Growing Beyond Earth
Evaluation Results Summary: 2016-2020

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Introduction

In 2015, Fairchild Tropical Botanic Garden (Fairchild), located in Miami-Dade County, Florida, entered into partnership with NASA's Kennedy Space Center (KSC) to help advance NASA's plant research through classroom-based STEM citizen science with a project entitled, *Growing Beyond Earth* (GBE). The project, initially launched at middle and high schools in Miami-Dade County, Florida has expanded to include schools throughout the United States.

GBE is designed to:

a) Increase middle and high school students' interest and skills in science by engaging them in authentic citizen science research, and
b) Increase plant diversity for spaceflight by evaluating edible plants that meet NASA's criteria for size and edibility.

Using equipment that mimics the environmental conditions aboard the International Space Station (ISS), students test factors that may influence plant growth, flavor, and nutrition. Fairchild provides each participating teacher with the necessary equipment (a mini botany lab), materials, detailed research protocols, pre-implementation training, and ongoing implementation support. During the school year, students closely follow GBE research protocols to test a range of plant varieties and growing conditions. The data that students generate are used by scientists at Kennedy Space Center to select plants for further evaluation in space on the ISS.

In addition to collecting and analyzing data, students have the opportunity to engage in other GBE activities such as:

Interacting with NASA scientists and students at other participating sites through Twitter, web conferencing, web-based data sharing, and an annual research poster symposium.

Designing and conducting their own research studies based on data they collect during each Fall's Trial 1 research.

This report summarizes the results of a four-year evaluation of Growing Beyond Earth conducted by an external evaluator between August 2016 and May 2020. Evaluation methods included surveys, interviews, observations, and document reviews. Data were collected from participating teachers and students as well as Fairchild and NASA staff.

Evaluation Results

Evaluation data generated during the four year evaluation period indicate that GBE is a highly engaging citizen science project for middle and high students. Over the course of the four year evaluation, Growing Beyond Earth:

1) Provided useful data to NASA that supported NASA's ongoing space botany research.
2) Engaged students in authentic STEM research.
3) Engaged a very large, diverse group of students from across the country.
4) Increased students' positive attitudes toward botany and science.
5) Increased students' botany and science knowledge and skills.
6) Demonstrated that it is replicable and scalable in a wide variety of contexts.
7) Illustrated a number of effective strategies for increasing student interest in STEM.

GBE provided useful data to NASA that supported NASA's ongoing space botany research.

GBE students have become valuable research partners to NASA by serving as a "feeder program" and "ideas factory" for NASA's new plant testing research. Often, the benefits of STEM programs are unidirectional with the benefits accruing primarily to students, not to science partners. However, with GBE the benefits are clearly bidirectional—both students and NASA benefit. NASA has acquired valuable data on:

- Plant varieties: Students tested more than 140 plant varieties.
- Growing techniques: Students tested various growing conditions and harvesting techniques including substrate, lighting, and fertilizer.

According to NASA scientists:

[Based on GBE student research], we've narrowed the crop list … We're putting those through our more rigorous testing and we're actually going to test at least two [in ISS]. And these are plants that we would probably have never looked at because there's so many potential crops out there.

A group of GBE students was talking about combining the root zones in one pot as opposed to separate pots. … we're thinking about how can we test this in our system.

We're growing plants with a repetitive harvest, a cut and come again technique. That was based on the data that the GBE students generated where they showed clearly

that you could get more than double the yield for these particular crops by doing repetitive harvest. We pulled that technique right from [GBE students].

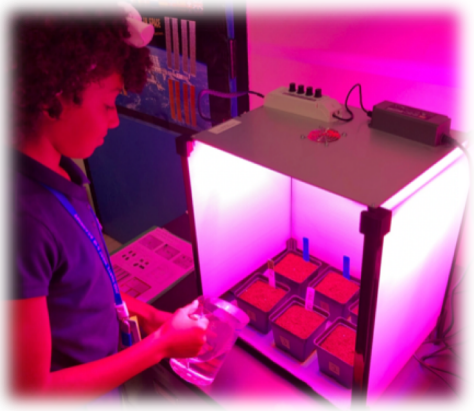
GBE engaged students in authentic STEM research.

Students investigate research questions for which there is no known answer. They are not conducting a scripted STEM classroom activity—which is typically the extent of students' hands-on science experience.

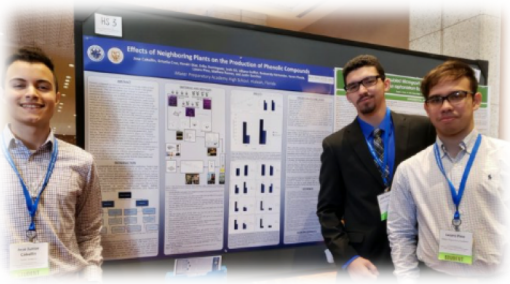
GBE demonstrates hallmarks of authentic research:

1) *Features real-world STEM content*: GBE students are engaged in addressing NASA's research questions related to growing edible plants in space.

