

Student protocol - High School 3D plant modeling

The Project

This is a project from the Education Research and Outreach Lab of the Donald Danforth Plant Science Center. The overall and long-term goal of this project is to promote the connection between science, technology, and design among high school students while providing direct learning opportunities that will guide them in choosing their future career paths. The STEAM (science, technology, engineering, art, and math) goal will be accomplished through four major objectives:

1. Science: Inspire interest in STEM careers among students and provide them with skills for a future STEM career.
2. Science: Foster knowledge and appreciation of plant science among high school students.
3. Design: Integrate art and design into STEM plant science education (STEAM).
4. Technology: Apply Augmented Virtual Reality (AVR) technology to advance plant science education through the use of novel tools and methodologies.

Learning outcomes

By the end of the project, you are expected to be able to:

- Use AVR technology and its applications to create 3D plant models, thereby building useful technological skills for potential STEM career paths.
- Identify and describe plant content and increase awareness of plants.
- Recognize the importance of art and design within STEM and appreciate science opportunities within art and design.
- Recognize the opportunities available for a future career in STEAM fields.
- Acknowledge the benefit of collaboration among peers, teachers, and scientists.

Before starting with the 3D model creation

Step 1. Project presentation

The program manager (PM) will coordinate the project implementation with your teacher. The PM will visit your school and introduce the project and explain the student's expected outcomes and commitments.

You will have access to a Google Classroom where you will be able to download information and upload files (photo release form, photos, 3D models, presentations, etc.).

Step 2. Education research

Since the 3D plant modeling project is offered by the Education Research and Outreach Lab, your teacher will ask you to complete surveys and reflection questions **before** and **after** the project is completed. The surveys are about your perceptions of STEAM disciplines, plant awareness, and your experience with 3D modeling and AVR.

If you are younger than 18 years of age, we will need parent consent to use your answers in future publications (your personal data will not be available). Complete the questionnaires and forms in the following links **before** the project starts.

- Parent consent form for students younger than 18 years of age:
https://survey.iad1.qualtrics.com/jfe/form/SV_bdCL901Up95Gyqi
- Pre-survey on student perceptions of scientific disciplines (STEM Semantic survey) with student consent/assent and demographics forms:
https://survey.iad1.qualtrics.com/jfe/form/SV_eOKH836OTaLs9Lg
- Pre-survey on student plant awareness:
https://survey.iad1.qualtrics.com/jfe/form/SV_8dFn8PWaTpiA3qe
- Pre-questionnaire for student written reflections:
https://survey.iad1.qualtrics.com/jfe/form/SV_7Wo2pXlbFptN78i

Also, a photo waiver form needs to be completed:

https://drive.google.com/file/d/10Keh6YAj8k1H_dMRVWfwiFuhOD-9hoNP/view?usp=sharing

Step 3. Teams

Your teacher will assign you to a collaborative team based on your qualifications, expertise, and self-identification as a scientist, technophile, or art student. You will have the opportunity to meet as a team and discuss which roles each of you will have. See the list below. Based on the number of students in your group, you may have more than one role or two students may have the same role. It is expected, however, that each member of the group will participate in all phases of the project development.

Roles:

- Lead role: Maintains communication among members, makes sure everybody is participating in all phases of the project, and maintains contact with the program manager.
- Scientist role: Coordinates the acquisition of information about the biological content and importance of the team's model(s). Maintains contact with mentor.
- Artist/Designer role: Coordinates the development of the concept art and ensures that the 3D model looks as accurate as possible. Supports the creation of the project presentation. Maintains contact with mentor.
- Technical role: Helps team members with the training and use of the applications to design, create, and use the 3D models. Supports the creation of material for the presentations of the project.
- Communication role: Coordinates the preparation and dissemination of the project

Student protocol – 3D plant modeling

EROL Education Research & Outreach Lab

(Preparation of posters, PowerPoint presentations and or videos). Maintains contact with teacher, program manager, and mentors.

Team etiquette. Please take into consideration the following guidelines to have a successful team dynamic.

- Listen to each other's ideas
- Treat everybody respectfully
- Distribute the work fairly
- Do the work you committed to do
- Reflect on the benefits of collaboration

To make the project development successful, also remember:

- to be patient, as you are learning by doing
- to be prepared for failing, as that is how we learn from our mistakes
- to be careful with the websites you access to prevent viewing inappropriate content
- to be responsible with any material and equipment provided

Document the project progress through photos:

- Take photos of yourself and your team conducting the different stages of the project.
- Take photos/screenshots of your sketches, on-line and in-person team meetings, and final products.
- These photos should be uploaded in your Google Classroom.

Step 4. What is 3D modeling?

Visit the following links for readings on 3D modelling. These readings are necessary to understand later how to use the 3D modeling software.

