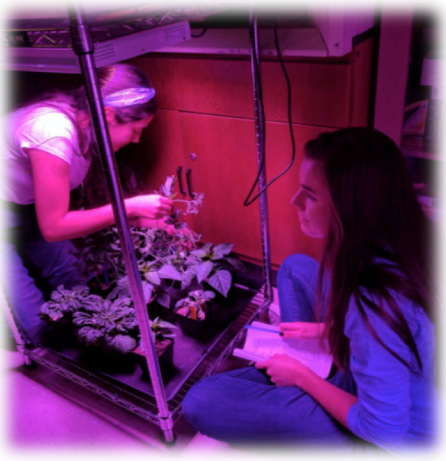
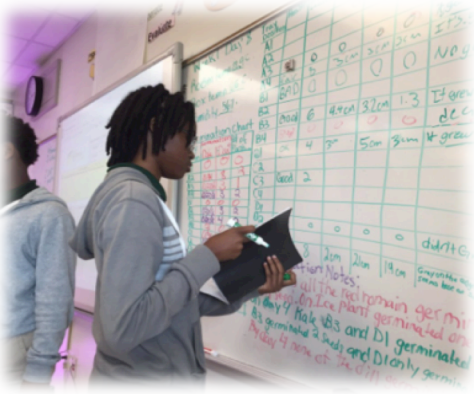
Year One Evaluation Report
2016-2017





July 2017

Growing Beyond Earth
Year One Evaluation Report

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I. Executive Summary

During the school year of 2016-2017, Fairchild Tropical Botanic Garden (Fairchild) implemented the first year of a four-year project entitled: Growing Beyond Earth (GBE). NASA is providing funding support for project implementation as well as an external project evaluation.

The evaluation activities conducted this year were focused on understanding project implementation and exploring project outcomes using data collected between September 2016 and May 2017. This report's findings and accompanying recommendations inform next year's project implementation and evaluation activities.

Analysis of the data yielded findings in three key areas of project implementation.

1. A large number of diverse students and teachers participate in Growing Beyond Earth.
2. Growing Beyond Earth is well designed, unique, and well run.
3. Students and teachers are engaged and satisfied with their participation.

Analysis also yielded findings in four key outcome areas including outcomes for participating students, teachers, and NASA scientists.

1. Students have an authentic STEM experience.
2. Students have the opportunity to strengthen research skills, increase botany knowledge, and improve attitudes towards STEM.
3. Growing Beyond Earth enables teachers to provide unique instructional experiences for their students as well as strengthen their own research skills and botany knowledge.
4. NASA scientists have access to additional useful data to support NASA research efforts.

Overall, Growing Beyond Earth has had a very successful first year of full-scale implementation—from both an implementation and outcomes perspective. During this first year an estimated 3,600 middle and high school students in 97 schools participated under the guidance of 110 teachers and Fairchild project staff. Additionally, the project is generating preliminary evidence of positive outcomes for students, teachers, and NASA.

As one stakeholder summarized:

> "I've done a lot of different things with different education and outreach initiatives but I've never been involved with one that's been organized in this way. It seems so well run and so well organized. It seems to have a very clear, well defined way of generating excitement for the students, generating data for NASA, and generating a very, very high, high quality educational program in general."

II. Evaluation Activities

Overview: An external evaluator is collaborating with Fairchild staff to conduct a four-year evaluation of the Growing Beyond Earth project. The evaluation employs a utilization-focused, participatory approach and a mixed methods design. This year's evaluation activities focused on the formative evaluation questions and also included preliminary exploration of the summative questions. The results presented in this report emerged from the analysis of data collected between September 2016 and May 2017.

Evaluation questions to be addressed throughout the four-year evaluation include:

Formative

1. Who participates in the project?
2. To what extent is the project implemented as planned?
3. How is the project implemented at the school level? What variations exist and how do they impact implementation?
4. In what ways can the project be improved?
5. To what extent are participants and partners satisfied?

Summative

1. What level of diversity is represented by participating students?
2. To what extent are project outputs and outcomes achieved?
3. To what extent is there variance in outcome achievement for subgroups of students, years of student/teacher participation and implementation delivery formats?
4. What, if any, are the project's unintended/unanticipated outcomes?
5. What factors contribute to/hinder the achievement of project outcomes?

"Broader Impacts"

1. What can we learn from the project about effective methods for increasing student interest in STEM?
2. How can the project be adapted to investigate other research questions?
3. In what ways does the project integrate with the Miami-Dade Public School Systems curriculum?
4. What can we learn from the project about developing effective partnerships between informal science education institutions, schools, and researchers?

