PLANTS FOR SPACE

ARC CENTRE OF EXCELLENCE

Teachers Guide

Story Cards

Year 7 & 8

Activity

Australian Government
Australian Research Council

PLANTS FOR SPACE
ARC CENTRE OF EXCELLENCE

Plants for Space Story Cards

Activity Objective

Plants for Space Story Cards are used to highlight the challenges and solutions to growing plants off Earth in the near future including, the science needed to achieve success, the people working on the solutions and the benefits for Earth that the centre of excellence will achieve.

Students will expand their understanding of the interdisciplinary sciences needed to re-imagine the way plants are grown, what they produce and what can be made from them.

Australian Curriculum Content

This activity is an open-end activity that can be used across multiple curriculum points and could be used to enhance capabilities in biological content knowledge, design, English, STEM, future careers, critical and creative thinking.

Resources and Equipment

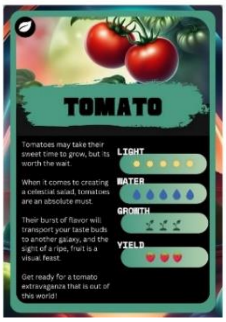
- Set of the Plants for Space Story Cards (link)
- Student Instructions and Challenge Sheets (link)
- Video: Plants For Space Introduction (link)

Activity

The Plants for Space Story Cards are used as a prompt and stimuli for students to investigate the science, technology, and careers being utilised by Plants for Space. Combined with the challenge cards students play the role of a plant designer and create plants that solve problems to help astronauts thrive in space.

Card Overview

There are 4 categories of story card (plants, tools, products, outcomes) . The categories have different background colours and icons. The front of each card has a short description introducing what it represents. On the reverse side a Plants for Space researcher and their work is highlighted to create a real-world connection to the activity.

Plants	Tools	Products	Outcome
			

How they can be used:

To make the most of the cards it is suggested that students are prepared with a foundational understanding of the science and challenges, and they use the cards to help visualise, organise and develop their thinking to create plant-based solutions that help people in space. Student ideas and solutions are articulated and documented in some way to allow a record of student understanding and thinking. Below is an overview of the suggested P4S story card phases you might wish to use:

Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
Build background understanding	**The Challenges**	**Iteration**	**Solutions/Stories**
• Story Cards • Readers • Videos • Posters • Self-directed research • Presentations	• Single Challenge • Science fiction Narrative	• Story Cards • Create daft or protype • Layer challenges	• Written description • Presentation • Diagram • Poster • Story • 3D model

Phase 1: Build background understanding

In this phase, teachers help students build their understanding of the need, the challenges, the science and the solutions being investigated by Plants for Space. Plants for Space resources such as readers, videos, posters and the background information (found below) can be used in activity-based learning sequences to help inform students.

Phase 2: The Challenges

During phase 2 students are asked to recognise the challenges and needs that P4S aims to address. To help students recognise these needs teachers can use the simple challenge cards. These are ‘Can you” prompts such as “Can you design a plant that produces a food and a medicine?”

For a more challenging exercise students can read one of the narrative scenarios. These are short science fiction narratives that present students with real world case studies that allow the application of theory, critical thinking, problem-solving and decision-making skills as well as empathy in a challenge to identify the needs.

Phase 3: Iteration

Students use the Story Cards to help organise thinking and their iterations for novel plant designs and solutions. It is worth noting that the card categories do not need to be in any particular order and multiple cards per category can be used. During the iteration process teacher have an opportunity to help students recognise other challenges, constraints and opportunities that might be a part of their chosen scenario.

Phase 4: Solutions/Stories

Students demonstrate their understanding by creating a body of work, a performance of understanding, that could be, but is not limited to: written description, presentation, diagram, poster, story, 3D model of their novel plant.

Example Use

Background Information for Teachers and students

Plants for Space (https://plants4space.com/)

The ARC Centre of Excellence in Plants for Space (P4S) are 5 Australian universities (Adelaide University, La Trobe university, University of Melbourne, Flinders University, and University of Western Australia) vertical farming companies, space companies, Australian Space agency and NASA. All are collaborating to develop technologies to enable humans to survive and thrive in space, reducing the dependence on constant resupply, and using this lens to transform the sustainable food and bioresource production on Earth.