- Key processes of 3D modeling
<https://everisus.medium.com/key-processes-of-3d-modeling-49de59ed7a6>
- 3D Modeling Basics
<https://all3dp.com/2/3d-modeling-basics-simply-explained/>
- Beginner Steps to Start Designing 3D Models (Tinkercad example)
<https://home3dprintguide.com/beginner-steps-to-start-designing-3d-models/>
- 3D Modeling Basics
<https://www.instructables.com/Intro-to-3D-Modeling/>

Step 5. Training

You will be responsible for your own training. In Table 1 are the links to videos that will help you learn how to create 3D models with the Tinkercad and Fusion 360 software. As you watch the videos, follow the steps to access Tinkercad and Fusion 360 (e.g. account creation), learn the basic controls and do the exercises to create 3D models.

Table 1. 3D modeling training videos (Watch videos in order)

3D modeling software	Description of videos and links (required to students)
Tinkercad Overview: https://www.tinkercad.com/	Video 1: Welcome to Tinkercad! (1:30 min) https://www.youtube.com/watch?v=LrU2zm_g7IE Video 2: Tinkercad_Setup. Account creation and basic controls (7:57 min)* https://drive.google.com/file/d/1KmkksBB_VLuCFuchx-ftuMYA8QO3Rxgc/view?usp=sharing Video 3: Tinkercad_Plant_Tutorial. Creation of a plant (5:36 min) https://drive.google.com/file/d/1DxO3mtBxJC7dTFjCw-NPuLgnltHdDhTg/view?usp=sharing Video 4: Tinkercad additional tutorial (9:46 min) (Optional) https://www.youtube.com/watch?v=gOs6Mdi7y_4
Fusion 360 Overview: https://www.autodesk.com/products/fusion-360/overview	Video 5: Fusion_Setup. Account setup for Autodesk to access Fusion 360 in computer or Chromebook (3:11 min)* https://drive.google.com/file/d/1ltnsWmUGmbFqJYrQKLdzCf9xRiyeybyW/view?usp=sharing Video 6: Fusion_Solids. Basic controls and creation of a cup (7:35 min) https://drive.google.com/file/d/1Rqa9aOnwkEUx8TUJLIqVCEu93LEohd4/view?usp=sharing Video 7: Fusion_Simple_Plant. Creation of stem and leaves (8:35 min) https://drive.google.com/file/d/1vmolz2-cUY_26_Btb8rM1CdNP5ROwsvt/view?usp=sharing Video 8: Fusion_Advanced_Leaf. Creation of a leaf (6:48 min) https://drive.google.com/file/d/1K88693bxu4Sgn4q8nNI_wNF_aj6nLRyC/view?usp=sharing Video 9: Fusion_Flower. Creation of a flower (9:59 min) https://drive.google.com/file/d/1J745AC3eXHHKOrebqMRQhis09w42RyD0/view?usp=sharing

* Tinkercad and Fusion360 are software that belong to the Autodesk platform. If you have an Autodesk account, you can access both programs. Watch Video 1: Fusion_Setup to create this account.

3D model design and creation

Step 6. Choose the models to create

Your teacher will discuss with you the potential models to create with the students based on the needs of the research labs at the Danforth Center. In Table 2 is a list of potential species to model that are under research at the Danforth Center.

Table 2. Information about potential plant species to choose for 3D modeling.

Danforth Scientists	Plant Species	Project and purpose	Resources
Andrea Eveland and Jiani Yang	Maize (<i>Zea mays</i>)	Studies on the regulation of architecture traits and yield potential in cereal crops.	Andrea Eveland's Lab website One-page project description
Jim Umen	Volvox (<i>Volvox carter</i>)	Studies on the evolution of multicellularity	Jim Umen's Lab website One-page project description
Jiani Yang	Green foxtail millet (<i>Setaria viridis</i>)	Grain production in cereals	Scientific publication Blog Blog
Allison Miller	Asteraceae: Rosinweed (<i>Silphium integrifolium</i>) Fabaceae: Alfalfa (<i>Medicago sativa</i>) Poaceae: Canada wild rye (<i>Elymus canadensis</i>) Black-eyed peas (<i>Vigna unguiculata</i>)	How plant traits, from shoots to roots, govern connections to aboveground components of terrestrial ecosystems to the soil.	New Roots for Restoration Institute
Toby Kellogg	Big bluestem (<i>Andropogon gerardii</i>) Little bluestem (<i>Schizachyrium scoparium</i>) Indian grass (<i>Sorghastrum nutans</i>) Switchgrass (<i>Panicum virgatum</i>)	Morphology of spikelets and ligules from prairie grasses	The Power of prairies Step Inside the Danforth Center Prairie

Step 7. Develop the concept art of your 3D model(s)

- The concept art is the visual concept of the 3D model that should be developed before starting to create the models.
- Start with the design of a simple model for one object. As you practice, you can develop more complex models made of different parts.
- Draw or sketch the design with pen and paper, or use tablets to make the digital sketch of the 3D model using the following free software:
 - Autodesk Sketchbook: <https://sketchbook.com/>
 - Google AutoDraw: <https://www.autodraw.com/>
 - Inkscape: <https://inkscape.org/about/overview/>

Step 8. Work with scientists and mentors

Depending on the concept art, scientists and other mentors will work with your team to advise you on the biological aspect of the planned 3D model(s). For example, the mentor will suggest certain colors, shapes, or sizes that will make your model(s) accurate when compared to the real plant object(s).