Data Collection: To increase the credibility and usefulness of the results and to ensure multiple perspectives are considered, data are collected from all key stakeholders (i.e., students and teachers as well as NASA and Fairchild staff). Data are collected through a variety of quantitative and qualitative methods that enable a more complete understanding of the project including: student and project products and records, focus groups, formal as well as unstructured interviews, observations, and online surveys. Additional details on the Year One data collection activities can be found in the Appendix.

Data Analysis: Descriptive statistics are calculated for quantitative data. Additionally, tests for statistical significance are conducted where feasible and relevant. Qualitative data are analyzed for themes and other responses of interest. Assessment of meaningful differences in responses between major subgroups is conducted, including academic level (middle vs. high school) and student gender. Meaningful differences, when present, are reported.

III. Results of the Evaluation

The first-year evaluation was focused on understanding project implementation and exploring project outcomes. This report presents the key synthesized evaluation findings below. Much more detailed results, including numerous graphs, are located within the Appendices, specifically:

1. Participating Teacher Characteristics: Detailed information on participating teachers and schools
2. Classroom Implementation Summary: Detailed information on how the project was implemented in participating classrooms
3. Classroom Observation Reflections: Evaluator reflections on project implementation and outcomes based on site visits
4. Twitter Analysis Results: Analysis of students' project-related tweets
5. Teacher Responses to GBE Results Summary: Teachers' perceptions of project implementation and outcomes collected via online survey
6. Student Responses to GBE Results Summary: Students' perceptions of project implementation and outcomes collected via online survey

Findings: Project Implementation

Analysis of the data yielded findings in three key areas of project implementation including who participates in Growing Beyond Earth, project design and support provided by Fairchild staff, and participant satisfaction. Each of these findings is presented below. Additional details can be found in the Appendices.

Implementation Finding 1: A large number of diverse students and teachers participate in Growing Beyond Earth.

Growing Beyond Earth is being implemented by science teachers in a large number of primarily public middle and high schools. The project engages a large number of ethnically diverse students with roughly equal participation of boys and girls.

- 97 schools participated in project activities. Just over 50% of participating schools are middle schools. Almost two-thirds of participating schools are public schools.
- 110 teachers participated in project activities with their students. A typical participating teacher has a Bachelor's degree and more than 10 years of teaching experience. Many participating teachers also participated in the pilot phase of the project during the prior school year.

- Teachers reported that more than 2,620 students participated in project activities. This is an undercount since only 73% of participating teachers reported student participation numbers. Extrapolating from the data, a reasonable estimate of actual participation is approximately 3,600 students—based on a reported average of 33 participating students per teacher.
- Roughly equal numbers of boys and girls participated.
- The racial and ethnic breakdown of participating students is estimated to be: 70% Hispanic; 15% Black; 12% White, non-Hispanic; and 3% Other.
- A small number of students with Individual Education Plans (IEPs) and Limited English Proficient (LEP) students also participated.
- Data regarding the family household income level of participating students was not collected.

Implementation Finding 2: Growing Beyond Earth is well designed, unique, and well run.

Growing Beyond Earth is a unique program design**.** Few current school-based programs combine all of these elements into one program:

1. Provides a hands-on, authentic, 'real-world' STEM experience
2. Generates data that is used by professional researchers
3. Serves a large number of students
4. Provides the opportunity for school-year-long engagement in research
5. Provides a flexible program design, necessary materials, and on-demand technical assistance

"I think [Fairchild] has done a fantastic job creating this project. I completed it in my science elective class and the class has grown from 20 students last year to 50 students this year all because of Growing Beyond Earth. Even the elementary students got involved with our project as observers which gave my students the opportunity to teach what they learned. This has been an amazing experience." Teacher

Additionally, the Growing Beyond Earth structure is flexible—teachers are successfully implementing the project in many different ways to suit their instructional context:

- Teachers were equally split between three modes of implementation: all students in one class participating, all students in multiple classes, or a subset of students (i.e., self-selected student volunteers).
- Most teachers integrated project activities into regular classroom activities at least occasionally; with 46% integrating project activities often.
- Most teachers assigned either grades or extra credit to participating students.
- The Classroom Implementation Summary located in the Appendices provides many specific examples of how teachers implement Growing Beyond Earth.

Fairchild provides the materials and technical assistance needed to implement Growing Beyond Earth. Materials provided include the growing unit, seeds, soil, etc. as well as detailed written instructions for all project-related activities. Technical assistance includes orientation and training workshops and project staff who are available to answer any questions about project activities. During the evaluation, some teachers and students provided recommendations on how to improve project implementation. These recommendations are presented in the final section of this report.

Implementation Finding 3: Students and teachers are engaged and satisfied with their participation.