2) *Conducted in a real-world STEM setting*: GBE studies are carried out in a grow chamber designed by Fairchild that is analogous to the *Veggie* grow chamber used by NASA on the International Space Station (ISS). Under the guidance of trained teachers, students rigorously follow specific research protocols designed by NASA and Fairchild. Additionally, students produce research posters disseminating their results and students can also participate in a research symposium—replicating professional research practices.



3) *Directly participates in scientific practices:* Teachers report that GBE is an excellent opportunity to provide their students with meaningful, hands-on scientific experiences that strengthen fundamental science practices such as:
   - Asking questions
   - Developing and using models
   - Planning and carrying out investigations (including problem-solving)
   - Analyzing and interpreting data
   - Using mathematics and computational thinking
   - Constructing explanations
   - Engaging in argument from evidence
   - Obtaining, evaluating, and communicating information



4) *Involves scientists and engineers as role models or mentors*: Students interact in-person and virtually with NASA and Fairchild scientists. NASA scientists conduct webinars, participate in the annual student research symposium, host field trips to Kennedy Space Center (KSC), and interact regularly with students via Twitter.

5) *Involves participants in collaborative project work*: A defining characteristic of GBE is the collaborative nature of the project. Typically, students work in groups and often divide roles and responsibilities.

GBE engaged a very large, diverse group of students from across the country.

- Over the course of the four year evaluation, student participation tripled—from 3,600 middle and high school students to 10,639. Students typically participate in GBE for one academic school year.
- Additionally, the project expanded from 97 schools primarily located within Miami-Dade County, Florida to 210 schools in 26 states and Puerto Rico.
- Overall, participating students reflected the demographics of their school districts ranging from large, urban school districts such as Miami-Dade, Florida to smaller districts in states like Alabama, Colorado, Ohio, and Nebraska, to name a few.
- About half of participating students were female.
- Students from Miami-Dade County, Florida comprised the largest group of students—about 90% in year one and dropping to 49% by year four as GBE expanded nationally. Participating students in Miami-Dade were predominately minority students attending schools in low-income communities.

GBE increased students' positive attitudes toward botany and science.

It appears that GBE even engages students who did not have prior interest in botany or science. Representative quotes from teachers include:

GBE opens a door to student interest in science.

GBE is so powerful. I have never seen students so attached and excited.

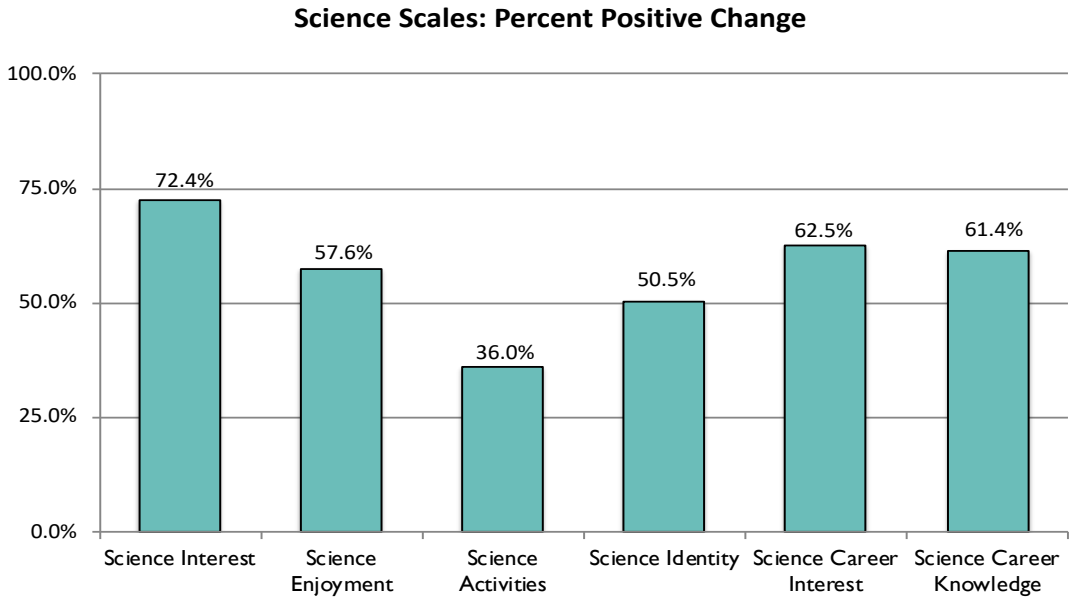
My students always get attached to the plant. They name it, they really care about the plants and they get really excited to see them grow.