Step 9. 3D model creation

- Become familiar with the 3D modeling software Tinkercad and Fusion 360.
- There are different file types for 3D models. These types will allow you to use the 3D models for different purposes (3D printing, zSpace, etc.).

Requirements for 3D models to be used in the zSpace and Oculus platforms

- Vertice count should not be greater than 20,000
- Export your models in .obj format
- The .obj export will be a zipped file and this entire file is necessary for importing into VR.
- When designing the 3D models, students should keep in mind the scientific accuracy, ease of use, and aesthetics of the product design.
- If you feel comfortable creating models, consider creating more than one 3D model per group. These models may represent a plant-related process such as pollination, germination, etc.).

Intellectual property rights. The 3D model(s) that your team will create through this project will be of open access. These products will be shared through the zSpace community, which will provide teachers and students across the world the opportunity to use them.

Step 10. Interaction with Augmented Reality (AR) and Virtual Reality (VR) tools

You will have the opportunity to learn how to use the zSpace computers for AR and the Oculus Quest head mounted devices for VR experiences. You will learn how your 3D models could be used in AR and VR platforms.

Dissemination of the 3D models in scientific events

Step 11. Prepare a presentation of your 3D models

Your team will prepare a PowerPoint presentation, video, or poster to share your experiences with 3D modeling and present your 3D plant models.

To prepare for the presentations, your team should take into consideration to:

- Include the following content:
 - motivation for choosing the target species and particular objects

Student protocol – 3D plant modeling

EROL Education Research & Outreach Lab

- biological content describing the species and importance of the species for Danforth research and for society
- design process
- product: 3D plant model
- challenges (positive and negative)
- Prepare slides/images that are visually appealing and look professional
- Practice the presentation in advance and test the timing of it
- (Optional) If your school has a 3D printer, consider creating a test print of the models to use during the presentation.

Step 12. Presentation of your 3D models

Your team will have the opportunity to present the 3D model(s) created during different events at your school, the Danforth Center, and or other venues.

The PM will help coordinate the attendance of mentors to the presentation event, and mentors will evaluate the teams' products based on:

- the use of technology through the products created
- the scientific accuracy, ease of use, and aesthetics of the product design

Step 13. 3D model worksheet

Your team will prepare a one-page worksheet that will support teachers' lesson plans related to your species and 3D model(s). The worksheets should include the following elements, some of which already will be available from your presentations:

- Title: the name of the species (common and scientific name)
- Images: photo of the plant and the plant part modeled if applicable (e.g., seed, flower), and photo(s) of the 3D model(s)
- Biology of the plant and its importance to society and or plant science research (1-3 paragraphs)
- 3D model: Description of 3D model (1-2 paragraphs)
- Questions: three to five questions formulated by the students (one per student) about what they will want to ask a student to learn about their model(s) and or science content.

Education research and evaluation

Step 14. Contribute to education research

To continue with the education research goals of this project, you will need to complete **at the end** of the project two post-surveys and post-reflection questions. The links are:

- Post-survey on student perceptions of scientific disciplines (STEM Semantic survey).
https://survey.iad1.qualtrics.com/jfe/form/SV_bK1wBTt5EjGqzau

Student protocol – 3D plant modeling

EROL Education Research & Outreach Lab

- Post-survey on student plant awareness
https://survey.iad1.qualtrics.com/jfe/form/SV_8A1qLdl8SSYxQ34
- Post-questionnaire on student reflections
https://survey.iad1.qualtrics.com/jfe/form/SV_1Late3fRTxwOu46

If you need help

You may find challenges while creating the 3D models.

- For technical questions about the use of Tinkercad and Fusion 360, contact Nate Ly at NLy@danforthcenter.org.
- For questions about the biology and importance of your species, contact the PM Sandra Arango-Caro (sarango-caro@danforthcenter.org) or the designated scientific advisors for your team.

Student protocol – 3D plant modeling

EROL Education Research & Outreach Lab

Project to do list:

- ☐ Have a team and choose your role
- ☐ Understand what 3D modeling is
- ☐ Train yourself in the use of Tinkercad and Fusion 360 to create 3D models.
- ☐ Decide which 3D plant model(s) to create
- ☐ Research the biological content and importance of the model(s)
- ☐ Develop the concept art
- ☐ Create the 3D plant model(s)
- ☐ Evaluate the accuracy, ease of use, and aesthetics of the model(s)
- ☐ Prepare a poster, PowerPoint presentation, and or video of your model(s)
- ☐ Present your project during a school, scientific, or public event
- ☐ Prepare a worksheet about your species and 3D model(s)