Many participating students and teachers are highly interested in, and engaged by, Growing Beyond Earth. One indicator of interest is evidence that many participating students talk to others about the project including parents, family members, and friends. Furthermore, most participating teachers and students who responded to the project evaluation survey were very satisfied with Growing Beyond Earth, would recommend it to a colleague/friend, and intend on participating next year. In their own words teachers and students recount their thoughts on the project:

"Growing Beyond Earth was a success. We have some of the plants in our school garden and they are growing. It was my first year in the project and I can't wait for the next year to do it again." Teacher

"I love it and I am going to encourage others to participate in this project next year." Student

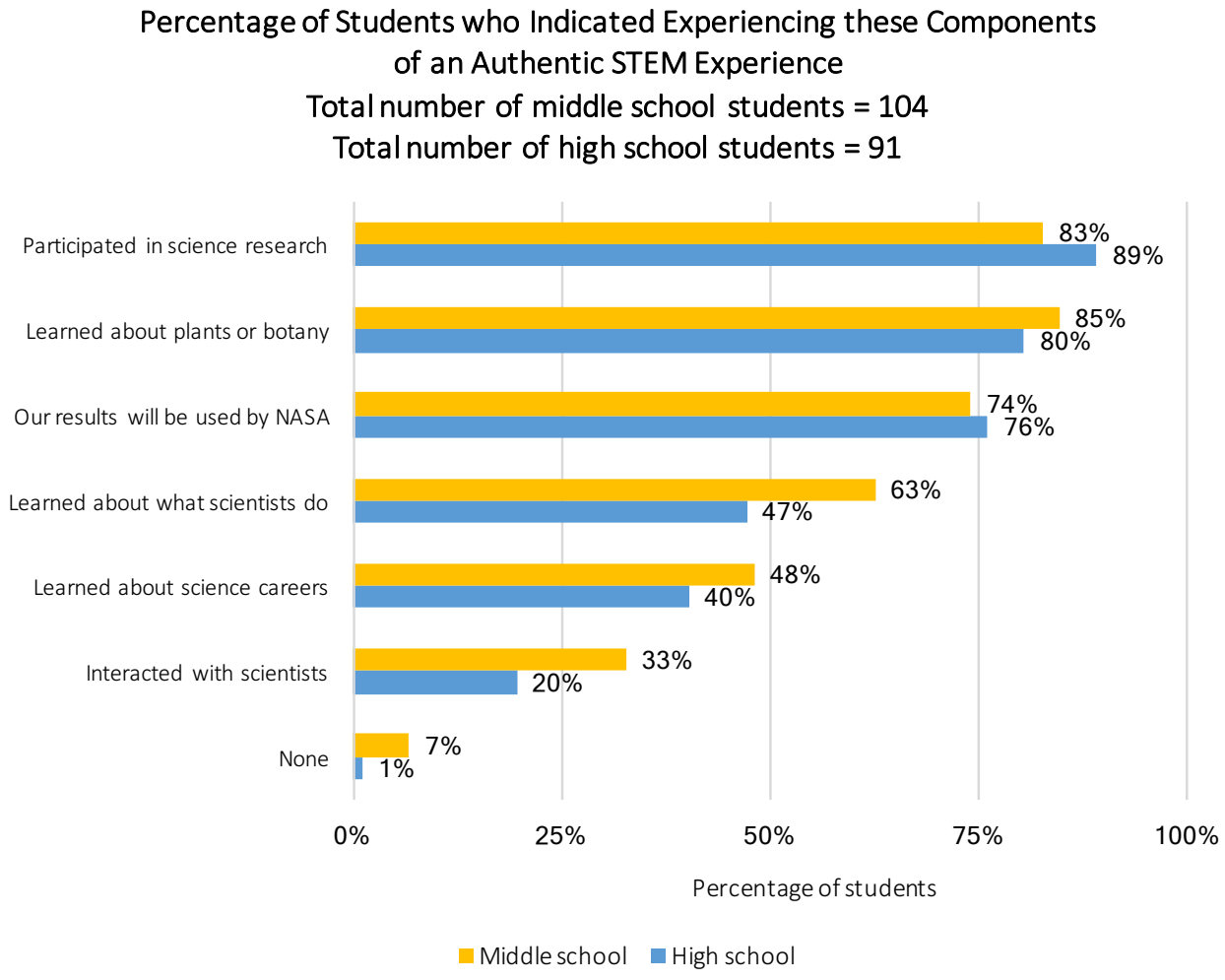
"Excellent STEM experience for my students. Once they started this research they could not stop researching and have established a continuing research project. They would love to have two veggie gardens next year in order to include more students." Teacher

Findings: Project Outcomes

Analysis of the data yielded findings in four key outcome areas including outcomes for participating students, teachers, and NASA scientists. Each of these findings is presented below. Additional details can be found in the Appendices.