P4S is a transdisciplinary endeavour involving plant biology, systems and process engineering, food chemistry, psychology, education, Agricultural technology and space law. The P4S team has four core missions:

1. On demand bioresource production.
2. Zero-waste plant growth optimised for controlled environments.
3. Complete nutrition via plant-derived sources in a variety of forms to support astronaut nutrition and psychology, and support on Earth market development.
4. Future ready workforce and society.

P4S Missions

On demand bioresource production.

P4S is using the team’s deep knowledge of plant processes and genomic technology to create programmable, tuneable plant factories for bioresource production. Initial novel products include flavours, pharmaceuticals, and polymer precursors for 3D printing by creating:

- A library of expression cassettes for rapid, on-demand biomolecule synthesis. Each cassette will drive plant expression of a single biomolecule providing an a la carte menu of flavours, nutrients, or drugs that can be harvested within hours.
- Smart Plants already programmed to produce a broad range of required biomolecules, each of which can be triggered by a specific cue, e.g. light, nutrients.
- Sentinel plants with in-built biosensors for monitoring agriculture plant health and harvest readiness.

P4S takes a system-wide approach to sustainability, assessing our plant and product innovations to ensure energy and resource sustainability and circularity targets.

Zero-waste plant growth optimised for controlled environments.

P4S is redesigning crops to generate bespoke plant varieties for Controlled Environment Agriculture (CEA) (in doors) by co-optimising plant traits and growth environments. i.e. humidity, light, temperature, CO2/O2 and nutrition. The aim is to develop fast growing, zero-waste plants by:

- Accelerating growth and optimal nutrition
- Enhancing growth conditions (e.g., reducing drought, starvation, defence against insects) and so plants re-direct energy to enhance growth
- Making all plant parts usable to achieve near to zero-waste production
- Enhancing nutrient and water use efficiency to minimise required inputs

Creating a future ready work force.

P4S's research will impact society through developing public understanding and perception, legal, regulatory, ethical, and psychological frameworks ensure we are Space prepared.

P4S aim to provide an industry-ready translation and STEM ready workforce pipeline through education and engagement for students and the broader community and nurture relations between academia, government, industry, and start-ups.

Off Earth Living

Humans have been living in space consistently since 2000 when the International Space Station became operational. However, before this the MIR space station operated for 14 years with an astronaut presence for most of its existence before being decommissioned. The advent of low Earth orbit space stations marked the beginning of longer-term space habitation. With this advancement comes the need to research and develop systems and products that enable astronauts to not only survive in space for extended period but to also thrive.

Everything that an astronaut needs to survive on the ISS, such as water, food, and air originates on Earth and is delivered by resupply spacecraft. It costs thousands of dollars per kilogram of material to reach the ISS. Further destinations such as the Moon and Mars would cost even more and take more time to resupply.

Aside from wastewater most of the waste generated by the astronauts is not reused or reprocessed and usually ends up being incinerated when resupply crafts re-enter Earth's atmosphere. Food production is extremely resource intensive yet is a fundamental need for humans to survive and thrive. Due to the highly constrained environment in space, developing any sustainable food production systems and products for these environments could also help Earth-based systems be more sustainable.

An astronaut's diet is a specially curated menu of food prepared on Earth. These meals must be carefully prepared with several factors considered, such as nutrition, shelf-life, palatability, ease of preparation and payload constraints.   Although food plants are being grown on the ISS the majority of what is being produced is for scientific study and not for consumption. For longer-term habitation such as on the moon and Mars the need for localised production of food and material resources is needed for astronauts to thrive.

For more information on food on the ISS go here: Space Station 20th: Food on ISS - NASA

Moon and Mars Mission

Artemis

NASA with support from international partners is currently under way with the Artemis program that with return humans to the surface of the moon. Artemis III will land on the surface of the moon near the lunar south pole by 2027 at the earliest. Two astronauts will stay on the surface of the moon for approximately a week where they will explore the surface and conduct a variety of experiments.   One of the experiments that will be conducted is the Lunar Effects on Agricultural Flora (LEAF). The Leaf module is a controlled environment module that the Artemis astronauts will place on the surface of the moon and activate. When activated three plants varieties will be grown in the LEAF module. The plants growth will be monitored using cameras, and other instruments to study the effects of low gravity, radiation and other stresses encountered while on the moon. Before the astronauts leave some of the plants will be harvested and preserved for study back on Earth. The remaining plants will be left behind and will continue to grow until the batteries run out on the LEAF module during lunar night. This will be the first time that plants grown on the moon will be returned to Earth.   When returned to Earth Plant for Space will have the opportunity to analyse some of these samples.