In students' own words:

I can imagine myself as a scientist because I am doing 'real' science.

It is an AMAZING project. I love being able to talk to people from NASA about what I learned. I think is a good way of learning about what people at NASA do and it encourages us to think more like scientists. I like that the work we are making is going to be valuable for the NASA.

As detailed in the chart below, a sample of GBE students reported statistically significant gains on items relating to Science Interest, Science Enjoyment, Science Identity, Science Career Interest, and Science Career Knowledge ($p < 0.05$)[1].



GBE increased students' botany and science knowledge and skills.

Teachers reported that GBE provides students with the opportunity to strengthen botany and science knowledge and skills particularly in the areas of growing plants, collecting data, planning scientific investigations, constructing explanations as well as reading, evaluating, and communicating scientific information.

> *GBE makes science processes come alive.*
>
> *Students [are] more comfortable implementing science protocols as well as gathering and analyzing data. They have learned to find anomalies in their data. …They investigated and … were able to problem-solve.*
>
> *My students were more engaged in this process than any other experiment I have ever conducted. Students were actively working on the trials, asking high level questions about the process, and actively explaining the process to others that visited our classroom.*

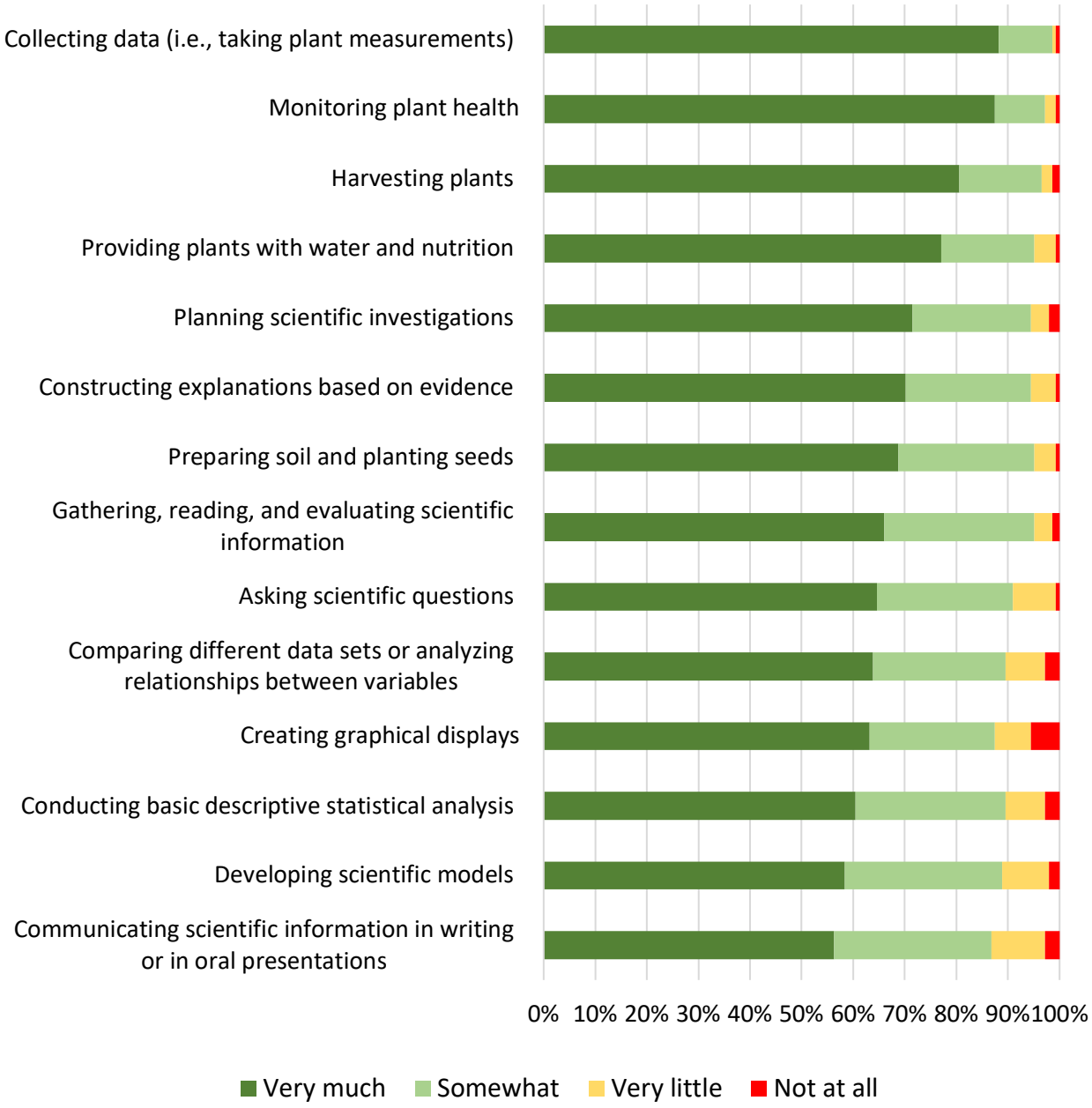
[1] Data collected during year two of the evaluation using a nationally validated assessment. Permission to use the Common Instrument Suite (CIS) was obtained from The PEAR Institute at Harvard Medical School and McLean Hospital.