Outcomes Finding 1: Students have an authentic STEM experience.

Growing Beyond Earth activities are centered around conducting a series of research trials following protocols developed by Fairchild staff and NASA scientists. The results of these student-run trials are then utilized by NASA scientists to support NASA research. Participating in Growing Beyond Earth entails engaging with real-world STEM content, interacting with scientists, and collaboratively participating in scientific practices such as generating hypotheses, recording/analyzing data, interpreting results, and communicating to public and scientific audiences—the very definition of an authentic STEM experience.



For many participating students, Growing Beyond Earth has been their first "real" research experience. Teachers and students reported that while students may participate in hands-on science activities as part of their science courses, for most students this was the first opportunity to participate in an authentic research study whose results actually contribute to building the body of knowledge in space botany. In their own words teachers and students describe their authentic STEM experiences:

> "GBE benefited my students by allowing them to conduct hands-on real-life research that is being utilized by scientists." Teacher

> "It was nice since we conducted research that helped NASA grow plants on the ISS." Student

> "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 like in the 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." Student

> "I enjoyed learning more about plants and their growth. I also liked learning more about programs such as Excel." Student

> "I liked how hands-on the experiment was and how every week you could be chosen to participate to measure and harvest the plants." Student

> "I think the project was interesting and a fun way to make science applicable in a real life situation." Student

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

Growing Beyond Earth also provides many opportunities for students to communicate about science in a wide variety of ways (e.g., Twitter, data visualizations, presentations) and to many different audiences (e.g., peers, family members, scientists, general public). In the image below students are teaching much younger students about plants.

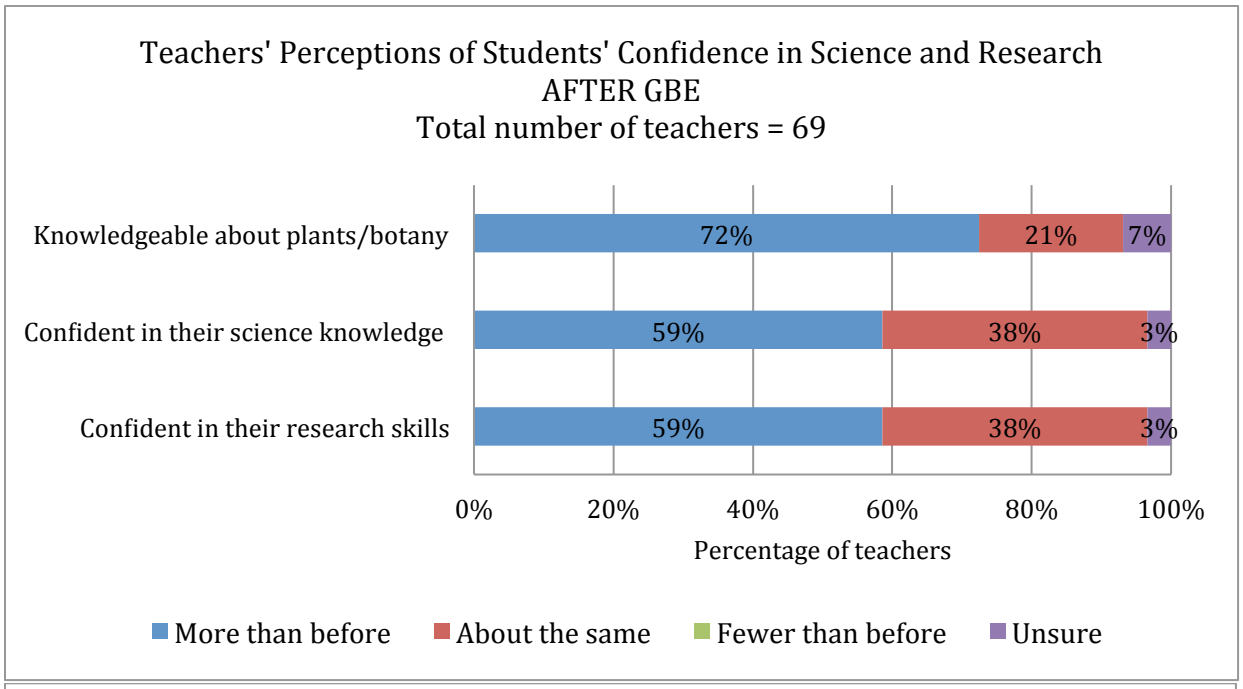
"I liked how I interacted with other members to make a tweet."