Each successive Artemis mission will build the knowledge base to develop the systems needed for long term moon habitation. The current thinking is that the lunar south pole will be the location for a lunar base that will be utilize to create a lunar economy and produce water and fuel to be used on the humans to Mars missions.

For more information on the Artemis program go here: Artemis - NASA

For more information on the Artemis III mission go here: Artemis III: NASA's First Human Mission to the Lunar South Pole - NASA

Form more information on the LEAF experiment go here: NASA's Artemis Astronauts Will Help Grow Crops on the Moon—And Much More | Scientific American

[Plants to be grown on the Moon when humans return | Newsroom | University of Adelaide]

Mars

Although a goal of extended moon habitation is to develop a lunar economy a more ambitious goal is to use the moon as a testing ground for the systems and technologies that would enable humans to travel to and eventually reside on Mars.

The Martian environment cannot support life and is extremely hostile. Any human presence on Mars would be in protect environments like those that would be developed for Lunar habitation. Although terra forming Mars is often mentioned when discussing humans on Mars there are currently no technologies developed to make this a reality.

Form more information on human habitation on Mars go here: [Humans to Mars - NASA]

P4S Science and Technology

Synthetic Biology

Synthetic biology is the design and construction of DNA-encoded parts, devices, machines, and organisms, and their application for useful purposes.

'Synthetic biology is the application of engineering principles to biology. It involves the design and construction of biological systems and devices, as well as the re-design of existing, natural biological systems, usually based on DNA-encoded componentry, and their application for useful purposes. Components include DNA, RNA, and proteins (commonly enzymes); these are used to build genetic circuits encoding cellular machinery, which may be applied either *in vivo* (inside cells) or *ex vivo* (in test tubes or other non-cellular environments). It is a highly interdisciplinary science, drawing on biology, engineering, and computer science, as well as many other fields, and has potential applications in areas as diverse as manufacturing, human health, agriculture and protecting ecosystems.' (CSIRO 2020 CSIRO)

For more information on synthetic biology go here: [Understanding synthetic biology – Synthetic Biology Future Science Platform])

P4S will utilise synthetic biology technology to develop biological circuitry that can be introduced into plants. This will allow a plant to produce a variety of compounds such as medicine, enzymes, proteins, and polymer precursors.

Video: **[Scinamation: Synthetic Biology on Vimeo]**

Switches

Plants that have been modified and designed using synthetic biology will act much like computer programs where certain outputs are produced by specific commands. Unlike computer programs plants do not have keyboards, WiFi or sensors to input commands to 'run" programs. Instead, plants will be programmed to detect an input signal and then transform it into an output cue. These input signals can be specific wavelengths of light, certain temperatures, or chemicals found in the plant's growth medium, or applied to leaves. Plant could have many different "programs" embedded into their DNA requiring different switch inputs to activate the program resulting a plant that has the potential to have many different uses.

Article: [Synthetic Switches and Regulatory Circuits in Plants | Plant Physiology | Oxford Academic]

Controlled environment

Plants grown in space, on the moon and Mars will be grown in controlled environments. Controlled environments can be simple greenhouses using natural sunlight or more advanced habitats where plants are grown under LED light and atmospheric conditions are carefully regulated. Although terraforming of Mars captures the imagination, realistically, plants grown on the moon and Mars will be grown in highly controlled environments that will maximize growth potential, space and product yield. To achieve these goals plants will have to be designed to be suited to specialised environments where water, nutrients, and light are readily available but are finite in abundance and space is a commodity.

Reader: (Link)

Automation

Farming on Earth is a labour, and area intensive practice and yields are often determined by how much labour and space is available. In space astronauts are time poor and habitable space is limited. To achieve sufficient yield of any crop automations will need to be part of any food production process. Agribots (agriculture robots) are an emerging technology increasingly being utilised to assist in food production here on Earth. Automated vertical farms are the meeting point of controlled environment agriculture and robotics and will be the systems used to upscale food production on the Moon and Mars.

P4S is working closely with controlled environment and vertical farm companies to integrate plants designs with their technologies.

AI / Imaging

Having sentinel plants designed by synthetic biology that exhibit visual cues or having robots able to pick strawberries are only useful if autonomous systems can identify cues and assess how to proceed when certain cues are detected. AI models and advance imagine technologies will be used to accurately monitor, and access plant conditions.

References ...

What referencing system have we decided on???