[Students displayed] deep thought into how our astronauts eat, what they eat, how often and what can be eaten in space. The use of the equipment linked into their understanding and inquiry of the LED lights … They saw how artificial lighting can promote growth of plants. Many questions and probing resulted from this unique opportunity.

Extent GBE Provides Students with Opportunity to Develop Skill

GBE year three evaluation data (2018-2019)

number of teachers = 144



In students' own words:

GBE gave me the chance to learn more about botany and science … before I only knew that botany was something associated with flowers.

I liked being able to interact with other researchers my age allowing me to be more comfortable when collecting information.

It was fun collecting data, making tweets and graphs. The data collection was an amazing experience for my future occupation.

GBE is replicable and scalable in a wide variety of contexts.

Over the course of the four year evaluation GBE was successfully replicated in a growing number of schools and within a broad range of educational contexts, including:

- *Academic content areas*: While students were most likely to experience GBE within the context of a science course, GBE was also successfully implemented within a variety of non-science courses including culinary, history, language arts, visual arts, and English as a Second Language, to name a few. Teachers reported that GBE lends itself very easily to interdisciplinary and collaborative approaches to learning.
- *Educational settings*: While GBE was typically implemented within a classroom setting, it was also successful implemented in a variety of informal education settings such as school-based extracurricular clubs, home school association programs, and youth development programs.
- *Pre-requisites*: Implementing GBE does not require specialized staff knowledge or skills. Nor does it require that students have prior science knowledge or skills. All required materials as well as implementation support are provided, at no cost.
- *School type:* While GBE was most frequently implemented within public schools, it was also successfully implemented at charter, private, and parochial schools.

- *Group size*: GBE was implemented with student groups ranging from 1 student to 300 students per participating teacher. Most frequently it was implemented with fewer than 20 students per teacher.
- *Location*: GBE was initially implemented in Miami-Dade County, Florida but by year four had expanded to urban, suburban, and rural schools in 25 additional states and Puerto Rico.

GBE illustrated a number of effective strategies for increasing student interest in STEM.

Taken together, these strategies enable GBE to engage students and increase their interest in STEM to a level not seen previously by many teachers.

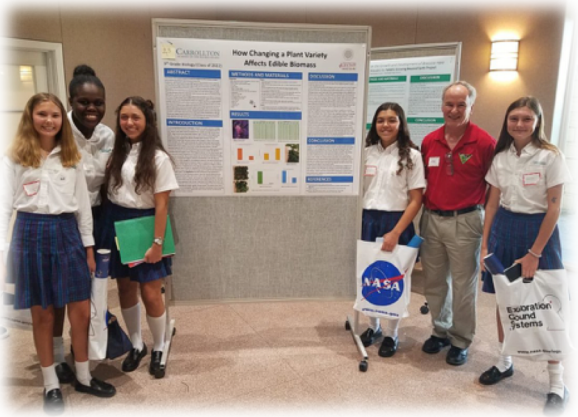
1) Engaging students in authentic research.
   This is for real, not just for a grade.

2) Engaging students in something they perceive as important: Students had direct interactions with NASA scientists and understood that NASA was using their research results to support ongoing NASA research.
   This is for NASA … so it is super important. We have to get this right.

3) Selecting compelling research subjects: Many students developed strong personal connections to the plants they were studying—expressing concern about their health and sometimes even naming them.
   My students always get attached to the plant. They name it, they really care about the plants and they get really excited to see them grow.

4) Making it "cool" and prestigious: Students were proud of their NASA affiliation and some included it in their resumes and college applications.

5) Addressing students' developmental needs and interests including their need to contribute, to have a sense of purpose, to feel valued, and to care for something (i.e., plants).
   I feel important because I am working with NASA and NASA is using our results.



6) Providing a "low barrier to entry" for participation: Participating in GBE does not require any special knowledge or skills. Students with a wide variety of interests and academic, cognitive, or language abilities can fully participate.