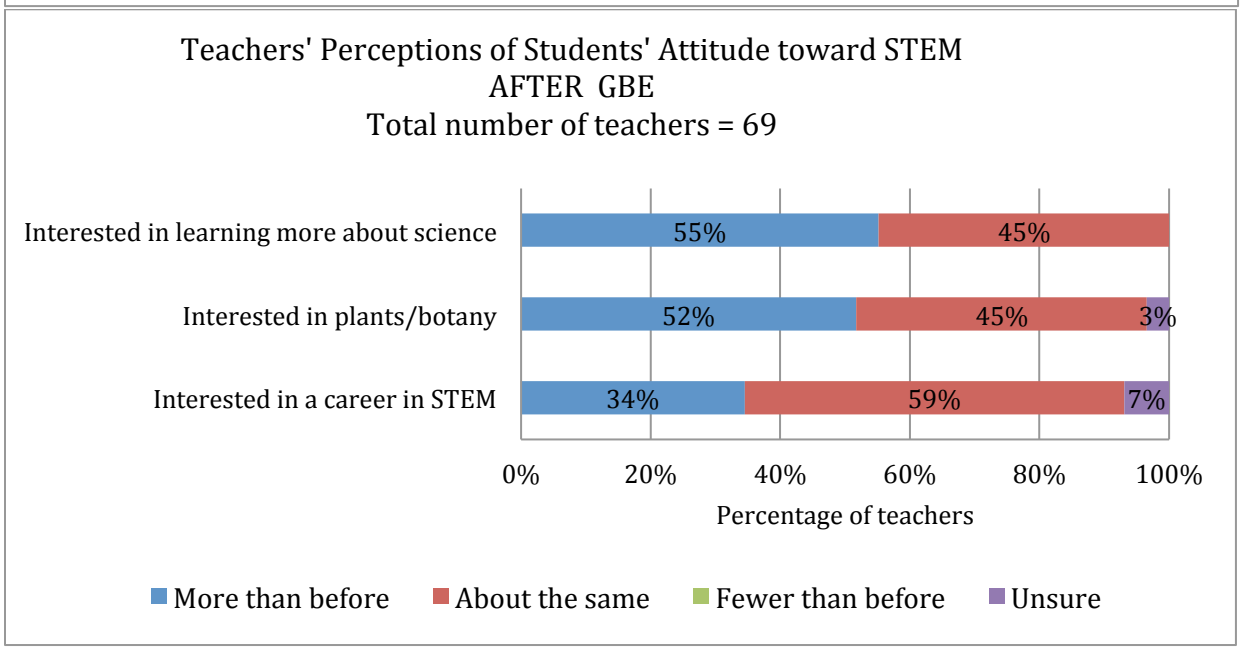
"I liked how we got to work together and communicate with different people every quarter."

"I liked the fact that we did a tweet every week [that] would test our knowledge and let us know how we are doing so far."

Outcomes Finding 2: Students have the opportunity to strengthen research skills, increase botany knowledge, and improve attitudes towards STEM.

