still have. Encourage your students to ask questions about anything they do not understand or to ask questions about further exploration to expand their knowledge. The last column is the S column. This column will be used by the students throughout this activity as a place for them to record any Vocabulary words that are important

to the guiding question.

As a last step for the KLEWS chart, ask the students to reevaluate the information they have gathered and consider if they should revise their claim in the L column. If students wish to revise their claim, ask them to keep the original claim and add the revised claim underneath with a line dividing the old claim from the new claim.

ELABORATION

Brief Description: In this activity the students will take their understanding of plant movement a step further and create a 3 dimensional model of plant based tropic movement (i.e. Tropism, Geotropism, Phototropism, Chemotropism, Hydrotropism, Thigmotropism, Traumatropism, Galvanotropism, Electrotropism) previously assigned to their team during the Exploration phase. Students will then participate in a Gallery Walk observing the other teams models, receiving explanations and asking questions.

Procedures:
Thoroughly describe the procedures for the activity, including time frame. Be sure to include background information of the content, teacher and student actions, opportunities for formative assessment, and possible adaptations for individual learners and/or virtual options.

Time Frame: 2 x 90 minute classes for design and modeling

Grouping: Same as the Exploration phase or new teams based on assessment from KLEWS Charts.

Set-Up and Materials: Ideally this activity will take place in a Makerspace Environment allowing the students access to a variety of crafting material (colored construction paper, markers, modeling clay, pipe cleaners, scissors, glue, tape etc…) with the inclusion of hydraulics syringe apparatus available in order to simulate tropic movement in plants. Here is a short video explaining how to set-up the hydraulic syringe system and many other useful videos can be found on YouTube describing the use of Hydraulic Actuators and how to produce movement in models.

Alternatively, if a hydraulic setup is unavailable or too advanced for the grade level physical movement of the model by hand is also viable.

Activity: Students will work in teams to create a 3D model that replicates plant movement. Student teams can remain the same as they were during the Exploration phase and will model the same plant movement as well or can allow students the choice of movement they wish to model. Students will be taken to the makerspace/lab and introduced to the modeling assignment. Allow students to become familiar with the crafting supplies they will be using and explain/review any safety concerns that need to be addressed when using the supplied materials.

Step 1 Define: 5-10 minutes. During this step, introduce the students of their build challenge, discuss the rubric, inform about the available materials and review any safety concerns. **If students have never been introduced to the Engineering Design Process (EDP), time should be taken to do this now.**

Step 2 Brainstorm and Design: 15 - 20 minutes. Students will review the plant movement video that corresponds with their model and begin brainstorming ideas on how to create a functioning/moveable model using the available materials. Have each student sketch out their own ideas, labeling the parts

and create a list of materials they plan to use to create the model. (10 - 15 mins)When each student is finished, have each team member communicate their design to each other member of the team and decide on which design to move forward with. Students may decide to use some parts of each other's design, if this is the case have the students resketch their new design as this is part of the design process.

Step 3 Building and Testing: 90 minutes.

During this step students bring their designs to the teacher for approval and focus on creating their models based on the sketches. Teachers should purposefully withhold information on how functionable the build will be and only withhold approval to the build if the students are trying to create something different than assigned. (This allows the students to fully explore the EDP.) Once the design has been approved students will gather their materials and begin construction of their design following the sketch as close as possible without improvising. When "finished" with their build students will test the prototype for functionality. If students are not satisfied with the testing results they should move back to the brainstorming phase of the EDP and move forward with design, build and test. If students are satisfied with the results they need to check in for a final approval from the teacher.

Step 3.1 Improve (optional): If students finish building and testing before the allotted time, have them improve their plant model by adding more detail to make it look more realistic using markers to add detail to the plant, create a planter or realistic terrain to house the model.

Step 4: Prepare Presentation: 30 minutes. During this step students will prepare to present their models to the class. Presentations of team models will be done using a modified Gallery Walk with teams creating a booth to mimic a science fair. Each booth will be set up showcasing the teams 3D model, including team sketches, revisions and the teams infographic they created during the Exploration phase. Each student should also take time to prepare to present information they have learned and be ready to answer questions.

Optional: A Virtual option to this activity is available through TinkerCAD.

TinkerCAD - Biomimicry Lesson Plan

EVALUATION

Brief Description: Students and teachers will participate in a Gallery Walk observing other teams builds, presenting information and asking questions. 1 x 90 minute class for Gallery-walk/Presentation.

Procedures: Each team will decide who will present first and who will walk the Gallery. The member that is presenting will stay at their booth and present information on which tropic movement they were assigned by discussing their infographic and how their model mimics that tropic movement in plants. Students will use specific vocabulary they have learned during the lesson plan when communicating their information and briefly discuss their Engineering Design Process and how they used the materials available to recreate plant movement. The other Team members will travel from booth to booth listening to each presentation asking questions, taking notes and making observations in their journals. Teachers will also take the Gallery Walk using this time for making Rubric Assessment asking questions

and giving direct feedback.

At the conclusion of the Gallery Walk teachers will completely fill out the student rubrics, supply feedback and ask the students to write a reflection piece over what they learned, how activity did or did not change their perception of plants and plant movement and their impressions of trying to recreate a realistic model of plant movement using lab materials.

REFERENCES

- Parsley, K. M. (2020). Plant awareness disparity: A case for renaming plant blindness. *Plants People Planet,* **2**(6), 598-601. https://doi.org/10.1002/ppp3.10153
- Strgar, J. (2007). Increasing the interest of students in plants. *Journal of Biological Education*, **42**(1), 19– 23. https://doi.org/10.1080/00219266.2007.9656102

APPENDIX

- ADI poster template
- High-Low-Buffalo
- Hydraulics syringe
- Hydraulics syringe setup (video)
- Makerspace
- NSTA Plant Movement Lesson Plan
- Plants in Motion
- Recap of Fundamental Plant Movements - by Jayla Wade (Howard University)
- Science Hub - Article search Engine
- TinkerCAD Tutorial for beginners
- TinkerCAD Biomimicry Lesson Plan
- TinkerCAD
- nagwa website
- KLEWS chart
- Rubric Assessment (build challenge)