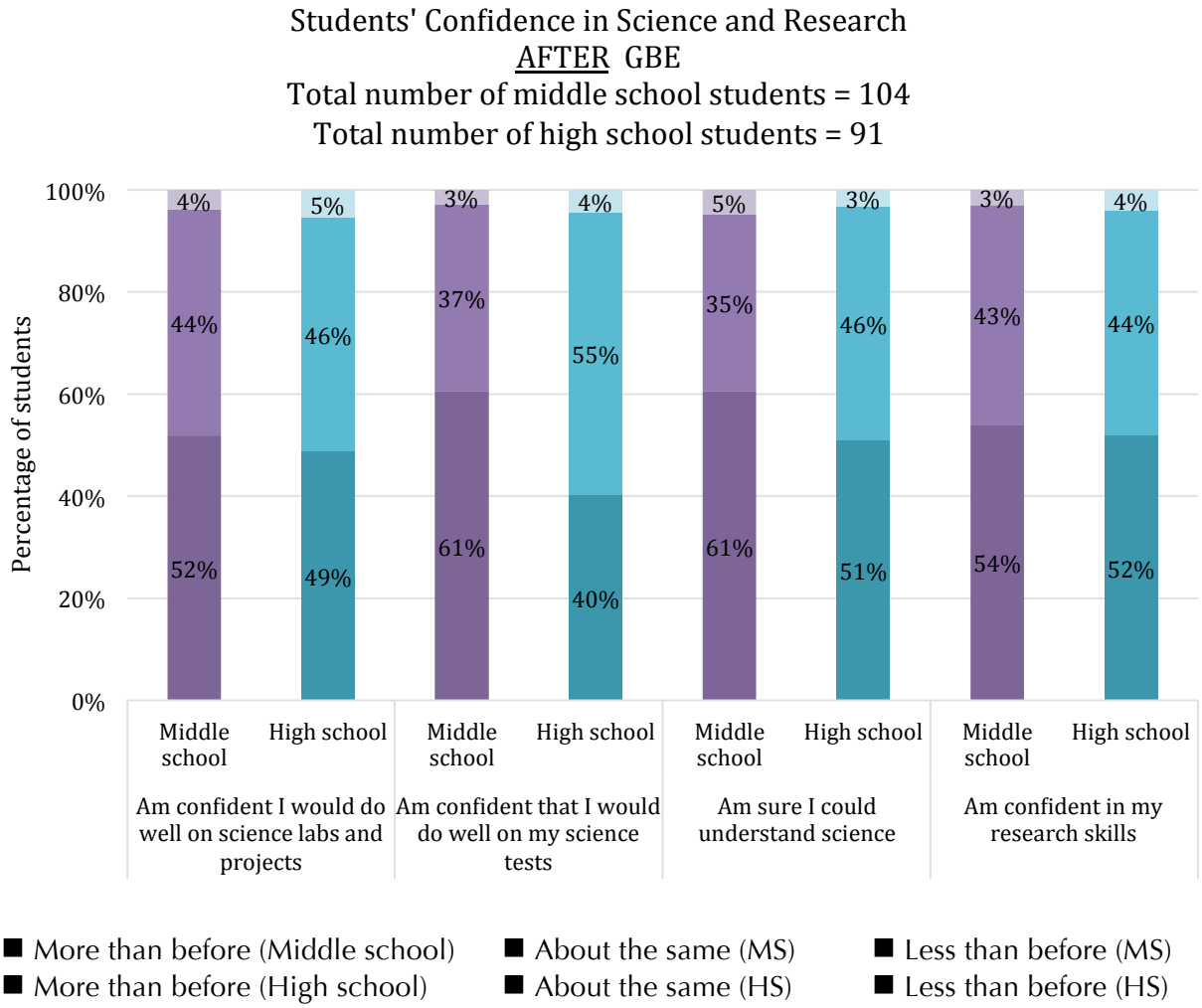
The two graphs below highlight teachers' perceptions of gains in their students' STEM knowledge, confidence, and interest after having participated in Growing Beyond Earth. With the exception of STEM career interest, a majority of teachers reported that their students increased in each of these areas. Middle school teachers perceived a slightly higher impact on their students' confidence and interest as compared to high school teachers.





The remainder of the results presented in this section of the report (outcomes finding 2) focus on students' perceptions as ascertained from an online student survey. While these results provide useful information about students' outcomes, they should be interpreted with caution. Less than 10% of participating students completed a survey and less than 25% of participating schools are represented in the survey responses. It is possible that the survey respondents are not representative of all participating students. As one example, many student survey respondents had relatively high levels of interest and confidence *prior* to participating in the project which could potentially reduce reported gains in these areas.

The graph below highlights students' perceptions of gains in their confidence in science and research after having participated in Growing Beyond Earth. Overall, about half of students increased confidence with middle school students showing slightly larger gains than high school students in some areas. These results are consistent with teachers' perceptions.



In addition to increasing confidence levels, about half of students reported increased plant/botany knowledge after participating in Growing Beyond Earth. In their own words students recount their learning.

> "I enjoyed planting and learning about the plants. At first I wasn't really interested in plants but now I'm kind of more interested in plants."

> "It gave me the chance to learn more about botany and science … before I only knew that botany was something associated with flowers, but now I know much more."

Some students, just less than half, increased interest in learning more about science.

"I didn't used to be interested in science, now I am."

"I learned more about science more than before and it was hands on kind of projects."

Some students, just less than half, also increased interest in a STEM career.

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

> "I think the GBE project was very helpful in learning about Botany and a region of science I wasn't too interested in before. It showed me I want to go into a science field."

In addition to providing opportunities to build STEM content and process knowledge and skills, Growing Beyond Earth provides many opportunities for meaningful collaboration and student leadership. By design, conducting the research trials requires that students work together to collect, manage, interpret, and communicate data. Examples include student pairs measuring and recording plant growth, problem-solving unexpected

challenges, and composing tweets. Additionally, in many classrooms, project activities were student-led with the teacher serving in a coaching role.

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

"This was a student generated project where individuals took ownership of their own learning. I simply acted as a guide for this advanced group of students." Teacher

"I allowed the students to have total involvement in the project. One student spearheaded the project and distributed each student a "job" to perform. Every other day the students would post on Twitter, documented their findings in a notebook and on Google docs." Teacher

"All students participated in each aspect of the project. Students prepared the soil, planted the seeds, arranged the pots on the tray, and created tables with the measurements for each trial." Teacher

Outcomes Finding 3: Growing Beyond Earth enables teachers to provide unique instructional experiences for their students as well as strengthen their own research skills and botany knowledge.

Growing Beyond Earth addresses gaps in teachers' instructional "tool boxes" (particularly in the areas of science process skills and botany) by providing teachers with opportunities to offer authentic, in-depth STEM experiences and build students' plant science knowledge. Additionally, many teachers build their own botany knowledge and research skills as they facilitate their students' learning. A majority of teachers agreed that their knowledge and skills in botany and research increased because of their participation in Growing Beyond Earth.

As one student stated: "I liked how, in class, the teacher would connect lessons to what we were seeing occur in the [GBE] botany lab."

Outcomes Finding 4: NASA has access to additional useful data to support NASA research efforts.

NASA scientists value, and utilize, students' research results to support NASA's space botany research. This is best illustrated by several quotes from NASA staff:

> "The actual methods that the students are discovering … They grew the plants and they looked at how long can they keep these plants growing by harvesting multiple leaves from the same plant and how much more food do they get? … It's a more sustainable approach - we can grow more from the same volume of soil or substrate and the same volume of fertilizer and the same seed … because the Fairchild students showed that it would work well, we immediately started testing those methods at Kennedy Space Center. We showed that we could get double the amount of food from the same input and so we did that on the space station, starting in October of 2016. That's been a huge and very clearly measurable impact [of GBE]."

> "The students are doing authentic research. They are adding to the body of knowledge of [space plant research]."

> "The students also gave us some ideas of new crops [to test]."

> "Another really big value that we're [NASA] getting out of this that we didn't really plan for is the students are giving us a lot of good ideas. It's really become an ideas factory for NASA."

IV. Discussion of Evaluation Findings

The findings of the evaluation presented within the body of this report represent the synthesis of a large amount of data collected during this year-one evaluation. An extensive array of more granular details on the evaluation findings presented above can be found in the Appendices.

As demonstrated by the evaluation findings presented in this report, Growing Beyond Earth has had a very successful first year of full-scale implementation—from both an implementation and outcomes perspective. The project appears to be well run and participants and partners are engaged and satisfied with their participation. Additionally, the project is generating preliminary evidence of positive outcomes for students, teachers, and NASA. Throughout the evaluation, data from multiple sources and methods were utilized in order to "triangulate" the evaluation findings by comparing and contrasting results across sources and methods. As one example, teacher and student survey results were highly correlated with evaluator classroom observations and interviews. Overall, there was a high degree of correlation amongst the findings —increasing confidence in these year-one evaluation findings.

While the year-one evaluation findings are very positive, they should be considered as preliminary evidence and interpreted with caution for several reasons:

- The design of this year's evaluation was exploratory with the intent to gain an initial understanding of the project—its implementation and possible outcomes. It was not the intent of this year's evaluation to draw any definitive conclusions about the project, which is still in early stage implementation.
- Participants in this year's evaluation activities may not be representative of all project participants. To a large extent, project participants self-selected to participate in the evaluation activities and thus may be more interested in, and engaged with, the project than the overall population of participants.
- Evaluation activities in years two through four of the project will address these limitations.

This year's evaluation includes a number of findings that merit consideration for additional exploration during upcoming evaluation activities and are discussed briefly below.

Of all of the findings of this year's evaluation, the most striking is the number of students and teachers who were able to actively participate in a high quality authentic STEM experience. There is a growing body of peer-reviewed research on the outcomes of authentic STEM experiences such as Growing Beyond Earth. Research indicates that when students engage in authentic STEM experiences, they tend to increase their interest in STEM, improve attitudes about STEM, improve their STEM identities, and imagine themselves as STEM professionals (Chapman, 2012; Feldman, Chapman, Vernaza-Hernandez, Ozalp, Alshehri, 2012; Laursen, Liston, Thiry, Graf, 2007; Walker & Molnar, 2014; Science & Health Education Partnership, UCSF, 2012; Walker & Molnar, 2014). There are also meaningful benefits for teachers, including increased confidence in teaching science, improved teaching ability in inquiry style, and a better understanding of inquiry skills (Buxner, 2011; Kazempour & Amirshokoohi, 2014; Science & Health Education Partnership, UCSF, 2012).

One of the most frequent comments made by students and teachers during the evaluation activities regards how excited—and proud—they are that NASA is using "their" research results. The explicit connection with NASA research appears to be a central factor in student and teacher interest and engagement. This aspect of Growing Beyond Earth is what makes the project truly "authentic" in the eyes of students and teachers. In this respect, Growing Beyond Earth is aligned with the Citizen Science movement.

The quotes below illustrate the importance of this connection to NASA:

> "I feel important because I am working with NASA and NASA is using our results." Student

"Students eagerly participate knowing they are helping in the journey to Mars. One student said, I will be able to tell my grandchildren that I helped choose which seeds should go to Mars." Teacher

"The opportunity to engage in authentic research with just a couple of degrees of separation from NASA is compelling and motivating." Teacher

"NASA tweeted that they are testing Chinese Cabbage. That is what we did [preliminary] testing on last year!" Teacher

An additional important engagement factor worthy of further exploration may be related to the design of the research protocols and equipment—specifically the novelty and allure of the "glowing purple" lights of the grow unit, the "immediate gratification" resulting from relatively rapid changes in plant growth, and the reward of eating the harvest. Each of these appears to be important for gaining student interest and sustained engagement. Teachers and students commented that even students who aren't formally involved in project activities would be initially attracted by the lights and then continue to "stop by" and observe the plants.

"I thought that the project was awesome and extremely interesting. I liked that we got to eat the harvested food afterwards." Student

Another important finding is the number of female and minority students that participated in the project. This is not surprising in some respects due to the whole class implementation approach used by a majority of teachers and the demographics of Miami-Dade County. However, it does provide an opportunity to explore potential relationships between student demographics and project outcomes. Given that females and minorities are traditionally underrepresented in STEM studies and careers, Growing Beyond Earth may provide useful information about how to best engage diverse students in STEM.

Two other findings from this year's evaluation are noteworthy and merit additional exploration:

- Initial evaluation results indicate that the outcomes of Growing Beyond Earth may be slightly more pronounced for middle school students and middle school teachers than for high school students and teachers. And in the area of self-efficacy, outcomes may also be slightly more pronounced for girls than boys.
- The "dosage" of students involvement in project activities varies widely ranging from less than weekly hands-on engagement for some students to daily hands-on engagement for other students. Dosage is often considered to be an important factor in outcomes achievement. It's impact on student outcomes in this project is unknown at this point.

V. Recommendations

A number of recommendations for refining the project design and implementation emerged from this year's evaluation and are listed below for consideration by project staff. Given that project staff are soliciting feedback from participating teachers on an ongoing basis, some these may already be under consideration.

Increasing the Number of Participating Teachers

1. To increase the number of teachers who participate (which is a year two project goal), explore possibilities for enhanced marketing to teachers and also enhanced implementation supports for teachers new to the project.
2. Additionally, consider ways to ease the amount of effort required to participate in the project. Participation can require a significant amount of effort for teachers and students (particularly tweeting, data collection and online data entry). Several ideas to ease participation for more students and teachers are discussed below.

Project Implementation

1. The most frequently made recommendation was for additional supports for some of the more challenging aspects of the project such as measuring plant growth. Consider providing additional "How-to" instructions (e.g., possibly video).
2. Consider setting up a teacher exchange page on the project website where teachers can post materials, ideas, and tips they have generated for the project. A number of teachers developed data collection forms and other tools that supplement the resources provided by project staff.
3. Provide suggested topics for tweets–potentially based on the themes that emerged from the Twitter analysis. Also, review and provide further guidance on tweeting requirements and frequency.
4. Provide more guidance on ideas for integrating Growing Beyond Earth into the classroom. This could be part of a teacher exchange on the project website and include ideas on:

a. How to use Growing Beyond Earth to address instructional requirements and curriculum standards
b. How to most effectively implement the project at the "whole class" level—which is difficult for some teachers to achieve

5. Provide additional props and signs to reinforce STEM messaging and desired outcomes (e.g., sign stating: Research for NASA being conducted here or Scientists at Work).
6. Review teacher-provided suggestions to identify additional opportunities for project refinement. These recommendations can be found in the Appendix: Teacher Responses to GBE Results Summary.

Project Outcomes

Overall, Growing Beyond Earth appears to be on track regarding progress towards the project's stated outcomes. However, there are two outcome areas that merit attention in year two project planning: STEM career exposure and botany science fair entries, as discussed below.

1. In reviewing the evaluation findings the lowest scoring areas in terms of students' authentic STEM experiences were related to exposure to STEM careers and interacting with scientists. Explore avenues to increase connections between teachers and students and Fairchild and NASA scientists to bolster this component of students' authentic STEM experiences.
2. Increasing the number of science fair botany entries is a stated project goal. Very few botany entries were submitted this past year. To increase the number of entries, specific strategies will need to be developed by project staff. Consider re-assessing this as a project outcome—it may be unrealistic given available resources allocated to the project.

In closing, congratulations on a successful year of project implementation. As demonstrated by the evaluation findings presented in this report, Growing Beyond Earth appears to be well run, participants are engaged and satisfied, and the project is generating preliminary evidence of positive outcomes. The results of this evaluation can be used to guide project refinements in support of the planned expansion of participation to more students and teachers and the addition of enhanced project components.